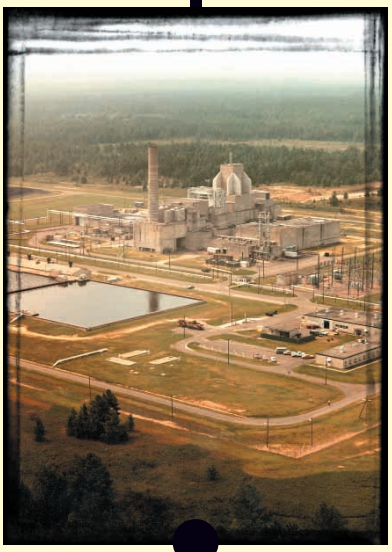
TITLE PAGE

Savannah River Site at Fifty















Savannah River Site at Fifty

Through text and images, this volume presents a comprehensive history of the Department of Energy's Savannah River Site, one of the major research and production facilities in in the United States' nuclear complex.

This history explores the events leading up to the decision to create the plant, the developments in nuclear science and world politics, the Manhattan Project, the Cold War, and the formation of the Atomic Energy Commission. Considered one of the major engineering and construction feats of its day, the creation of the Savannah River Site is an epic story set in the Central Savannah River Area. The transformations that occurred are shown through 1950s photography, historic maps, and documents, all which present a clear before and after picture of the era. The roles of Du Pont and local politicians are chronicled, along with the sacrifices made by those who were asked to leave their homes for reasons of national interest.

The heart of the book is a historical treatment of Savannah River Site's operations during its peak period of production, 1953 to 1979. Developments in reactor technology and chemical separations, heavy-water production, waste management, and the research goals of the Savannah River Laboratory are described in layman's terms and are amply illustrated. This history profiles the individuals who brought the plant to maturity and explores the two themes that define the nuclear weapons workplace, safety and security.

The environmental section opens with descriptions of landmark studies completed during the 1950s that document the site's natural history and the enduring partnerships with the US Forest Service, University of Georgia, and the Academy of Natural Sciences. The discussion includes the national rise of environmentalism in the 1970s and its impact on the site's operation as well as the public perception regarding the site.

The end of the Cold War and the evolution of the plant into the Savannah River Site are the focus of the final section. Operated by the Westinghouse Savannah River Company and its partners, the mission of SRS broadened from research and production to include environmental restoration and cleanup.

SAVANNAH RIVER SITE

at

Fifty

Reed
Swanson
Gaither
Joseph
Henry

About the Book

Savannah River Site at 50 was written and produced as a component of the Savannah River Site History Project, a cooperative agreement between the Department of Energy and New South Associates, a professional cultural resources consulting firm based in Stone Mountain, Georgia. This project documented the site's architectural legacy, recovered important equipment and objects associated with the Savannah River Site's operations, and along with researching and developing this history, produced other brochures and studies.

About the Authors

MARY BETH REED served as the Project Director and lead author. A public historian with New South Associates, Ms. Reed has researched Cold War related Department of Defense sites throughout the US as well as in the Republic of Panama. She developed the local historical themes, the construction era, heavy-water production, and environmental issues.

Historian **MARK SWANSON**, also with New South Associates, has written extensively on Cold War topics and the history of technology. The book sections on reactor technology, the development of the AEC, the environment, and the Westinghouse decade reflect his emphasis.

Historian **STEVE GAITHER** of Kestrel Vector has a strong background in Cold War studies. The research on Du Pont, separations processes, and waste management were developed by Mr. Gaither.

Project Manager, **DR. J. W. JOSEPH** is a native of Aiken and the son of Savannah River Site staff member, Walt Joseph. He has been involved with numerous federal historic preservation projects, and contributed to various sections of the book.

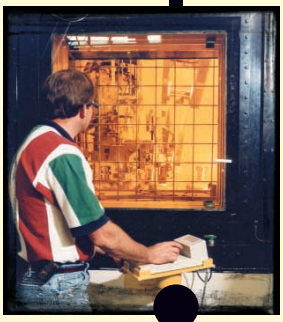
WILLIAM HENRY, with FEMA and New South Associates, has considerable experience in the documentation of historic structures and lent his expertise to the building discussions.

TRACEY FEDOR, graphic artist at New South Associates, designed Savannah River Site at 50. She also designed the DOE anniversary brochure, Patriots of the Atomic Age.

BARBARA SMITH STRACK, of Aiken, edited this volume and compiled the indices.


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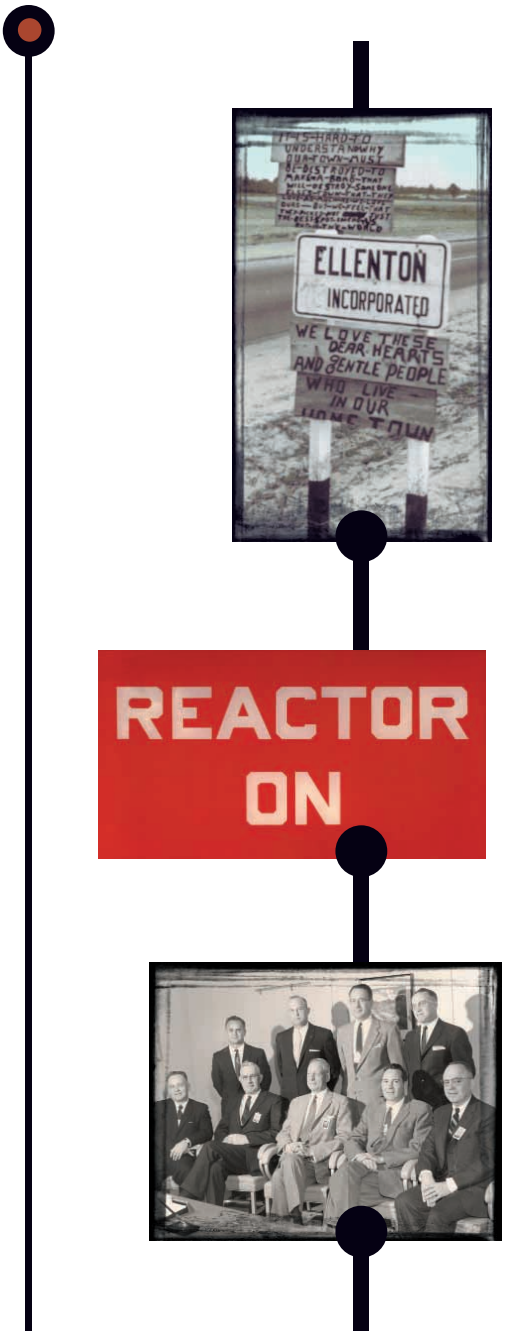








Savannah River Site at Fifty



Contents

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Savannah River Site at Fifty







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Mary Beth Reed

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T-1
ADMINISTRATION
BUILDING
Don't SUPPLY THE
AMMUNITION
We
MAY BE THE
TARGET!
U.S.A.
TALK

PREFACE

Until I was 6 years old, I believed that my father worked as a barber. His job and work were not the topics of conversation at our dinner table. He left in the early hours of the morning, riding with a group of other men in a carpool, and came home just in time for dinner. Some weekends there would be a late night phone call and he would leave for work in the middle of night. The explanation my sister and I received was simply, that our father had to go to work, with nothing further said about why he had to go, or more importantly, what it was that he did. Every few weeks, however, my mother, my sister, and I would get in the car in the early evening and drive to pick my father up, and when we did we picked him up at a barber shop in a shopping center on the highway which ran from Aiken to New Ellenton. This was the only business I could associate my father with in the first six years of my life, so I made the logical assumption. My father was a barber.

When asked what my father did by a guest at a family cocktail party, I replied that he was a barber. My grandmother was not amused. She took my parents aside and informed them that they needed to tell me what my father actually did for a living. And so, at the age of six, I learned that my father worked at a place called the Savannah River Plant. He worked for the government, as an employee of a company called Du Pont which was working for the government. He was a nuclear scientist, helping the government create things which would protect our way of life. What he did was top secret. He couldn't talk about it, we couldn't ask him about it, it was a matter of national security and we had an obligation as citizens to help maintain that security. And so my father went from being a barber to a nuclear scientist, and I think in some respect I must have been uncomfortable with this transition, because while I knew what barbers did, I had not a clue about the lives of nuclear scientists and the place they worked. I grew into an adult without understanding my father's work, and it is only now, having read *The Savannah River Site at 50*, that I can understand what he and his co-workers at the site accomplished, what they created, how important the Savannah River Site was to our national defense and to our understanding of nuclear technology.

Savannah River Site at 50 chronicles the first 50 years in the history of the site. The Savannah River Site is both historical and a product of history. In the current climate of nuclear disarmament it may be difficult to understand the importance of the plant, but when seen within the context of the Cold War, its need and purpose are clear. Part One

(Opposite Page) Administrative employees leaving TC-1 at the end of the day. Security sign mounted over entry door was a daily reminder of the need for constant vigilance. Courtesy of SRS Archives, negative M-545.

presents this historical context, looking at the discovery of radiation and the understanding of the atom, the introduction of atomic technology to military operations during World War II, the political debate surrounding nuclear weapons in the immediate post war years and the formation of a federal agency to administer the nuclear arsenal, and the Soviet Union's detonation of their first nuclear bomb and the arms race that followed. We must also recognize that had there not been an arms race there might have been a nuclear war.

The construction of the Savannah River Plant itself was a monumental undertaking, on par with the great engineering achievements in this nation's history like the building of the Panama Canal. Part Two looks at the building of the plant, and the years between 1949 and 1956 when the landscape was changed from a series of dispersed farms and small communities to a carefully designed massive industrial complex. The decision to build the plant, the selection of the Du Pont Company as its builder and operator, local efforts to promote the Central Savannah River Area as a place for industrial development, the selection of the plant's location, the acquisition of the land and the removal of the people who lived there, the construction of the site, and the changes in the surrounding communities are all covered in this part. The scale of this effort, particularly when seen against the brevity of time it took, speaks of a heroic effort by the site's planners and builders, as well as the citizens of the communities the plant displaced and the residents of the surrounding towns whose existence would be changed forever by the dramatic influx of settlers from other parts of the nation.

The industry and technology of the site, as well as the people behind the machines, form the topic of Part Three. As one of a handful of nuclear industrial complexes, the history of the site's technology and industrial development is important to the present, as well as future, generations of scientists and engineers. This section looks at the site's start-up and operations, heavy water production, the reactors, chemical separations and waste management, research and development in the Savannah River Laboratory, and the site's middle years between 1965 to 1975, that include both its maturation and the beginnings of change.

The Savannah River Site has since its beginnings been aware of both its environmental consequences and responsibilities. The environment is the topic of Part Four, which looks at the ways in which the site affected the environment, the ways in which those effects were measured and evaluated, and efforts made to protect and preserve the site's natural setting.

The history of the Savannah River Site can be divided into two stages: the period in which it was known as the Savannah River Plant, a ground-breaking facility for the research and production of nuclear materials, and the time in which it was identified as the Savannah River Site, when responsibilities shifted from research and production to research, production and remediation. This latter stage, beginning with the transition to a site in 1989 and encompassing Westinghouse's replacement of Du Pont as the site's contractor, is the topic of Part Five. This period, while not as historically intense as the early days of the plant, is none-the-less crucial, as the site has continued to serve this nation as a leader in nuclear research and as Westinghouse has tackled the difficult jobs of environmental remediation and diversification.

This history is written as the site reaches its 50th anniversary. It has been prepared in cooperation with the Department of Energy as part of the Savannah River Site History Project, whose objectives are to document the history and record and collect the resources

which help us to understand the first 50 years of SRS. It is clear, in doing so, that the site has accomplished a tremendous amount in its first 50 years, that it has assembled a team and created a place which fostered the best of American research and ingenuity. It is clear that the site was integral to protecting this nation's freedom and promoting its interests, and it is clear that that role is one which it continues to fulfill. We look forward to seeing the history of the site on its centennial, and learning what great accomplishments it will achieve in the next 50 years.

Dr. J. W. Joseph, III, 2000


uman Announces—
REDS HAVE ATOM BOMB
Herald American
FLASH
EDITION
Evidence of Blast
in Recent Weeks!

PART 1

The Big Picture

CONTENTS

Chapter One
Nuclear Awakening

Chapter Two
World War II and the Manhattan Project

Chapter Three
The Cold War and the Early Atomic Energy Commission (1945–1950)

The Savannah River Plant was a product of history and science, a child of the Cold War which began at the end of World War II, as Communist Eastern Europe emerged as a threat to western democracy. By the late 1940s, the Communists would test their own nuclear weapon and the United States' brief tenure as the only nation with a nuclear capacity would end. The Communists were global in their vision. As tensions increased between east and west, and conflict arose from communist insurrections in various corners of the world, the threat of nuclear warfare increased. The only defense available was one of retaliation, and the United States unleashed its technological and industrial forces to refine the nuclear bomb and stock the atomic arsenal. The Savannah River Plant was a key element in this national system of defense.

The uses of atomic energy were debated from the discovery of radiation on. From the almost casual discovery of x-rays in 1895, scientific knowledge of atomic structure and radioactivity underwent exponential growth in the early 1900s. By the late 1930s, the discovery of nuclear fission opened up the possibility of an atomic bomb, a significant discovery in a world that was almost immediately engulfed by the Second World War. The Manhattan Project emerged, and the atomic bomb resulted from the efforts of its military, scientific, and industrial personnel.

In the immediate wake of World War II, and in light of the destruction witnessed at Nagasaki and Hiroshima, many scientists felt that nuclear warfare was too horrible to consider and should not be pursued. The emergence of the Soviet Union and its atomic capabilities cut short that debate. Part One of *Savannah River Site at 50* looks at the national and international events and discoveries that would ultimately result in the creation of a new facility for the production of plutonium and tritium, the Savannah River Plant.

(Opposite) Leo Szilard with newspaper announcing first Soviet atomic blast, 1949. Courtesy of AIP Emilio Segré Visual Archives.

1 Nuclear Awakenings

The work done at the Savannah River Site is the culmination of over a hundred years of nuclear research. Modern physics, the study of the properties, changes, and interactions of matter and energy, is basically the study of the atom and its components. It began with the discovery of radiation in 1895, even though it was not then known that radiation came from the atomic decomposition of radioactive elements. Slowly at first, and then with increasing speed, physicists unlocked the secrets of atomic structure, the awesome power of fission, and finally, thermonuclear reactions. From the smallest components of the natural world came what could be its biggest threat and perhaps its greatest opportunity. This chapter will show how these momentous events occurred, beginning with the discovery of x-rays at the end of the nineteenth century.



Marie Curie, 1906. Courtesy of AIP Emilio Segré Visual Archives.

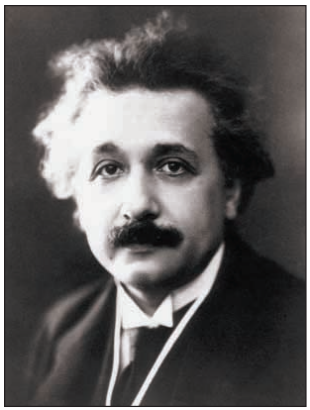
EARLY DEVELOPMENT OF NUCLEAR PHYSICS

Wilhelm Roentgen discovered x-rays in 1895 as a mysterious emanation from the fluorescing glass wall of a cathode ray tube.[1] Even though the source and the nature of the new rays were unknown, they found almost immediate medical application as a means of seeing into the human body.[2] The discovery of x-rays led to the testing of various naturally fluorescing materials to see which, if any, produced the mysterious rays. Henri Becquerel soon discovered that uranium salts also produced these rays, and Marie and Pierre Curie continued his work. Marie Curie named the mysterious force "radioactivity."[3] The Curies devoted their lives to the study of radioactive elements, or unstable elements that emitted radiation. In addition to the previously known uranium and thorium, the Curies discovered radium and polonium. By the early 1900s, their studies led to the identification of some 30 radioactive isotopes.[4]

While the Curies studied radioactivity, English physicist J. J. Thompson discovered the first component of the atom, the electron, in 1897. This new particle was identified in the course of Thompson's work with cathode rays, which Thompson showed were actually small negatively charged particles he called "corpuscles." The new particles were lighter than atoms of hydrogen, the lightest of the elements. For this reason, Thompson guessed that they must be a part of an atom that was somehow ejected from the whole.[5]

Between 1898 and 1911, this work was continued by Ernest Rutherford, who studied the nature of the radiation emitted by uranium and thorium. Rutherford was the first to discover and name alpha and beta radiation, and link them with Thompson's electrons. Rutherford also discovered that radioactive elements, whether they were uranium, thorium, or radium, would all spontaneously disintegrate by emitting alpha and beta particles. The longevity of these elements was determined in "half-lives."[6]

Albert Einstein not only provided more pieces of the puzzle; he put the puzzle in a new frame. In 1905, while working in the Swiss Patent Office, Einstein prepared five papers on the nature of modern physics, any one of which would have secured his fame. One of the five, and the one for which he later received a Nobel Prize, dealt with the "photoelectric effect." In it, Einstein theorized that light is made of discrete packets or "quanta," and that the energy of each packet is determined by the wavelength of the light, not its intensity. Two of the five papers dealt with new evidence for the existence and size of atoms and molecules. Another two expounded a radical new theory on the relationship of time and space: one dealt with the theory of relativity, while the other posited that mass has energy—expressed as the equation "$E=mc^2$."[7] This equation became one of the hallmarks of modern physics. It stressed the interchangeability of matter and energy, and suggested the huge amount of energy that could come from a small amount of matter.[8] It also paved the way for an understanding of gamma rays, the third and most penetrating type of radiation emitted by radioactive elements.



Albert Einstein, 1922. Burndy Library, courtesy of AIP Emilio Segré Visual Archives.

By the time Einstein published his theory of relativity, the notion of atoms as the building blocks of all elements was coming into acceptance. Before then, the idea of the atom, which went back to the ancient Greeks, was useful only as a concept. Prior to the 1900s, no one actually knew anything about atoms, or if they even existed. Although John Dalton had hypothesized their existence in the early 1800s, at the end of that century, even as respected a physicist as Max Planck could publicly doubt the existence of atoms as actual particles.[9] By the early 1900s, this was no longer the case. Not only were atoms thought to exist, but Rutherford's increasingly sophisticated experiments also indicated that the area of each atom was not solid, but mostly empty space. In 1911, Rutherford showed by bouncing alpha particles off atoms at large angles, that the bulk of an atom was contained in a central nucleus that had a positive charge.[10] This experimentation identified the basic electrical structure of the atom, with negatively charged electrons orbiting a positively charged nucleus.



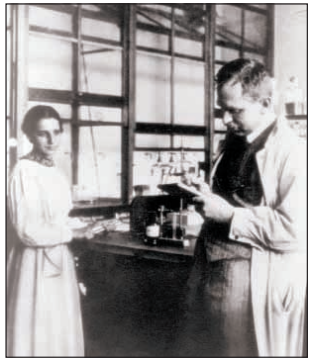
Ernest Rutherford, circa 1920. *Nature*, courtesy of AIP Emilio Segré Visual Archives.

This scheme, which can be visualized as a small solar system with the nucleus at the center surrounded by orbiting electrons, was only a useful way to describe what was really unknown in 1911. The bond that tied an electron to the nucleus was recognized to be much greater than a gravitation field. The nature of the force that bonded the components of an atom remained a mystery until Danish physicist Niels Bohr wrote *On the Constitution of Atoms and Molecules* in 1913. According to Bohr, the forces that made for a stable atom could not be explained by the laws of classical physics, but only by the quantum principles pioneered by Planck and Einstein.[11]

In 1919, after the First World War, Rutherford, working at the Cavendish Laboratory at Cambridge, became the first person to artificially transmute an element. Using alpha particles, he bombarded atoms of nitrogen to create hydrogen atoms.[12] As a result of this work, he also discovered, within the nucleus, a high-energy positively charged particle he called a "proton."[13] This discovery completed the electrical make-up of the atom, with a

positively charged nucleus (protons) surrounded by negatively charged electrons. The year 1919 was also important because it provided scientists the opportunity to prove Einstein's theory of relativity when light was observed to bend during a solar eclipse.

DEVELOPMENTS IN THE 1920s



Lise Meitner and Otto Hahn, 1913. Courtesy of AIP Emilio Segré Visual Archives.

In the decade after World War I, physics took its place at the cutting edge of modern science throughout Europe and the United States. Berlin in particular came into its own during this period. The physics faculty of the University of Berlin included Albert Einstein, Max Planck, and Max von Laue, the 1914 Nobel laureate in physics. In addition, there were the various Kaiser Wilhelm Institutes for chemistry and physical chemistry in the Berlin suburb of Dahlem. Among the researchers there was the team of Otto Hahn and Lise Meitner.[14] The great achievements of this period were theoretical breakthroughs. In 1922, Niels Bohr explained basic atomic structure, with atoms having various orbital "shells" of electrons, each shell capable of holding only a certain number of electrons. Bohr linked chemistry to physics when he discovered that atoms of a particular element display a unique chemical behavior because of the number of electrons in their outer shells. Molecular bonds could now be explained as a tendency to fill or empty the outer shell by trading or sharing electrons.[15]

In the mid-1920s, Bohr, Werner Heisenberg, and Erwin Schrodinger advanced quantum theory with their exploration of the wave–particle duality of both matter and light. Heisenberg's theory led to the "uncertainty principle," the concept that complementary variables such as location and momentum could not both be measured precisely at the same time. Schrodinger's wave treatment yielded similar results when it was determined that many variables could be evaluated only in terms of statistical probabilities.[16]

American physics was less theoretical, but more practical, and it too came into its own during this period. By the late 1920s, John Douglas Cockcroft and E. T. S. Walton in Britain were developing a voltage multiplier, Robert Van de Graaf was working on his electrostatic generator, and Ernest Lawrence at the Berkeley Radiation Laboratory was perfecting his atomic particle accelerator, the cyclotron.[17] Although Cockcroft and Walton are credited with making the first transmutation using artificially accelerated protons, Van de Graaf's generator and Lawrence's cyclotron became the more useful machines. Conceived by Leo Szilard in Germany as early as 1928, the cyclotron was a device for accelerating nuclear particles in a circular magnetic field.[18] It was designed to bombard the nuclei of different atoms, using accelerated protons speeding at million-volt energies.[19] The tremendous speed was needed to overcome the electrical repulsion of the positively charged protons fired against the positively charged nuclei. At the time of the first cyclotron, the neutron, the neutral portion of the nucleus, had not yet been discovered.

DISCOVERY OF THE NEUTRON: NUCLEAR PHYSICS COMES OF AGE

The discovery of the neutron by James Chadwick, in 1932, completed the identification of the major components of the atom. The neutron, with the same mass as a proton

but without an electrical charge, was discovered when Chadwick bombarded various light elements with alpha particles from a polonium–beryllium source. When the beryllium source consistently knocked protons out of a whole range of light elements, he knew it was the work of something more powerful than gamma radiation. As a result of this work, Chadwick was able to show that the force that kicked out the protons was a new particle with a mass similar to that of a proton. Since it had no charge, the new particle was called a "neutron."[20]

The discovery of the neutron marked the true beginning of modern physics. Not only did it provide the missing link to man's knowledge of the atom, but it also provided a more practical means of transmuting an atom. Electrically neutral, neutrons could be used as a more efficient probe to further explore the nucleus of the atom. The discovery of the neutron put physics on the road to the atomic bomb and the development of atomic energy.[21]



Leo Szilard, circa 1930. *Bulletin of the Atomic Scientists*, courtesy of AIP Emilio Segré Visual Archives.

FIRST TRANSMUTATION OF NUCLEUS AND ITS IMPLICATIONS

The discovery of the neutron in 1932 was followed almost immediately by additional work on the transmutation of natural elements. Ironically, neutrons had nothing to do with these early achievements. In 1932, researchers at the Cavendish Laboratory turned lithium into helium, each lithium nucleus split into two helium nuclei, after bombarding the lithium with protons made in a particle accelerator.[22] In France, Joliot-Curies offered the first chemical proof of artificial transmutation, and his work was done with alpha particles.[23]

Despite these successes, it appeared that this remarkable knowledge would never have more than a limited application. Splitting atoms with proton beams and alpha particles required powerful accelerators and a huge amount of energy. Both protons and alpha particles are positively charged, and they have to be driven against a positively charged nucleus, since the natural tendency of both is to avoid each other. The collision success rate is at best about one in a million.[24] Even though physicists knew of the awesome energy that could be released by splitting the atom, they also knew that to do it with proton beams and alpha particles was to use more energy than could be generated. A chain reaction would be virtually impossible. It was for this reason that Ernest Rutherford, in 1933, called the idea of atomic power "moonshine."[25]

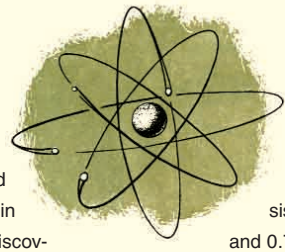
Leo Szilard, in 1933, was one of the first persons to envision a nuclear chain reaction, and one of the first to consider using neutrons as the bombarding agent. Because neutrons had no electrical charge, they could slip past other electrically charged atomic particles, and thus would not have to be driven into the nucleus at high speed.[26] For Szilard, however, the idea remained a quixotic notion. An unemployed refugee from Hitler's Germany, then living in England, Szilard had neither the means nor the laboratory techniques to further this idea. The man for this job was Enrico Fermi.

FERMI'S WORK WITH NEUTRONS, 1930s

In the 1930s, Fermi worked at the edge of the physics world in Mussolini's Italy. After the discovery of the neutron, Fermi decided to concentrate on experiments in artifi-

cial radioactivity. His goal was to induce radioactivity or to transmute an element into another similar to itself; the idea of actually splitting a nucleus with neutrons was not part of the plan. Using radon and powdered beryllium as a neutron source, Fermi began bombarding the whole range of elements, beginning with the lightest in the periodic table. The first element to be made radioactive through this process was fluorine, followed by aluminum. As a result of this work, Fermi found that light elements usually mutated into even lighter elements by losing a proton or an alpha particle. Heavier elements tended not to split, but became heavier.[27] Fermi also discovered that the speed of the invading neutrons was not an advantage, as it was with protons and alpha particles. With a few exceptions, neutrons were absorbed more strongly at low energies, the absorption varying

Components of the Atom



By the mid-1930s, the basic concept of the atom had been established. The core is a positively charged nucleus, comprised of neutrons and positively charged protons, orbited by negatively charged electrons. As a rule, protons and electrons are equal in number, balancing each other out. (Physicists have discovered a number of subatomic particles, but the behavior and make-up of ordinary matter is determined by neutrons, protons, and electrons.) In the mid-1930s, Bohr arrived at the basic configuration of the nucleus, which does not form a solid mass, but is comprised of protons and neutrons closely packed together in such a way that they could be split apart. This theoretical framework is supple enough to allow for the existence of isotopes, which are unstable radioactive variants of more stable elements.

By this time, the main parts of the atom were also classified in a modern fashion. Protons and neutrons, which together compose the nucleus of the atom, each have an atomic mass of 1; electrons have a much smaller mass, 1/1840 of either a proton or a neutron. The number of protons, also identified as the **atomic number**, determines the element of the atom. For example, carbon has an atomic number of 6 because there are 6 protons in each carbon nucleus. In similar fashion, uranium has an atomic number of 92 since each of its atoms contains 92 protons. **Mass number** represents the total number of protons and neutrons in the nucleus. The most stable of the lighter elements have an even number of protons and neutrons. The heavier elements have more neutrons than protons, an arrangement that helps to hold the heavier nuclei together. For elements heavier than lead, the nucleus is so unstable as to generate radioactivity. Such elements are more susceptible to the formation of isotopes.

Isotopes of a given element are composed of atoms with the same atomic number as the most common form of that element, but with different mass numbers. In other words, their nuclei contain a different number of neutrons. Chemically, isotopes are indistinguishable from other variants of a given element, since both contain the same number of protons. They do, however, have different nuclear properties, and these are identified by their **atomic mass number**, or number of protons and neutrons. In this fashion, natural uranium basically consists of two isotopic forms; it is 99.28 percent uranium-238 and 0.712 percent uranium-235.

Isotopes with too many, or few, neutrons for their own stability emit radioactive particles to correct the imbalance, a process known as radioactive decay. Although other types are known, three basic kinds of radiation are emitted during this decay: alpha particles, beta particles, and gamma radiation, all of which were identified by the mid-1930s. **Alpha particles** are formed by two protons and two neutrons, and have a positive charge. Very weak, alpha particles can be stopped by skin or a sheet of paper. The more powerful **beta particles** are formed when a nucleus contains too many neutrons for stability. At that point, a neutron changes to a proton and ejects one of the orbiting electrons. Beta particles can also be formed when there are too many protons for stability, and a proton changes to a neutron by ejecting its positive charge in the form of a **positron**, a particle discovered by Carl Anderson at California Institute of Technology in 1932. **Gamma rays** have neither charge nor mass. Gamma rays typically appear as a result of alpha or beta emission. Positive beta particles, or positrons, provide an additional source of gamma rays. When positrons combine with electrons, they annihilate each other and create gamma rays. This is the only common reaction in which isolated masses are totally converted to pure energy.

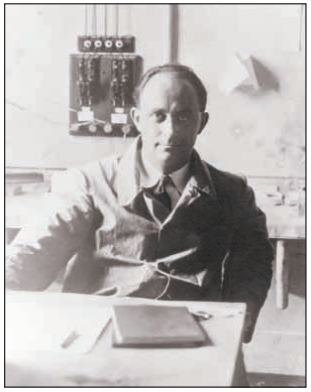
Source: E. H. Lockwood, *Reactor Physics Primer* (Richland, Washington: Operational Physics, Research, and Engineering Operation, GE, Hanford Atomic Products Operation, 1957), 2-8. Henry DeWolf Smyth, *Atomic Energy for Military Purposes: The Official Report on the Development of the Atomic Bomb Under the Auspices of the United States Government, 1940-1945* (Princeton; New Jersey: Princeton University Press, 1945), 12.

inversely with the velocity. Fermi also discovered a suitable medium for slowing down the neutrons: paraffin—or more specifically, hydrogen atoms.[28] Later, carbon was found to be a good "moderator."[29]

Unusual things happened when Fermi got to uranium, the heaviest of the natural elements. Neutron bombardment led to the creation of a heavier isotope, uranium-239, which then decayed to a new man-made element with an atomic number of 93. Other substances were created that could not be identified since they were not similar to uranium. The possibility that uranium nuclei had split, creating totally different elements much further down the periodic table, was not considered at the time.[30] Fermi continued this line of work until 1938, when Mussolini issued his first anti-Semitic laws, threatening the safety of Fermi's wife. When he was awarded the Nobel Prize that same year, Fermi and his family took the occasion to escape to London before moving on to the United States.[31] By then, others had joined in the exploration of the unusual nuclear properties of uranium.

NATURE OF URANIUM

Long thought to be an extremely rare substance, uranium ore, originally known as pitchblende, was first used to color ceramics in Renaissance Europe. At that time, and for centuries to come, the only known source was from the Joachimsthal mines in what is now the Czech Republic.[32] The heaviest natural element on earth, uranium is radioactive, but not strongly so, and can be handled without special protection. Like most natural radioactive elements and isotopes, uranium is radioactive because it is in the slow process of decaying—in the case of uranium, to a stable isotope of lead. The only reason it even exists naturally is that it has an extremely long half-life: 4500 million years for uranium-238; 700 million years for the much rarer uranium-235.[33]



Enrico Fermi, circa 1930. NARA, courtesy of AIP Emilio Segré Visual Archives.

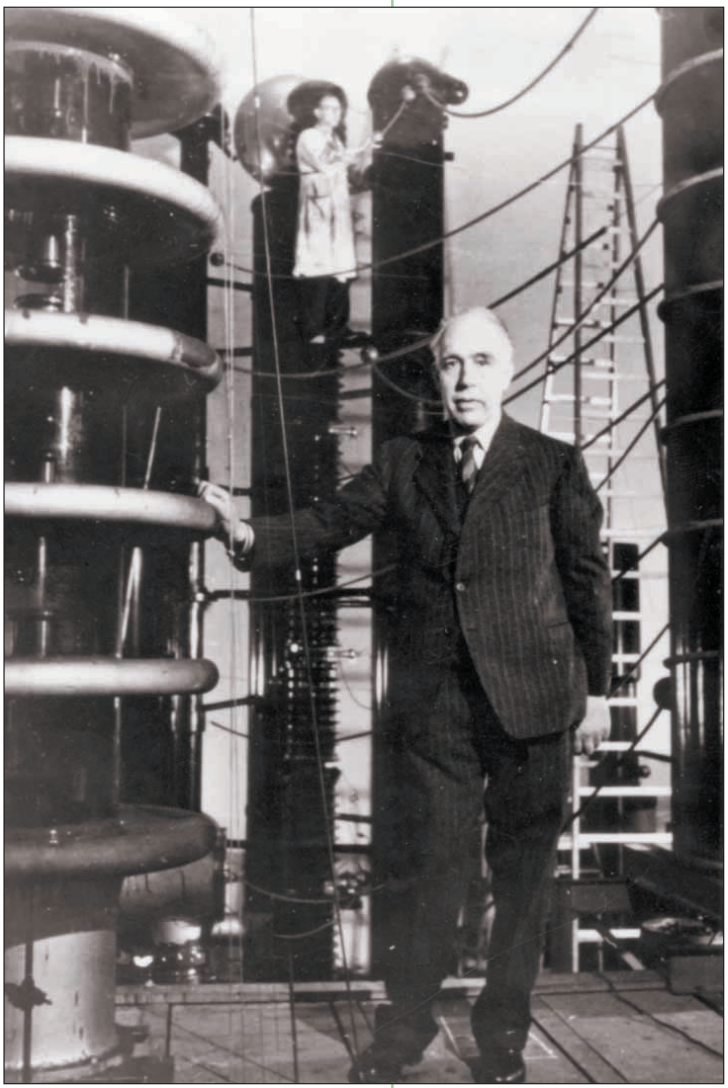
All forms of uranium have 92 orbital electrons and 92 protons in the nucleus, which gives them an atomic number of 92. There are 14 known isotopes of uranium, each with a different number of neutrons in the nucleus. Identified by their mass number (protons plus neutrons), these isotopes range from uranium-227 to 240. By far the most important of these are uranium-238 (with 146 neutrons) and uranium-235 (with 143 neutrons).[34] The uranium atom requires a high number of neutrons because its nucleus is so crowded with positively charged protons that they tend to repel each other. These properties make the nucleus unstable and relatively easy to split.

This instability is more pronounced in the man-made "transuranium" elements, which are packed with even more protons than natural uranium. In the 1930s, these artificial elements were theoretical, but tentatively identified. Element 93 (later known as neptunium) and Element 94 (later known as plutonium), were originally known as Eka-rhenium and Eka-osmium, respectively, based on their theoretical position in the periodic table.

DISCOVERY OF FISSION, 1938/1939

During the 1930s, when nuclear physics was assuming its modern form, the physics world itself was convulsed by the rise of Hitler and his anti-Semitic agenda. Appointed German chancellor on January 30, 1933, Hitler assumed dictatorial powers in the wake of

the Reichstag fire a month later. By March, Jewish judges and lawyers were dismissed from their positions in both Prussia and Bavaria, with the other German states soon following. In April, the Nazis began a national boycott of Jewish businesses, and Jews began to lose their university positions.[35]



Niels Bohr with the Cockcroft-Walton accelerator, 1930. Niels Bohr Archive, courtesy of AIP Emilio Segré Visual Archives.

These developments, and the worse ones to follow, devastated the world of German physics. Before the end of 1933, Albert Einstein, Leo Szilard, Eugene Wigner, and Edward Teller had left Germany for positions in England and, eventually, the United States. Others soon followed. In all, over 100 physicists left Germany during the 1930s.[36] While this exodus was a disaster to German physics, it was a boon to the United States. In the 1930s, the physics world shifted its center of gravity from Britain and Germany, to a new trans-Atlantic nexus.

Despite the devastation to German physics, there were still enough scientists in the Third Reich to make new discoveries. Among those who stayed, or were allowed to stay, were Werner Heisenberg, Fritz Strassmann, and the team of Otto Hahn and Lise Meitner. Although Meitner was Jewish, she was allowed to remain at the Kaiser Wilhelm Institute because she was an Austrian national.[37] Taking a cue from Fermi's work in Italy, Hahn and Meitner concentrated their efforts on further unlocking the secrets of uranium. By 1938, they had made 10 different isotopes of the element, and were already exploring the transuranics. That year, their research was interrupted by Hitler's seizure of Austria, which forced Meitner to flee to avoid the impact of Hitler's anti-Jewish laws.[38] Hahn and Strassmann continued the uranium work.

In December of 1938, Hahn and Strassmann made the momentous discovery that uranium atoms (atomic number 92), when bombarded with neutrons from a radium–beryllium source, would actually split into two radioactive atoms of roughly equivalent mass, the heaviest of which was barium (atomic number 56).[39] This had been done earlier by Fermi and others, but none had recognized the result. Hahn quickly relayed this breakthrough to Meitner, then working in Sweden with her nephew, Otto Frisch.

Meitner and Frisch did further calculations on the results in December and into January of 1939, and were able to show theoretically that the splitting of uranium atoms released a large amount of energy. The secret to the process was Einstein's old formula, $E=mc^2$, with energy created by reducing a part of the mass of the nucleus.[40] Frisch and Meitner even named the new process, "fission," from a biology term for the binary separation of a cell.[41] Later that same month, they told Niels Bohr of their calculations, just before Bohr left Copenhagen for a trip to the United States.

Bohr's news of the fission process swept through the American physics world later in January of 1939.[42] The theoretical possibility of a nuclear chain reaction was almost instantly perceived. Fermi, now at Columbia University, certainly considered this a possibility.[43] It was an avenue further explored throughout the rest of 1939, as Europe slid into war, and as the awesome possibilities of uranium fission increasingly pointed to the possibilities of an atom bomb.

FISSION DEVELOPMENT, 1939

Almost overnight, fission became an obsession within the nuclear physics community.[44] While work also continued on the development of transuranic elements, especially Element 93, the year 1939 was largely dedicated to unlocking the secrets of the uranium atom, and determining the methods by which it could be split.

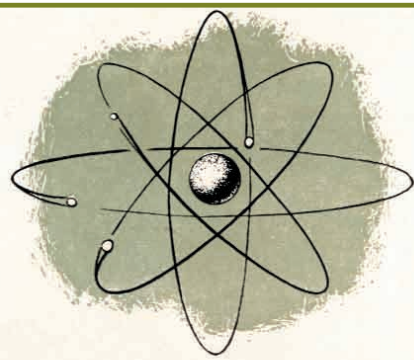
In early 1939, while Bohr was still in the United States, he realized the significance of uranium-235 to the fission process. Knowing that both thorium and uranium captured slow neutrons, while only uranium fissioned, Bohr reasoned that the difference between the two had to be the presence of uranium-235, which is less than one percent of natural uranium. Bohr's insight was that only uranium-235 fissioned.[45] This insight commenced experimental work to isolate enough uranium-235 to test Bohr's theory.

The possibility of a chain reaction, first conceived by Leo Szilard, quickly took on heightened significance as fission research continued. A fission chain reaction required that a neutron enter and split a uranium nucleus, which would then send off other neutrons that would enter yet more nuclei, and so on. It was quickly realized that, under most circumstances, a chain reaction could not occur in natural uranium; uranium-235, however, offered possibilities. A controlled chain reaction, which might be used to harness electricity, could be achieved with natural uranium enriched with a higher percentage of uranium-235. An uncontrolled reaction, or a bomb, might be achieved with a much higher concentration of uranium-235.[46] Beginning in early 1939, Szilard, Fermi, Walter Zinn, and others studied the possibilities of a nuclear chain reaction.[47]

An important component of this chain reaction work was the study of suitable "moderators," the material placed around the uranium to slow down the neutrons and increase the chances of nuclear fission. The first agent to serve as a moderator was water, which contains the hydrogen needed to slow down the neutrons. Water, however, had a high parasitic absorption rate, and would not work for natural uranium, even though it could be made to work if the percentage of uranium-235 were increased. This left beryllium, graphite, and deuterium oxide, also called "heavy water." Beryllium was both too expensive and too hazardous. Graphite and heavy water were much more promising, but the use of either would not be easy.[48] In the case of graphite, the problem was quality; in the case of heavy water, quantity. It was difficult to make graphite of sufficient purity to serve as a moderator. In the case of heavy water, there simply was not enough. The only industrial facility that produced heavy water was a plant in Norway, and it produced relatively small amounts for electroplating. It would not be easy to produce more. Deuterium could not be made chemically, but had to be "harvested" from natural water, where it is found in minute quantities: one deuterium atom for every 7000 regular hydrogen atoms.[49] Even the placement of the moderator had to be worked out to achieve optimum effect. The use of heavy

(Overleaf) Graphic illustration of the difference between fission and fusion used in 1950s era booklet on atomic energy. Source: M. Phillip Copp, Booklet entitled *The Atomic Revolution*, 1957. Courtesy of SRS History Project.

FISSION



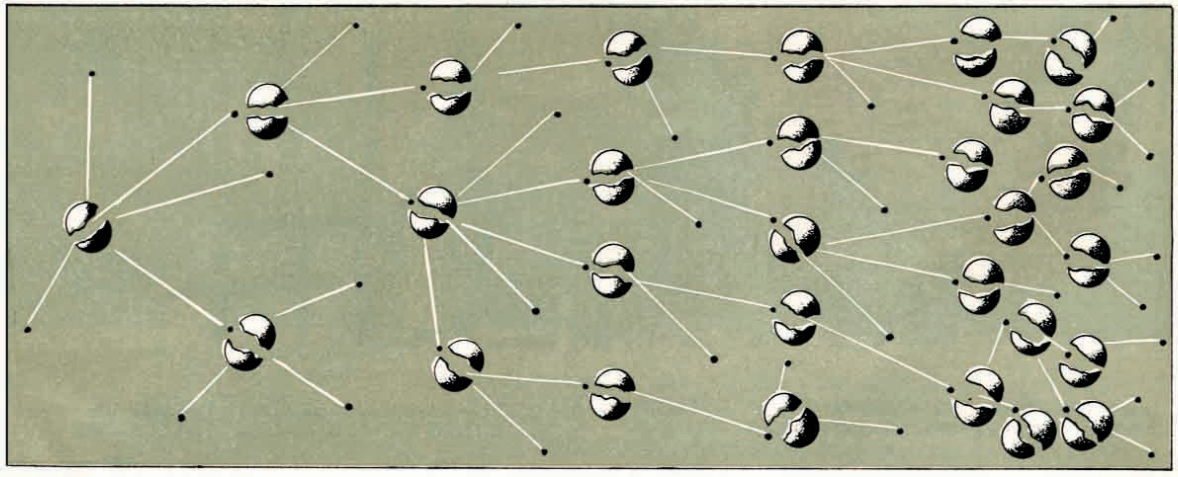
IN THE SYMBOL OF THE ATOM, THE OUTER CURVED LINES REPRESENT TINY DROPLETS OF ELECTRICITY, CALLED ELECTRONS. THESE SURROUND A CENTRAL CORE IN MUCH THE SAME WAY THAT THE PLANETS SURROUND THE SUN. ALL COMMON CHEMICAL REACTIONS SUCH AS THE BURNING OF COAL, THE RUSTING OF IRON, AND THE EXPLOSION OF TNT INVOLVE CHANGES IN THESE OUTER FRINGES OF ATOMS. NO SUCH REACTION TOUCHES THE CORE, OR NUCLEUS. YET IT IS HERE THAT NEARLY ALL OF THE MIGHT OF THE ATOM IS CONCENTRATED. AND FROM HERE COMES ATOMIC ENERGY – FREQUENTLY CALLED NUCLEAR ENERGY.

ATOMIC ENERGY CAN BE RELEASED FROM THE NUCLEUS OF AN ATOM IN ONE OF TWO WAYS: BY "FISSION", OR BY "FUSION."

THE ATOMIC CORES OF THREE SUBSTANCES — URANIUM-233, URANIUM-235 AND PLUTONIUM — CAN MOST EASILY BE SPLIT IN TWO. IN THIS PROCESS, CALLED FISSION, VERY SMALL AMOUNTS OF MATTER ARE CONVERTED INTO VERY LARGE AMOUNTS OF ENERGY. THIS CONVERSION TAKES PLACE ACCORDING TO EINSTEIN'S FORMULA, $E=MC^2$, WHICH MEANS THAT THE ENERGY PRODUCED EQUALS THE MASS DESTROYED, TIMES THE SPEED OF LIGHT SQUARED.

IN FISSION, EACH SPLITTING ATOM RELEASES SEVERAL TINY PARTICLES CALLED NEUTRONS, WHICH, IF THEY STRIKE OTHER FISSIONABLE ATOMS, WILL CAUSE THEM TO SPLIT AND FLY APART. IF ENOUGH U-233, U-235, OR PLUTONIUM CAN BE ASSEMBLED IN ONE PLACE, AN ATOMIC "CHAIN REACTION" CAN BE SET UP IN WHICH THE NEUTRONS RELEASED BY EACH SPLITTING ATOM WILL SPLIT OTHERS. THIS REACTION TAKES PLACE IN A FRACTION OF A SECOND IN THE ATOMIC BOMB AND RELATIVELY SLOWLY IN THE ATOMIC REACTOR.

ONLY ONE OF THE THREE EASILY FISSIONABLE MATERIALS IS FOUND IN NATURE. THIS IS URANIUM-235, WHICH COMPRISES 7/10THS OF 1% OF NATURAL URANIUM METAL. URANIUM-233 CAN BE PRODUCED, HOWEVER, BY EXPOSING THE METAL THORIUM TO THE NEUTRONS CREATED BY A NUCLEAR CHAIN REACTION. PLUTONIUM CAN BE PRODUCED BY THE SAME MEANS FROM A PREVALENT KIND OF URANIUM CALLED U-238.



FUSION



FISSION INVOLVES SPLITTING AN ATOMIC NUCLEUS, FUSION INVOLVES UNITING TWO NUCLEI. THE SUBSTANCES MOST EASILY FUSED ARE HYDROGEN ATOMS OF A SPECIAL KIND CALLED HYDROGEN-2 AND HYDROGEN-3.

IN A TYPICAL FUSION REACTION, TWO ATOMS OF HYDROGEN-2, WITH A TOTAL ATOMIC WEIGHT OF 4.028, CAN BE FUSED INTO ONE ATOM OF HELIUM, WITH AN ATOMIC WEIGHT OF 4.003. THE DIFFERENCE IN THE TWO WEIGHTS REPRESENTS MATTER THAT HAS BEEN CHANGED INTO ENERGY, IN ACCORDANCE WITH EINSTEIN'S FORMULA, $E=MC^2$.

UNLIKE FISSION, WHICH IS CAUSED BY NEUTRONS, FUSION IS CAUSED BY EXTREMELY HIGH TEMPERATURES, APPROACHING THOSE IN THE SUN. ONCE A FUSION REACTION IS STARTED, IT WILL GENERATE ENOUGH HEAT TO KEEP ITSELF GOING FOR SO LONG AS FUEL REMAINS AVAILABLE TO IT. THE PROBLEM IS TO START IT.

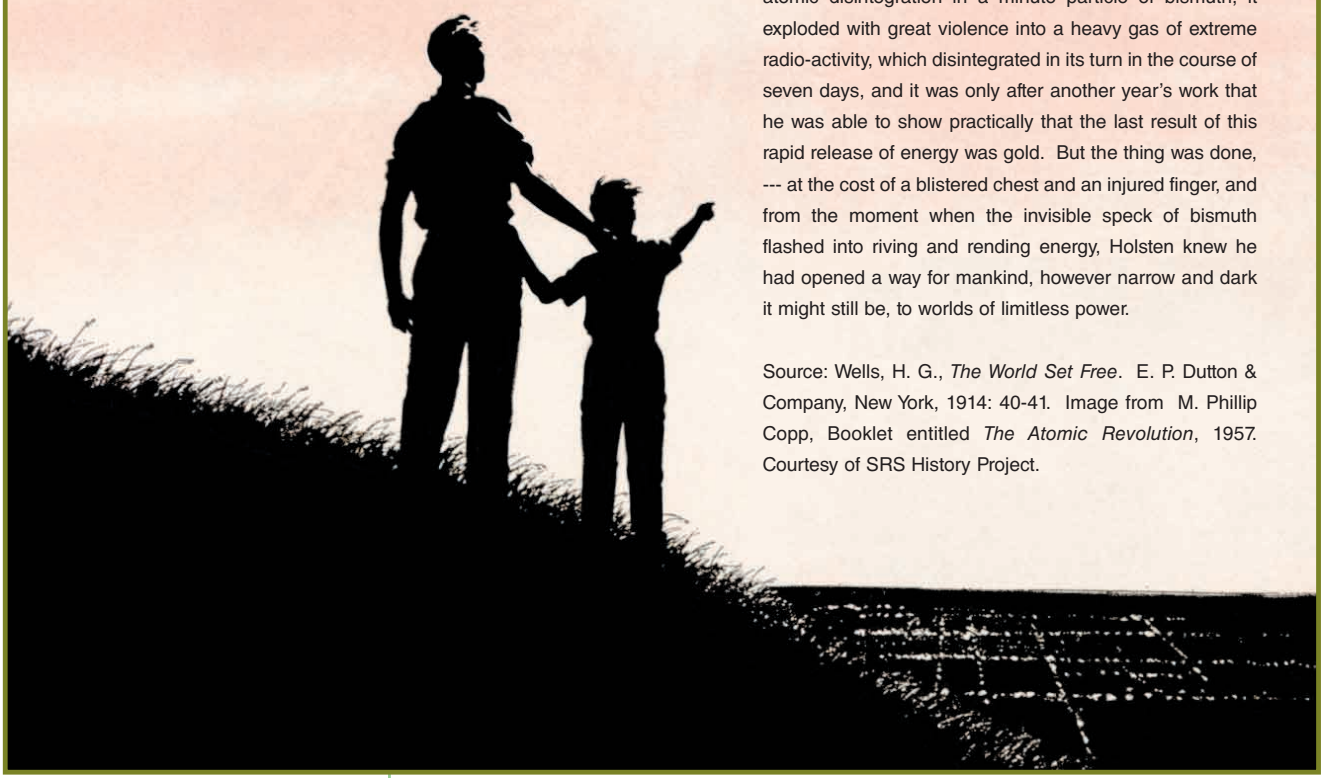
WITH THE INVENTION OF THE ATOMIC BOMB, MEN WERE ABLE FOR THE FIRST TIME TO PRODUCE TEMPERATURES ON EARTH THAT WERE SUFFICIENTLY HIGH TO START A FUSION REACTION. AS A RESULT, IT BECAME POSSIBLE TO DEVELOP A HYDROGEN BOMB — THE FIRST USE OF FUSION.

NOW SCIENTISTS ARE TRYING TO DEVELOP METHODS BY WHICH FUSION REACTIONS CAN BE STARTED AND MAINTAINED IN A SLOW AND CONTROLLED FASHION. WHEN THEY SUCCEED, IT WILL THEN BE POSSIBLE TO HARNESS FUSION, LIKE FISSION, FOR CREATIVE PURPOSES.

water required tanks and plumbing systems, while graphite blocks would have to be arranged both around and in between the uranium. In 1939, Szilard came up with the idea of a lattice arrangement for the graphite blocks as a moderator.[50]

At the end of 1939, most of these issues and their solutions were still theoretical. No one had gathered enough graphite or heavy water to test these materials as actual moderators in a chain reaction. More importantly, no one knew how to gather enough uranium-235 to create a chain reaction, much less make a bomb. There were a number of possibili-

THE WORLD SET FREE
by H.G. Wells, 1914



"The problem which was already being mooted by such scientific men as Ramsay, Rutherford, and Soddy, in the very beginning of the twentieth century, the problem of inducing radio-activity in the heavier elements and so tapping the internal energy of atoms, was solved by a wonderful combination of induction, intuition and luck by Holsten so soon as the year 1933. From the first detection of radio-activity to its first subjugation to human purpose measured little more than a quarter of a century. For twenty years after that, indeed, minor difficulties prevented any striking practical application of his success, but the essential thing was done, this new boundary in the march of human progress was crossed, in that year. He set up atomic disintegration in a minute particle of bismuth, it exploded with great violence into a heavy gas of extreme radio-activity, which disintegrated in its turn in the course of seven days, and it was only after another year's work that he was able to show practically that the last result of this rapid release of energy was gold. But the thing was done, --- at the cost of a blistered chest and an injured finger, and from the moment when the invisible speck of bismuth flashed into riving and rending energy, Holsten knew he had opened a way for mankind, however narrow and dark it might still be, to worlds of limitless power.

Source: Wells, H. G., *The World Set Free*. E. P. Dutton & Company, New York, 1914: 40-41. Image from M. Phillip Copp, Booklet entitled *The Atomic Revolution*, 1957. Courtesy of SRS History Project.

ties for harvesting uranium-235, but no one knew if any of them would work, and all of them promised to be prohibitively expensive. In effect, this was the state of fission research when Hitler invaded Poland and began World War II in Europe. Germany, Britain, and the United States, all had the knowledge and the means for making an atomic bomb. All they lacked was the will.

On the eve of the First World War, H. G. Wells published *The World Set Free*, a novel that described a world run by "atomic energy," and a global war in which cities were destroyed by "atomic bombs." Physicists from Heisenberg to Szilard had long been intrigued by Wells' story.[51] What had been an outlandish fantasy during the First World War would be within the realm of possibility during the Second. Most physicists knew this, and, at varying levels of involvement, so did their governments. In late 1939, Heisenberg, Hahn, and others were commissioned by the German military to continue research into the possibility of a nuclear chain reaction and the possibility of a bomb.[52]

Similar research began in both Britain and the United States, even though the U.S. government was not yet involved. Leo Szilard moved to correct this situation by enlisting Einstein to write a letter to President Roosevelt in August of 1939, warning him of the possibility of a new and potentially awesome type of bomb, a bomb the Germans were probably working on. As a result of this letter, in October, Roosevelt commissioned the first U.S. government agency to look into the potential of this line of research: the Advisory Committee on Uranium.[53] This was the first in a long series of steps toward the Manhattan Project.

2 World War II and the Manhattan Project

The 1930s were a time of rapid progress in the development of nuclear physics. Research accelerated in the early years of the Second World War, when new developments were conceived and implemented in the midst of increasing wartime urgency. American government interest in these developments was limited at first, but increased as the war broadened, and as the possibility of a fission bomb became more probable. After Pearl Harbor and the final decision to pursue the bomb, the American effort was coordinated and partially militarized under the aegis of the U.S. Army Corps of Engineers. This led to the establishment of the "Manhattan Engineer District," commonly known as the Manhattan Project.

Before Pearl Harbor and direct American involvement in the war, the U.S. government's role in nuclear research was basically that of an observer. Funding began only as the promise of success increased in 1940 and 1941. The government certainly provided little direction during that time; it was the physicists themselves, especially the foreign scientists, who organized a restriction on the publication of fission research in late 1939 and early 1940.[1] Only the scientists knew what was at stake.

The government's involvement increased by degrees in response to Hitler's military achievements. The first U.S. government agency to oversee nuclear developments, the Advisory Committee on Uranium, was created in October 1939 in response to Einstein's letter to Roosevelt in August of 1939—and Hitler's invasion of Poland in September. The National Defense Research Council (NDRC) replaced the Advisory Committee in June 1940, after the fall of France. The NDRC in turn was folded into the Office of Scientific Research and Development (OSRD) after the invasion of the Soviet Union in June 1941. In each of these steps, there was a growing coordination between the physicists and their government. More will be said about the agencies that preceded the Manhattan Project, but it would be better to first examine the developments that increased government interest in the two years before Pearl Harbor. Beginning with research into fission chain reactions and the separation of uranium-235 from natural uranium, these developments culminated in the discovery of the remarkable fissile properties of Element 94, soon to be known as plutonium.



Chicago Pile No. 1 was set up in the squash court underneath the west stands of Stagg Field at the University of Chicago. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negative 1-785.

THE FERMI-SZILARD PILE AND URANIUM RESEARCH

The first government funding for nuclear research was allocated to purchase graphite and uranium oxide for the chain reaction experiments being organized by Fermi and Szilard at Columbia University in February 1940.[2] This work, which began in New York City, soon spread to Princeton, the University of Chicago, and research institutions in California.[3] Even at this stage, the scientists knew that a chain reaction would need three major components in the right combination: fuel, moderator, and coolant. The fuel would contain the fissile material needed to support the fission process. The neutrons generated by the fission process had to be slowed by the moderator so that they could initiate additional fission reactions. The heat that resulted from this process had to be removed by the coolant.

Fermi's initial research explored the possibility of a chain reaction with natural uranium. It was quickly determined that high-purity graphite served as the best neutron moderator out of the materials then available.[4] After extensive tests throughout 1940 and early 1941, Fermi and Szilard set up the first blocks of graphite at Columbia University in September 1941. The graphite blocks were called a "pile," a name that was soon extended to all other forms of reactors. Fermi and Szilard's pile consisted of graphite blocks around a core of natural uranium. Unfortunately, the pile did not work well, largely because the graphite blocks were not arranged for optimum results.[5] Additional work perfected what came to be called the "lattice" arrangement, where channels of uranium coursed through a matrix of graphite blocks.[6] Another achievement of those early days was a better understanding of the chain reaction itself. In order for a chain reaction to be maintained, each fissioned nucleus had to send off at least one neutron that caused another nucleus to fission, and so on. A chain reaction that continued indefinitely at a constant rate had a multiplication factor ("k") of 1, and was identified as "k = 1." When k was greater than 1, there was an increase in both the fission rate and the reactor power level. If k was less than 1, the reaction could not sustain itself.[7]

Even though Fermi and Szilard's early work in chain reactions failed to achieve k = 1, they learned much from the experience. The usefulness of graphite as a neutron moderator was firmly established. The lattice was found to be the best arrangement for the uranium and the graphite blocks to achieve maximum neutron efficiency.[8] Most importantly, it was learned, or at least affirmed, that piles stocked with natural uranium could produce nuclear energy in the form of heat, but would not produce a workable bomb. Fermi and Szilard's early work with piles demonstrated that a much higher concentration of uranium-235 would be needed for that task.[9]

THE SEARCH FOR URANIUM-235

Alfred Nier, at the University of Minnesota, first separated uranium-235 from natural uranium the same month Fermi and Szilard received government support for their chain reaction work. In March, Nier conclusively demonstrated that uranium-235 was the uranium isotope responsible for fission.[10] Almost immediately, this discovery threw a major roadblock in the path of the development of the atomic bomb. As Fermi's chain reaction research increasingly demonstrated, a uranium atomic bomb would be possible only with

concentrated uranium-235. Natural uranium is composed of two isotopes (over 99% uranium-238 and less than 0.7% uranium-235), so it is not possible to separate the isotopes chemically. Isotopes had to be separated physically, atom by atom. In 1940 and 1941, there was no known way to separate isotopes in the quantity needed to make a bomb. There were, however, various theoretical possibilities.

A promising method of isotope separation was the electromagnetic method, pioneered by Alfred Nier and championed by Ernest Lawrence, head of the Radiation Laboratory at the University of California. This method was based on the theory that uranium atoms in gaseous form, when passed through a vacuum and subjected to an electromagnetic field, would tend to separate into lighter and heavier isotopes. The lighter atoms of uranium-235 could then be gathered separately.[11] Lawrence's first prototype for this process was a converted cyclotron dubbed a "calutron" or "racetrack," perfected in late 1941 and early 1942. The world's largest electromagnet at that time, the 184-foot-diameter calutron, soon proved to be relatively successful at forcing uranium-235 and 238 atoms into different trajectories, allowing them to land in different receptacles.[12]

Another method considered for the separation of uranium-235 was gaseous diffusion, a technique pioneered in Britain and championed in the United States by John Dunning of Columbia University. In this method uranium gas passes through a series of membranes with openings small enough to block the heavier uranium-238 while allowing uranium-235 to pass through. The immediate problem posed by this method, and the problem that continued to plague this method for years to come, was the difficulty of manufacturing a membrane suitable to the task.[13]



(Left to Right) Ernest Lawrence, Arthur Compton, Vannevar Bush, James Conant, Karl Compton and Alfred Loomis, 1940. Ernest Orlando Lawrence Berkeley National Laboratory, courtesy of AIP Emilio Segré Visual Archives.

Other methods that surfaced during this period included centrifugal separation and liquid thermal diffusion. Jesse Beams of the University of Virginia championed the centrifuge method, while the liquid thermal diffusion method was favored by Philip Abelson of the Carnegie Institute. Both methods were later dropped by the Office of Scientific Research and Development.[14]

THE PROMISE OF PLUTONIUM

Uranium is the heaviest naturally occurring element on earth. Ever since the 1930s, however, it was known, at least in theory, that man-made elements of greater mass could be made by bombarding natural uranium with neutrons. The first two artificial elements were identified as eka-rhenium (Element 93) and eka-osmium (Element 94). In the early 1940s, they would be formally named neptunium and plutonium, respectively.

With the discovery of fission and the possibility of a fission bomb, there was renewed interest in Elements 93 and 94 for a number of reasons. Calculations suggested that Element 94 would fission just as well as, if not better than uranium-235, and the produc-

tion of Element 94 would provide a use for all the uranium-238 that otherwise would not be suitable bomb material. Also, because this was a new element, with a different atomic number from any isotope of uranium, it could be separated from uranium by chemical means.[15]

Edwin McMillan and Philip Abelson made the first serious attempts to make Elements 93 and 94 in the laboratory at the University of California's Radiation Laboratory in early 1940. This discovery was featured in the last publication on fission research before the American physics community dropped a curtain on the subject. That publication, however, detailed how both man-made elements were the decay products of neutron capture in uranium-238. Specifically, the researchers found that neutron bombardment of uranium-238 produced uranium isotope 239, which quickly decayed into Element 93, which in turn decayed into Element 94. When this process was complete, Element 94, later identified as plutonium, proved relatively stable, with a half-life of 24,000 years.[16]

Research on the nature of Element 94 accelerated throughout the rest of 1940 and 1941 because the new element promised to be more fissionable than uranium-235. Much of this work was done at the Radiation Laboratory by researchers including Glenn Seaborg, Joseph Kennedy, and Arthur Wahl.[17] In February and March 1941, Seaborg and others succeeded in isolating Element 94 through chemical means. They also found other isotopes of the new element (plutonium-236 and 238).[18] The next year Seaborg named the new elements: Element 93, the first after uranium, was named "neptunium" (Np) after the first planet past Uranus; Element 94 was named for the next planet, Pluto, and was called "plutonium."[19] Bucking a tradition that would have mandated "Pl" as the scientific shorthand of the new element, Seaborg chose "Pu," in large part because of its unfavorable connotations.[20]

Element 94 lived up to "P-U." Research in 1941 suggested and later demonstrated that plutonium was 1.7 times more fissionable than uranium-235.[21] Heavier and less stable than uranium, plutonium could also be separated chemically, which meant that its production might be cheaper than the laborious process of harvesting uranium-235. This advantage, however, was offset by a major drawback: the new element was much more radioactive than uranium. Every step of the production process would require considerable shielding for the work force.

Despite this disadvantage, the promise of plutonium was too great to leave untouched in the search for fissionable material. In early 1941, Ernest Lawrence turned his cyclotron on the new man-made elements to learn more about their fission properties. Lawrence came away from this work convinced that the new element could be produced in large quantities by bombarding uranium-238 with neutrons in Fermi's pile.[22] This discovery gave a boost to Fermi and Szilard's chain reaction research, and to the concept of the pile in general. The discovery of the usefulness of Element 94 provided a purpose for Fermi's pile, not yet known as a "reactor."

EARLY U.S. GOVERNMENT INVOLVEMENT

The government's participation in fission research gained momentum as the results became more promising. The first of the Manhattan Project's predecessors, the Advisory Committee on Uranium, was not terribly active, as might befit an agency that oversaw a

process that, at the end of 1939, was almost wholly theoretical and potentially expensive.[23] In early 1940, the committee recommended that the government become directly involved in funding fission research, specifically concentrating on uranium-235 separation and Fermi and Szilard's chain reaction work at Columbia University.[24]

In June 1940, the Uranium Committee was folded into a much larger umbrella organization, the National Defense Research Council (NDRC), established to oversee and coordinate military and civilian scientific work that might prove useful if the United States entered the war. This action was in response to recent successes in uranium work, as well as the invasion of Western Europe by the Germans. The NDRC was headed by Dr. Vannevar Bush, president of the Carnegie Institute. Fission work still concentrated on isotope separation and nuclear chain reactions, but there was a growing emphasis on plutonium research.[25] On June 28, 1941, just days after the Germans invaded Russia, the NDRC was subsumed by a new organization with broader scope and greater powers, the Office of Scientific Research and Development (OSRD), established by Executive Order. Vannevar Bush was again placed in charge, this time with a mandate to report directly to Roosevelt.[26]



(Left to Right) Ernest Lawrence, Glenn Seaborg, and Robert Oppenheimer at control panel of 184 inch cyclotron, circa 1942. Ernest Orlando Lawrence Berkeley National Laboratory, courtesy of AIP Emilio Segré Visual Archives.

Despite all of these organizational changes, and the remarkable developments in the various proposed methods for harvesting uranium-235 or producing plutonium, no one at the governmental level was at all certain that any of these methods would produce fissionable material on an industrial scale. This uncertainty began to change with the appearance of the MAUD report in July of 1941.

MAUD was a British committee of scientists and government officials established to study the possibility of a fission bomb. A meaningless acronym adopted as a wartime safeguard, "MAUD" was first organized in June 1940, during the dark days after Dunkirk. In the months that followed, it charted the developments of nuclear fission research on both sides of the Atlantic.[27] The committee released its report in July 1941, when it appeared the Soviet Union was in imminent danger of collapse. The MAUD report called for a fission bomb based on the use of gaseous diffusion of uranium, and dismissed other methods including thermal diffusion, centrifuge, electromagnetic racetracks, or the use of plutonium. It also stated that close cooperation with the United States was essential to the success of the enterprise. Even though American physicists disputed the report's concentration on gaseous diffusion, MAUD had great and positive impact in the United States. The report concluded that a nuclear fission bomb was not only feasible, but also possible within a time frame of two years, making it available for use in the present war.[28]

In November of 1941, the OSRD, drawing on the MAUD report and subsequent reports by the National Academy of Sciences, made its own recommendations to President Roosevelt on the feasibility of a fission bomb using uranium-235. Unlike the MAUD report, which favored gaseous diffusion, the other separation methods were fully consid-

ered. Estimates were projected on how much uranium-235 would be required for a fission bomb and that this amount could be gathered through the various uranium separation techniques at an estimated cost of between 50 and 100 million dollars. The following month, on December 7, 1941, the Japanese attacked Pearl Harbor. Four days later, Hitler declared war against the United States as well. When Roosevelt approved the OSRD report in January of 1942, there was an increased urgency to the fission programs that would only intensify over the next few months, as the government sought to organize an atomic bomb program. It was also during this confusing period that plutonium was formally included as one of the viable options for a fission bomb.[29]

With Roosevelt's consent, Vannevar Bush implemented the first reorganization of the American nuclear effort in December 1941 and January 1942. First, there was a decision to make an all-out effort for the bomb. Next, the NDRC, which previously ran the Uranium Section (S-1) for the OSRD, was determined to be inadequate for this effort. S-1 was placed directly under the OSRD.[30] Eger Murphree, a chemical engineer with Standard Oil, was put in charge of engineering studies and pilot plant construction. Ernest Lawrence, Arthur Compton, and Harold Urey were made program chiefs. Lawrence was made overseer of electromagnetic and plutonium research. Compton was placed over chain reaction and weapons theory research, while Urey headed up work on gaseous diffusion, centrifuge work, and heavy water development. Bush himself coordinated the engineering and scientific work, and made the final decisions for all construction contracts. The planning and construction of the pilot plants led to the first cooperation between the OSRD and the Army Corps of Engineers.[31]

Compton, the new head of chain reaction work, was now directly in charge of the graphite and uranium-lattice research. In January 1942, Compton decided to transfer all pile research to Chicago. This led to the creation of the Metallurgical Laboratory on the grounds of the University of Chicago. Fermi, Szilard, and Seaborg were among the physicists who moved to the new facility in the months that followed.[32] The primary goal of the Metallurgical Laboratory, soon known as Met Lab, was the development of ways to transmute uranium into plutonium on an industrial scale.[33]

As the war intensified in the early months of 1942, with Japanese advances throughout the Pacific and German U-boats unchecked in the North Atlantic, it was soon clear that even this level of organization was not sufficient to guarantee the success of the fission bomb project. Rather, an increased level of militarization and engineering know-how would be required to safeguard the project and see it through to completion. This led to the direct involvement of the U.S. Army Corps of Engineers and the creation of the Manhattan Project.

Ironically, just as the American bomb program was about to go into high gear, the German program was being demoted. German fission research, which looked so threatening before the veil of secrecy went down in early 1940, took a number of wrong turns in the crucial early years of the war, not the least of which was the faulty assumption that graphite would not work as a reactor moderator. There is also evidence that crucial physicists involved in the program, such as Heisenberg and Weizsacker, either dragged their feet or misled those in authority as to the potential for the bomb. Either way, in the summer of 1942, the High Command decided that the fission bomb was too much of a long shot, given Germany's economic over-extension and the projected time frame of the war itself; fission research was removed from immediate military supervision.[34] Unknown to the

allies at the time, the Germans never really got close to making an atom bomb, in large part because it would have been too expensive given the state of their economy.



General Groves and Robert Oppenheimer reviewing report, world map in the background suggests the global nature of their endeavor. Courtesy of SRS History Project.

THE MANHATTAN PROJECT

Early on, Niels Bohr discounted the possibility of making an atomic bomb by saying that it could only be done by diverting the resources of an entire nation.[35] He was not far wrong. Only a large and powerful nation could gear up for the effort and drive it to conclusion. The Manhattan Project proved to be such an effort, one that the United States was in the best position to achieve. The country had a huge industrial and capital base, as well as a skilled work force. It also had no shortage of brilliant scientists, many of whom were refugees from Hitler's Europe. They not only supported the effort, but also were in the forefront of the push to see the program through. Finally, there was the U.S. Army Corps of Engineers, trained to design and construct large projects and to provide the leadership needed to see them to completion.[36]

In the early summer of 1942, when the Army Corps was brought into the program, leadership and organization were unresolved. When Col. James C. Marshall was called to head up the program on June 17, 1942, it was still called "S-1," the old NDRC nomenclature for the uranium research project.[37] Marshall was commissioned to build the facilities needed to produce an atomic bomb, and reorganize the effort so that it would be done as quickly as possible.

Marshall did not have the clout to get top priority in the struggle for wartime supplies. In mid-July, the S-1 project got a rather low-priority AA-3 rating, largely because the program was considered such a long shot.[38] In other respects, the project dragged. Marshall's first scientific meeting with Vannevar Bush and the S-1 Executive Committee of the OSRD, did not take place until July 25. At that time, the scientists were urging the acquisition of a large tract of land in east Tennessee, near the town of Clinton, for the site of all major nuclear manufacturing. Marshall later described the tract as "four isolated sites in one big isolated site."[39] No action was taken to acquire the land.

In an effort to better coordinate the efforts of the S-1 project, Marshall put the program under the umbrella of a formally instituted corps district, like those established for specific geographical areas throughout the country. Unlike other corps districts, however, this one would have no territorial boundaries. On August 16, 1942, S-1 was folded into the "Manhattan Engineer District" or MED, with headquarters in New York City.[40] Even though project headquarters was soon moved from New York to Washington, DC, the original name stuck. Few today remember the Manhattan Engineer District, but the program to make the first atomic bomb is still called the "Manhattan Project."

Marshall proved to be a good coordinator, but that was not enough. The program needed someone to cut through the logjam of military-supply restrictions, and through the dissonance of the scientists themselves, who could not reach a consensus on the best way to produce fissionable material. Bush himself realized this, and was instrumental in getting Marshall replaced by a more dynamic leader.[41] Even though Marshall retained the title of District Engineer until well into 1943, his effective replacement was Leslie Groves, who had achieved renown by building the Pentagon in record time.[42] Anticipating an overseas assignment, Groves was not pleased to be put in charge of a project that many military experts considered a pipe dream.[43] Like it or not, Groves assumed formal command on September 23, 1942.[44]

This lack of faith in the project sometimes worked to Groves' advantage. He was made brigadier general to help break the military supply problem, and he was given huge leeway in directing the work of S-1. Otherwise, he was left alone, since many of his superiors wanted to avoid all responsibility for what they thought would be its inevitable failure. As Groves himself put it in later years, he was the impresario of "a two billion dollar grand opera with thousands of temperamental stars in all walks of life."[45] He himself had no idea if the project could be made to work. As he stated, "if our gadget proves to be a dud, I and all of the principal Army officers of the project . . . will spend the rest of our lives so far back in a Fort Leavenworth dungeon that they'll have to pipe sunlight in to us."[46]



S-1 Committee Meeting. September 13, 1942 at Bohemian Grove, California. (Left to Right) Harold Urey, Ernest Lawrence, James Conant, Lyman Briggs, Eger Murphree, and Arthur Compton. Ernest Orlando Lawrence Berkeley National Laboratory, courtesy of AIP Emilio Segré Visual Archives.

Groves moved on several fronts simultaneously. He got the triple-A rating required to give MED top priority in the allocation of supplies and equipment. He purchased a large supply of uranium from the Belgian Congo. He also acquired the 52,000-acre tract near Clinton, Tennessee, as the manufacturing site for the various processes needed to produce fissionable material.[47] Working closely with Robert Oppenheimer, the man who would direct the making of the bomb, Groves selected the site of the bomb design laboratory at Los Alamos, New Mexico, in November of 1942.[48]

The science end of the project was more difficult to resolve. While the plutonium program seemed relatively secure, Groves was not pleased to have four different methods (electromagnetic, gaseous diffusion, thermal diffusion, and centrifuge) for producing uranium-235. He wanted one method designated the clear front runner to avoid what promised to be an exorbitantly expensive program.[49] Unfortunately, there was no clear choice. As late as May, the S-1 Executive Committee had de-emphasized the potential of thermal diffusion, but still recommended that the other three—electromagnetic, gaseous diffusion, and the centrifuge—all proceed to the pilot plant stage.[50] In November, Groves was unable to get a consensus from the physicists involved in the various uranium-235 programs, but he was able to narrow the field. The electromagnetic method emerged from the fray the favored method—both a pilot plant and the regular plant were approved for construction at Clinton. Gaseous diffusion still had promise, and it too went forward, even

though no one knew how to make the necessary filtration membrane. Thermal diffusion was de-emphasized, and the centrifuge was eliminated altogether.[51]

By the end of November 1942, there were three top contenders for making fissionable material: electromagnetic and gaseous-diffusion methods for harvesting uranium-235, and the pile or reactor method for producing plutonium. For these three methods, full-scale production was recommended.[52] Up until November, it was assumed that the Clinton site in Tennessee would contain all manufacturing work required to produce fissile material for the bomb. In that month, however, it was decided that the plutonium manufacturing works should be kept separate from the other processes. Even though Hanford in Washington State would not be selected as the plutonium site until early 1943, the selection process was well underway by the end of 1942.[53]

In keeping with accepted military tradition—and to the annoyance of some of the physicists—Groves courted large private firms to run the various aspects of what would be a huge industrial complex.[54] Tennessee Eastman, which had already done work at Holston Ordnance Works, was retained to run the electromagnetic plant at Clinton. The M. W. Kellogg Company and Union Carbide and Carbon Corporation were detailed for the gaseous diffusion plant, also to be at Clinton. E. I. du Pont de Nemours and Company, commonly referred to as Du Pont, was retained for the operation of the plutonium works, no longer to be at Clinton, but not yet assigned to Hanford.[55]

Groves succeeded in getting Du Pont to assume the responsibility for the operation of the plutonium works plant in November of 1942.[56] Groves was particularly interested in getting the giant chemical firm to carry out this part of the project. Not only did Du Pont have a history of explosives manufacture and long association with the U.S. military, but the company also had the organizational strength and design and engineering capabilities to do the work. Since Du Pont specialized in chemical processes, it was ideally suited to the chemical separation of plutonium from the irradiated materials that would leave the piles or reactors.[57]

The reactor work that Du Pont was scheduled to perform got a serious boost when Fermi's pile went critical on December 2, 1942. This was the first time a self-sustaining chain reaction had ever been created. This achievement was the result of almost a year of research at the Metallurgical Laboratory on the grounds of the University of Chicago. Fermi himself had moved to Chicago in April of 1942, bringing together all pile research at the Met Lab. Final design work for the pile was begun that summer, followed by instrument design, the machining of the graphite blocks, and the creation of dies needed to press the uranium oxide into suitable forms.[58] The pile itself was set up in the squash court underneath the west stands of Stagg Field and was designated Chicago Pile No. 1 or CP-1.[59] Shaped like a flattened sphere, CP-1 was 25 feet wide in the middle, 20 feet high, and composed of 57 layers of graphite block.[60] Arranged in a lattice formation, the pile consisted of 400 tons of graphite, 6 tons of uranium metal, and another 50 tons of uranium oxide. When the pile went critical on December 2, it reached a power level of one-half watt.[61] Even though the power level was inconsequential, the results of the test pile were extraordinary. Fermi's pile demonstrated that a nuclear chain reaction with uranium was possible, and it paved the way for the large-scale nuclear reactors that would be able to turn uranium to plutonium. Among those present on that day was Crawford Greenewalt, the man slated to head Du Pont's technical efforts at Hanford, and, after the war, to become president of Du Pont itself.

The success of Fermi's pile was further complemented by advances in the chemical separations work that would have to be an integral part of the plutonium project. The first chemical separation of plutonium from uranium-238 was achieved on August 20, 1942. It was also the first occasion where there was enough plutonium to be seen with the naked eye.[62] Additional work by Seaborg and others established that a separation matrix of lanthanum fluoride and other materials would successfully separate the plutonium from the other irradiated materials.[63] The separation work would still be difficult, especially at the industrial level, but it was now established that it could be done.

The Manhattan Project was ready to jump from the laboratory to industrial operation. The results of the project to date, as well as the industrial plans, were laid before President Roosevelt at the end of 1942. In late December, the Manhattan Project was authorized to proceed full-steam with industrial production, using the three methods for obtaining fissionable material.[64] Clinton had already been selected as the site of the electromagnetic and gaseous diffusion plants, as well as the plutonium pile semi-works. Los Alamos had been chosen as the intellectual nerve center and bomb assembly point for the project, and Hanford was about to be selected as the site for the nuclear reactors and the chemical separations plants.[65] The Manhattan Project was on the verge of take-off.

PRODUCING THE FISSION MATERIAL

By the time the first atomic bombs were detonated in the summer of 1945, the Manhattan Project had cost around two billion dollars. The bulk of that money was spent creating three top-secret government facilities devoted to production of the fissionable material and the creation of the bomb mechanisms needed to detonate that material: the Clinton Engineer Works, later known as Oak Ridge; the Hanford Works; and the Los Alamos Scientific Laboratory. While much of this work went on simultaneously, the bulk of the fissionable material production had to take place before the bomb could be assembled. For ease of presentation, the uranium-235 production facilities at Clinton will be discussed first, followed by the plutonium pilot plant at Clinton and the large plutonium production facility at Hanford. This in turn will be followed by the work at Los Alamos, where the uranium and plutonium bombs were designed and assembled.

URANIUM FACILITIES AT OAK RIDGE

The Clinton Engineer Works, now known as Oak Ridge, was the designated location for the production of uranium-235. Built in late 1942 and early 1943 on 59,000 acres west of Knoxville, there were two large-scale facilities at Oak Ridge for the production of uranium-235: the electromagnetic plant, designated Y-12; and the gaseous-diffusion plant, designated K-25.[66] The experimental plutonium pile and separation facility, X-10, will be discussed in the next section.

Planned by Ernest Lawrence and other researchers at Berkeley, Y-12 was built by Stone and Webster of Boston, for operation by Tennessee Eastman Corporation. Excavation began in February 1943; operation commenced in October of that same year. The heart of the Y-12 area were the two electromagnetic racetracks that separated urani-

"All In One Lifetime" - Jimmy F. Byrnes

Of all the South Carolina political figures who would play a role in the rooting of nuclear industry in his home state, Jimmy Byrnes was the most knowledgeable about what was ahead. Known as Franklin Delano Roosevelt's "assistant president," Byrnes, under the titles of Director of Economic Stabilization and, later, Director of War Mobilization, ran the country while FDR dealt with the war and foreign affairs. Described as "a small, wiry, neatly made man," who had the ability to place issues before his personal agenda, Byrnes also acted as a buffer between the influential Bernard Baruch, another native son of South Carolina, and the president. After Roosevelt's death, Byrnes served as Secretary of State under Truman, bringing his considerable skill in negotiation and political maneuvering to the job.

Byrnes, a Charlestonian, was born in 1879 to Irish-American parents. His mother, Elizabeth E. Byrnes, who learned dressmaking to support her family after her husband's death, raised him. At age fourteen he found a job in a Charleston law firm as an office boy where a member of the firm took an interest in him and acted as his mentor. Seven years later Byrnes was appointed to the position of court reporter in Aiken for the 2nd Judicial Circuit, a job he enjoyed for eight years. During that time, he continued with his education at night, studying in the office of attorney James Aldrich. He passed the bar in 1903, and began practicing law in Aiken, seeking election as a solicitor in 1908 in the Aiken circuit. He married Maude Busch, a local woman and became editor of Aiken's weekly newspaper, *The Aiken Journal and Review*.

He was elected to Congress in 1910, in 1930 to the Senate. He is credited with helping establish the first national highway system–U.S. Highway 1–that runs through Aiken. An active supporter of Franklin Delano Roosevelt, then governor of New York in 1928, Byrnes worked as a speechwriter for Roosevelt during the 1932 campaign. Byrnes was part of the Roosevelt team but he was not in favor of all of Roosevelt's domestic policies. His support for Roosevelt and the New Deal measures he advocated did land him a seat on the United States Supreme Court in 1941. One year later, he resigned to assume his position as "Economic Czar" within the wartime emergency program of wage and price. South Carolina benefited from Byrnes' presence in the White House. The state received over $400 million in federal assistance during the Depression, a result of the state's political leadership's alliance with Franklin Delano Roosevelt's administration. Byrnes, Charleston's Mayor Burnet R. Maybank, and Governor Blackwood successfully lobbied for the Santee Cooper Project. It was the largest New Deal project the state received.

In 1944, Byrnes was hopeful that he would be Roosevelt's vice presidential candidate for his fourth term and Roosevelt encouraged him along those lines. However, when push came to shove, the Missourian, Harry S. Truman, was selected. Despite his work as "assistant president," Byrnes' politics and background as a conservative Democrat from the Deep South was considered a liability.

Within twenty-four hours of Roosevelt's death, two men told his successor, Harry Truman, about the race for the atom bomb. The first was Henry Stimson, the Secretary of War; the second was Jimmy Byrnes, then a private citizen of South Carolina. Truman selected Byrnes as his Secretary of State shortly afterward and requested that he serve on the "Interim Committee" a top-secret group in charge of establishing American policy on when and how the bomb would be used in the war, its testing, and its postwar applications. As a member of the Interim Committee, Byrnes rubbed elbows with members of the scientific community that created the bomb and the Secretaries of War and of the Navy. He also met with the industrialists and engineers who created Oak Ridge and Hanford to learn about what was entailed in their operations.

> " I had often heard naval officers say that a new defensive weapon was developed for every offensive weapon. I asked the scientists what defense there could be against the atom bomb. But these distinguished gentlemen, who had directed the advisory work on the bomb, could think of no defense. They did anticipate the development of still larger and more destructive bombs. I asked them if I should believe the only defense against further development was to kill off all the scientists. This suggestion did not appeal to them."

On July 3, 1945, he became Secretary of State. In that capacity, he accompanied Truman to the Potsdam Conference. Between 1945 and 1947, he earned an international reputation for his role in world events, that ranged from policy making on the bomb to postwar control over atomic energy. Byrnes remained with the post until 1947, after which he retired to South Carolina. He had served with distinction in all three branches of federal government and he played a significant role at Yalta and Potsdam, as a key player in the Truman cabinet effecting an end to World War II, and setting out the foundation for early Cold War policy.

Source: James F. Byrnes Papers, Mss 90, Special Collections, Clemson University Libraries, Clemson, South Carolina. Secondary Source: www.byrnesscholars.org. (Inset) Source: James F. Byrnes, *Speaking Frankly*, (New York: Harper, 1947), 260.

um-235 from natural uranium. The two racetracks were designated Alpha and Beta, and each track was 122 feet long, 77 feet wide, and 15 feet high. Alpha provided the first step in the separation of uranium-235, while Beta took that material and further enriched it.[67]

The gaseous diffusion plant, K-25, got off to a later start. Planned by physicists from Columbia University and by Kellex Corporation, K-25 was built by J. A. Jones Construction and Ford, Bacon & Davis. It was to be operated by M. W. Kellogg Company and Union Carbide and Carbon Corporation. Excavation for this facility did not begin until the summer of 1943, after which the huge U-shaped building took shape. Each wing of the building was 400 feet wide, and a half-mile long. Uranium hexafluoride gas was to be pumped through 11 miles of tubes and literally thousands of porous barriers, perforated with billions of holes, all designed to select for uranium-235 atoms, which would tend to travel through the process slightly faster than uranium-238. Even at this point, it was not known how to produce the barrier or "membrane" that was at the very heart of the separation process.[68]



Meeting prior to the start of the "Big Three" at Potsdam, Wednesday, July 18, 1945. In the foreground, left to right, Generalissimo Stalin, President Truman, Secretary of State Byrnes, and Foreign Commissar Molotov on the lawn outside of Stalin's residence in Babelsburg, Soviet Union. James F. Byrnes Papers, Mss 90, negative 49965. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

By the spring and summer of 1944, there was a crisis in the operation of both Y-12 and K-25.[69] At Y-12, problems began to crop up almost immediately after the Alpha track went on line in October 1943. The vacuum tanks leaked and were pulled out of alignment by the force of the magnets. In addition, rust formed in the magnetic coils, which tended to short out, forcing a closure of the racetrack in December of 1943 for extensive repairs. Even after these problems were addressed, there remained the matter of gathering the uranium-235. Not enough thought had been devoted to the physical process of isotope recovery; much of the uranium-235 was located on the walls of the vacuum tanks, and it was found to be difficult to collect.[70]

If possible, K-25 was in worse shape. When the gaseous diffusion plant was constructed, it was not even known how to make the porous membrane needed to separate uranium-235 from 238, the very crux of the whole procedure.[71] Continuing problems with the membrane soon made it apparent that K-25 could not produce uranium with a high concentration of uranium-235. In desperation, the Army turned to thermal diffusion, a process that had been dropped by the Manhattan Project, but one favored by the Navy. Groves took the Navy's thermal-diffusion process and had a small plant called S-50 built at K-25 to handle the work. Able to provide massive quantities of slightly enriched uranium, S-50 essentially saved the gaseous-diffusion process. Even with this help, however, K-25 could only produce 50% enriched uranium, suitable only as feed material for the Y-12 plants.[72]

After solutions were found to the problems associated with Y-12, the electromagnetic process was enlarged in scope to provide most of the fission material for the uranium-235 atomic bomb that would be dropped on Hiroshima in August of 1945.[73] Even before that time, however, the uranium-235 work was somewhat overshadowed by the plutonium process, which promised an even more powerful bomb. But this process too had its share of problems.

THE PLUTONIUM PROCESS: ARGONNE AND OAK RIDGE'S X-10 PILE

The first stage in the plutonium process was the pile or reactor, and the seat of that knowledge during the Manhattan Project—and for many years to come—was the Metallurgical Laboratory run by the University of Chicago. Shortly after the success of Fermi's pile in December 1942, all Met Lab reactor research was transferred to the greater safety of the Argonne Forest section of the Palos Park Forest Preserve on the outskirts of Chicago. It was the Met Lab at Argonne that developed the pile designs used in the plutonium pilot works at Oak Ridge, and in the much larger facility at Hanford.[74]



Fourth anniversary reunion of CP-1 scientists. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negative 201-5282.

Fermi's first successful pile was relatively primitive, and it was the work of the Met Lab to improve the designs of new reactors. This included new safety features and the best possible use of the available neutrons, a concept called "neutron efficiency." The pile designs worked out by the Met Lab included reactors with moderators that ranged from graphite to heavy water. Coolants included helium, air, heavy water, and light water. When the Du Pont engineers came on board the plutonium project, they had their own preferences: the plutonium semi-works at Oak Ridge, known as X-10, would be air-cooled, with a graphite moderator.[75] As a back-up for both moderator and coolant, Groves insisted on the production of heavy water at a number of distillation plants, the largest of which was the Wabash River Ordnance Works, near Dana, Indiana.[76]

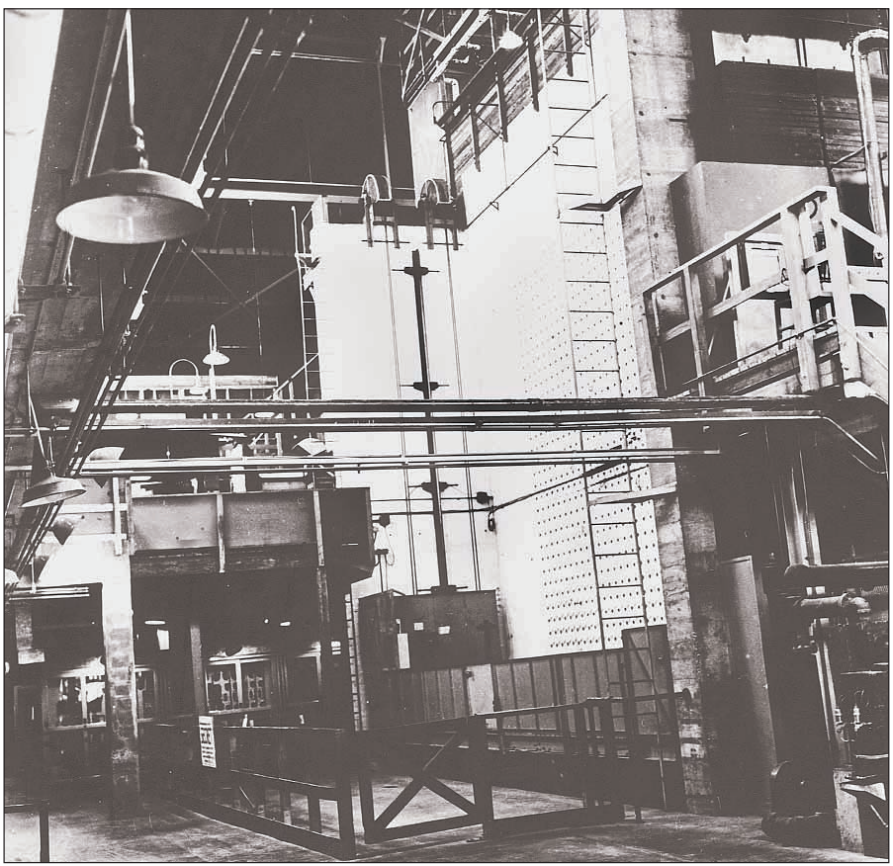
Construction work on X-10 began in February 1943 and was finished in October of that same year. In addition to an air-cooled experimental pile, there was a pilot plant for chemical separation.[77] Built by Du Pont and supervised by Met Lab, the X-10 pile was a graphite cube, 24 feet to a side, with 1248 separate channels for the insertion of nuclear materials.[78] The X-10 reactor was designed to produce small amounts of plutonium, which could then be used in various separations experiments.[79] When the reactor went critical on November 4, 1943, it became the world's second nuclear reactor, and the first one dedicated to production.[80] In the months that followed, X-10 was a training ground for Du Pont personnel who would later run the much larger and more complex facilities at Hanford. X-10 would continue to serve in this fashion long after the war, when it became part of the Clinton Laboratories and finally Oak Ridge National Laboratory.[81]

THE PLUTONIUM WORKS II: DU PONT AND HANFORD

At Groves' behest, the Du Pont company had come on board to design, build, and operate the plutonium works required for the Manhattan Project. It was a decision that did not find favor with the Metallurgical Laboratory, especially Fermi and Compton, who wanted to do much of the work themselves, or at least preferred General Electric or Westinghouse for the task.[82] Groves stood by his choice, and the manager chosen by Du Pont, Crawford Greenewalt—and these were probably the wisest of his many sage decisions.

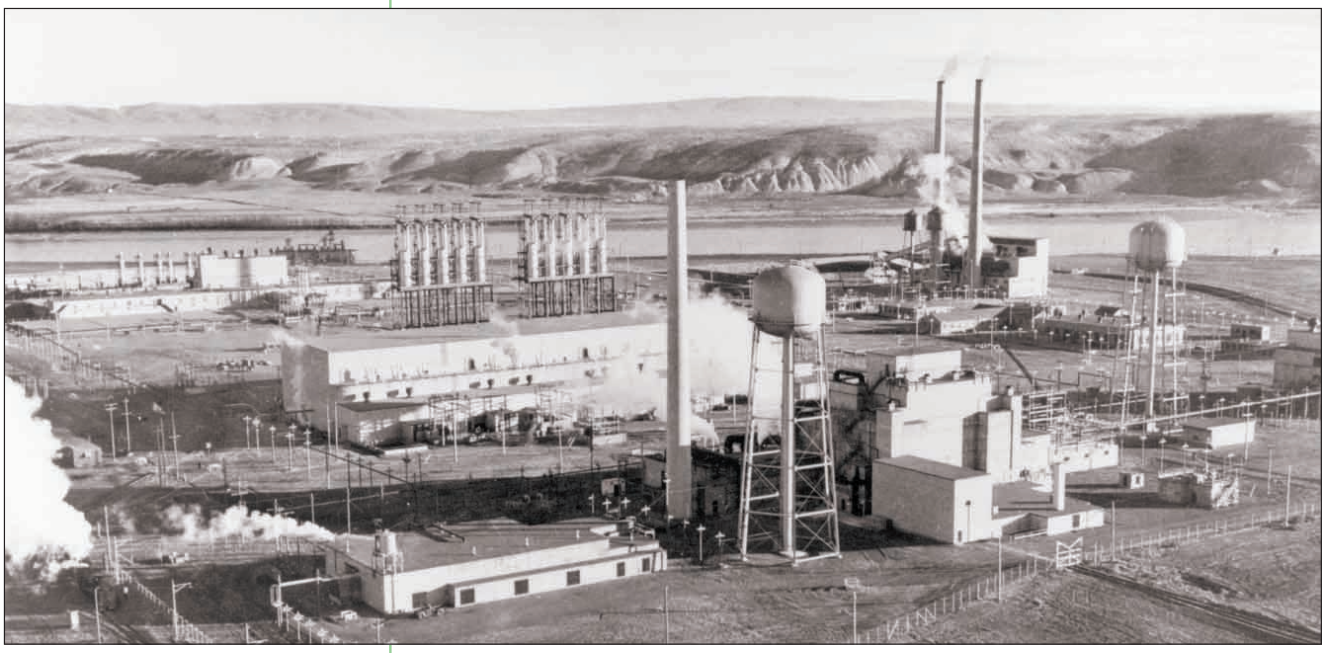
Undoubtedly, one reason for the reluctance of Fermi and others at the Met Lab to welcome Du Pont into the nuclear fold was Du Pont's reputation as an explosives manufacturer. The Du Pont family, based in Delaware, had been involved in making gunpowder since the early 1800s, and had a long association with the U.S. military as a munitions manufacturer. Anti-trust legislation in the early 1900s forced the Du Pont company to split into three firms, but this did not keep Du Pont from making great profits after the First World War broke out in Europe in 1914. Du Pont sold high explosives to Britain and France, and later, after the United States entered the war, filled all the Army and Navy orders for powder. It has been estimated that the company provided 40 percent of all the explosives material used by the Allies in the First World War.[83]

This led to huge profits for the company, and enabled it to expand further into chemical work, which had proven so useful during the war. In particular, research was directed toward nitrocellulose, previously used for gun cotton. Breakthroughs in various highly marketable plastics, such as Duco, rayon, cellophane, and the biggest seller of all, nylon, followed.[84] About this same time, in 1934, Senate committee hearings on exorbitant wartime profits tarred the company as infamous "merchants of death," a label Du Pont felt was unjustified and anachronistic. Hoping to avoid bad press in the aftermath of a project that would make World War I munitions look like a pop gun, Du Pont insisted on a contract with the government that would earn it a profit of one dollar.



X-10 pile was a graphite cube, 24 feet to a side, with 1248 separate channels for the insertion of nuclear materials. Courtesy of Oak Ridge National Laboratory.

Groves selected Du Pont for a number of reasons. Du Pont was a large company with a healthy corporate structure capable of handling the plutonium project. The company also had engineering and design capabilities that would be essential at Hanford. As a chemical company, it would be not only capable of, but also comfortable with, the basic industrial procedures that would have to be used to separate plutonium from the irradiated material that would come out of the reactors. Because of its industrial experience with the manufacture of gunpowder, Du Pont had an obsession with worker safety, and the plutonium works at Hanford were going to require all the safety measures that could be brought to bear.



As part of the Manhattan Project, Du Pont designed, constructed, and operated the world's first production-scale reactors at Hanford. Photograph taken by U.S. Army Signal Corps, courtesy of the Collections of the Library of Congress, negative US762, 101676, 211317.

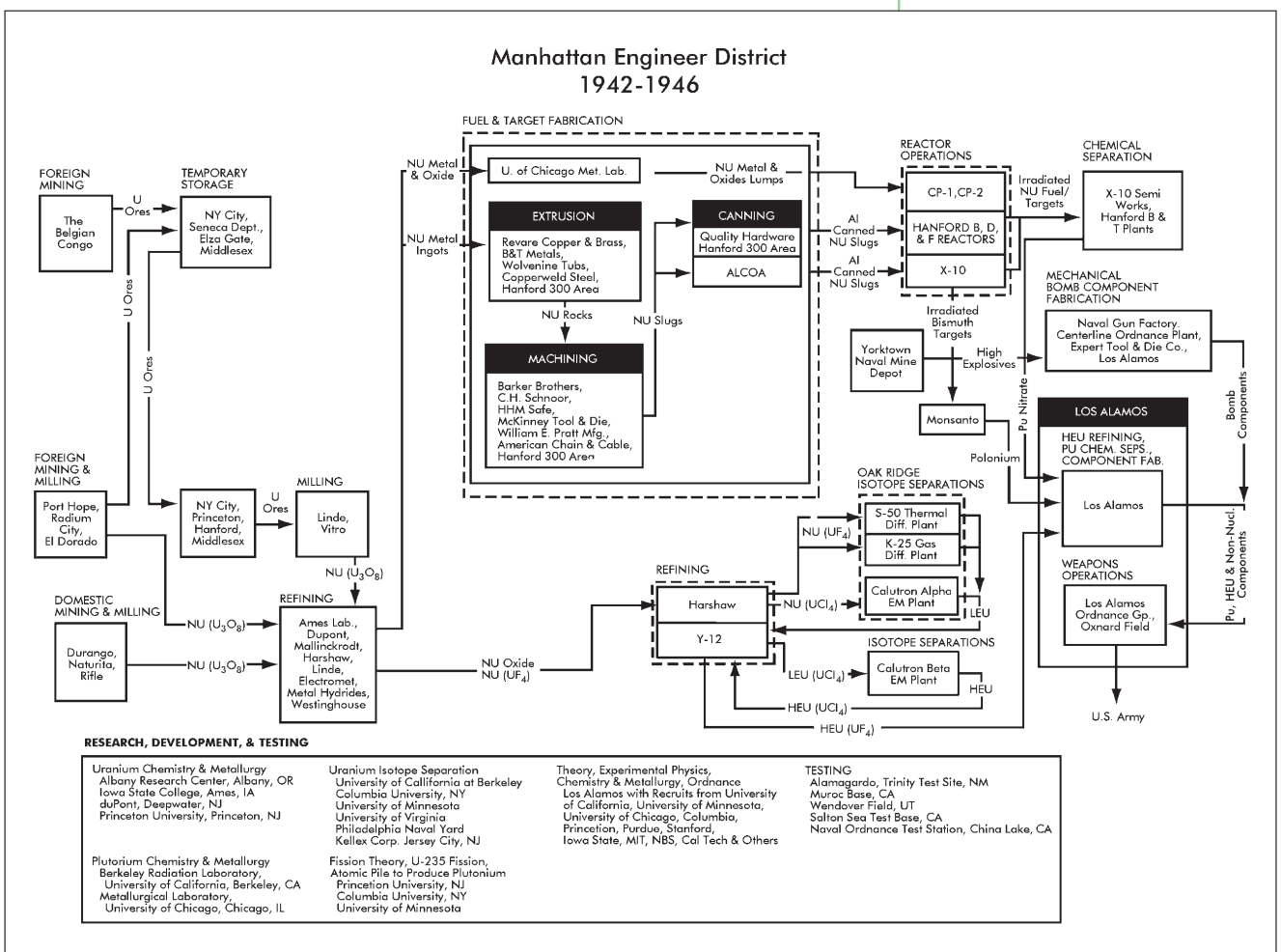
Hanford, one of the largest of the Manhattan Project engineering feats, was the last to get started. In December of 1942, it was known only that the plutonium site would be along the Columbia River, near the Bonneville and Grand Coulee dams.[85] The real estate appraisals began in January 1943,[86] and the Hanford site itself was not formally selected until February. Construction, however, proceeded quickly, and was well under way by summer, months before it was known whether the X-10 pilot reactor would even work.[87] Construction continued non-stop for a year, when the construction force peaked out at 42,400 in June of 1944.[88] By that time, the total population at Hanford, counting both construction and operating force, was around 50,000 people.[89] The project itself cost 400 million dollars.[90] By the time the dust settled, there were three graphite piles or reactors, three separations buildings, and a host of auxiliary buildings, all designed to create and process plutonium.

The three Hanford reactors were designated "B," "D," and "F." All three were water-cooled and graphite-moderated, and were designed to operate at a power level of 250 megawatts.[91] Essential components of these piles were the solid uranium cylinders or "slugs" encased in aluminum that were loaded into the reactors through openings built into the graphite core.[92]

Just as important as the reactors were the three separations buildings, each 800 feet long, 65 feet wide, and 80 feet tall. Dubbed "Queen Marys" due to their size, they were more commonly referred to as "canyons," a term still used today for such buildings. Two of the three canyons were put into operation; the third was held in reserve for emergency use. Inside the canyons were 40 process pools designed to mix the radioactive batch with the chemicals that would separate and purify the plutonium. For that work, Greenewalt chose bismuth phosphate for the bulk of the separation work, and lanthanum fluoride for the final concentration. The end product, plutonium nitrate, would then be shipped to Los Alamos, where it would be converted to plutonium metal.[93]

Before anything could be shipped, however, the reactors had to transmute uranium-238 into plutonium, and the reactors at first seemed destined to fail. In September 1944, twelve hours after B Reactor was loaded with uranium slugs and went critical for the first time, the reaction died down, ran again for a while, and died again. Upon examination, it was determined that the culprit was xenon, which was created as a byproduct of the fission reaction. Even though xenon had a short half-life, it was a powerful neutron absorber. Productivity would be greatly reduced if the reactors had to endure such oscillations.[94]

Organizational flow chart for the Manhattan Project showing the production complex between 1942 and 1946. Source: U.S. Department of Energy, Office of Environmental Management, *Linking Legacies: Connecting the Cold War Nuclear Weapons Productions Processes to their Environmental Consequences*, Report No. DOE/EM-0319 (Washington, DC: GPO, 1997).



Fortunately, the solution had already been built into each of the reactor cores. The Met Lab had mandated a total of 1500 reactor openings to admit the uranium slugs, the neutron fuel rods, and the control rods. Du Pont insisted on adding another 500 openings in the corners of each reactor as a precautionary measure. It was this extra feature that saved the plutonium project. By loading the extra 500 slots, the Du Pont engineers were able to simply override the effect of the xenon.[95]

After the necessary corrections were made to the reactors, they were quickly placed on line. Both B and D went critical in December 1944, followed by F in February 1945.[96] By early 1945, Los Alamos was getting regular amounts of plutonium from Hanford, as well as uranium-235 from Oak Ridge. It was now up to the scientists at Los Alamos to create the devices needed to house and detonate the fission material.



Portrait of Robert Oppenheimer, head of the Los Alamos Scientific Laboratory. Source: Los Alamos National Laboratory.

(Opposite page) Four frames of employee badge photographs for Los Alamos Scientific Laboratory. Hans Bethe is shown in the top frame. Source: Los Alamos National Laboratory.

LOS ALAMOS AND THE ATOMIC BOMBS

While the uranium facilities at Oak Ridge and the plutonium plant at Hanford all worked their way through production problems in the course of 1944, problems of a different sort plagued the physicists assigned to create bomb devices at Los Alamos. When Groves spoke of the Manhattan Project as a grand opera with temperamental stars, he probably had Los Alamos in mind. He once told his military staff that, "at great expense, we have gathered on this mesa the largest collection of crackpots ever seen."[97] Considering the difficulties involved, it was certainly one of Robert Oppenheimer's crowning achievements to have managed Los Alamos so successfully.[98] It was a job that entailed staying on top of the many scientific problems, as well as smoothing the ruffled feathers of a great many scientists.

Los Alamos began operation in the spring of 1943, when Oppenheimer and his staff moved into the facilities. Among the people in charge of crucial aspects of the program were Hans Bethe (theoretical physics), Robert Bacher (experimental physics), Joseph Kennedy (chemistry and metallurgy), William "Deke" Parsons (ordnance), Felix Bloch, and Edward Teller.[99] The Los Alamos Scientific Laboratory, as it was officially known, was the nerve center of the Manhattan Project. Production of fission material was coordinated here, plutonium was purified, and finally, but certainly not least, the bombs themselves, known as "gadgets," were designed and made.[100]

In addition to the scientific laboratory, operated by Oppenheimer and the University of California, Los Alamos was also guarded by the Army. Security was tight, and often resented, creating tension between the civilian scientists and the military force required to guard them. It was not until late 1944, when Groves put Colonel Gerald Tyler in charge of the military side of Los Alamos, that matters were brought under some control.[101]

By early 1945, regular shipments of uranium-235 and plutonium-239 were arriving at Los Alamos. This material first had to be purified and stored in a safe configuration to prevent inadvertent criticality. The metallurgy section then turned the fission material into metal form for bomb use.[102] Long before this occurred, however, Los Alamos was embroiled in one of the main problems of the Manhattan Project: how to assemble a plutonium fission bomb. It was a dilemma that plagued work throughout 1944, and was not solved until well into 1945.

In the beginning, it was assumed that both the uranium and the plutonium bombs would be detonated using the "artillery method." This entailed a "cannon" that would fire a sub-critical mass of fissionable material into another sub-critical mass, and trigger a chain reaction almost instantaneously in thousands of generations, creating a nuclear explosion. This method was perfectly adequate for the uranium bomb, dubbed "Little Boy," which was improved from an initial gun length of 17 feet, to one that only required 6 feet.[103] The plutonium bomb was a different matter. From the beginning, there were difficulties with the plutonium gun design, referred to as "Thin Man." The gun method was simply too inefficient, and there were problems with the unwanted plutonium-240, an almost unavoidable consequence of the original irradiation. As a result, Thin Man was eliminated as a feasible bomb design as early as July of 1944. This left the "implosion" method for the plutonium bomb, and "Fat Man," as this device was called, was fraught with challenges that no one had ever thought to solve.[104]

The basic problem with a plutonium bomb was that the core, reacting to countless generations of chain reactions within a split second, would expand too fast to achieve the optimum explosion. Seth Neddermeyer came up with the solution when he proposed packing a spherical layer of high explosives around an assembly that consisted of a tamper inside of which was a hollow spherical core of fissionable but subcritical plutonium. The high explosives would blast inward, creating an "implosion" that would squeeze the tamper from all sides. This would likewise reduce the hollow sphere of plutonium to a solid ball of fissionable material that would achieve criticality far faster than possible with the gun method.[105] The problem remained of how to create such a device.

The push for an implosion device led to the final shift at Los Alamos from research to production.[106] The shock waves created by the sphere of surrounding explosives had to be coordinated to the microsecond, and they had to have just the right magnitude. This required highly sophisticated calculations, and led to the first use of computers at Los Alamos. IBM calculation equipment arrived at the laboratory in April 1944.[107]

The successful completion of the implosion device was one of the great achievements of the Manhattan Project. When the bombs were finally ready, in the summer of 1945, the war was already over in Europe, but Japan was still a potential target. There was little doubt that the uranium bomb, Little Boy, would work as planned. The plutonium bomb, Fat Man, was more problematical. Even though an implosion device had been created, no one could know if it would work without a test run. This was arranged at the Trinity Test Site within the Alamogordo Bombing Range in New Mexico. There, a plutonium bomb was set up on a 100-foot tower, and was detonated successfully on July 16, 1945, yielding an explosive force equal to 21 kilotons of TNT.[108] Groves, Oppenheimer, and all that were present for the Trinity test, knew immediately that the atomic bombs could end the war. Some suspected, even then, that it would cast a long shadow over the world to come.

The first bomb to be dropped on Japan was the uranium device. On August 6, 1945, a B-29 bomber named the *Enola Gay* dropped a 9700-pound Little Boy over Hiroshima, a city of 300,000 inhabitants. The device went off at 1900 feet with a force of between 15 and 20 thousand tons of TNT. Seventy thousand died outright, with another 70,000 injured. By the end of the year, another 70,000 would be dead due to burns and radiation poisoning. Within five years, the total death toll would rise to 200,000.[109] Three days later, on August 9, the 10,000-pound plutonium implosion device, Fat Man, was dropped on Nagasaki with a force of between 20 and 21 thousand tons of TNT. The loss of life



was less than that of the uranium bomb only because Nagasaki's hilly terrain blunted the full effects of the blast.

Little Boy and Fat Man convinced the Japanese to capitulate. On August 10, they conveyed their desire to surrender on condition that the emperor could be retained. When the United States concurred the following day, the Japanese government surrendered on August 14. Formal surrender documents were signed on September 2 aboard the USS Missouri in Tokyo Bay.[110] Two atomic bombs ended the Second World War, a global conflict that had killed more soldiers and civilians than any other war in world history.

Many believed, and many more hoped, that the close of the war would mark the beginning of a new era of peace. Certainly the United Nations, organized in San Francisco that same year, was established with this goal in mind. However, it would not be long before the two wartime superpowers, the United States and the Soviet Union, would be at odds over the postwar arrangements that each inherited in Europe and East



Aerial view of damage from the fission bomb dropped on Nagasaki. Courtesy of the Collections of the Library of Congress, negative US762, 104726.

Asia. One of the biggest factors in this new contest was the atomic bomb, a device more powerful than any previous ordnance by many orders of magnitude. And that was just the beginning. Waiting in the wings was the fusion bomb, many times more powerful than the fission devices dropped on Japan. The theoretical workings of this device were studied at Los Alamos well before Hiroshima and Nagasaki.[111] The atomic genie was out of the bottle, but it would be a few years before it was ready to mature.

3 The Cold War and the Early Atomic Energy Commission (1945–1950)

The conclusion of World War II in August 1945 produced tremendous euphoria, in which it was widely hoped that the world would finally achieve the stable peace that had not been won by the First World War. The United Nations, established in San Francisco and later moved to New York, was a concrete expression of that wish. Still, it could not be forgotten that final victory had been achieved by two atomic bombs, and that only one nation had them. Interest in the new weapons was only heightened by the release of the official report of the *Manhattan Project, Atomic Energy for Military Purposes*.[1] The ultimate fate of atomic energy was a major controversy—both in this country and around the world—in the first year after the war, from the summer of 1945 to the summer of 1946.

Prime Minister Winston Churchill, President Harry S. Truman, and Marshal Josef Stalin face a battery of photographers prior to the start of the Big Three Meeting in the Potsdam area of Germany. James F. Byrnes Papers, Mss 90, negative 209237-S. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.



THE QUESTION OF INTERNATIONAL CONTROL

In 1945, the nuclear inner circle consisted of Britain, Canada, and the United States, and only the latter could actually make a bomb. Many nuclear physicists, guilt-ridden over having created such a powerful weapon, advocated international control over atomic energy to guarantee mutual security and to prevent an international arms race. Niels Bohr, Enrico Fermi, Robert Oppenheimer, David Lilienthal, and Dean Acheson were among the physicists and politicians who spearheaded this drive. Their view was roughly summed up in Bernard Brodie's 1946 book, *The Absolute Weapon: Atomic Power and World Order*, which argued that peace would be more assured if every power had the bomb, or an essential part of the bomb, rather than one nation with a monopoly.[2]

Most politicians, no less awed by the bomb but less guilt-ridden, were not swayed by the internationalist argument. Most were incredulous when it was suggested that a weapon—built with billions of dollars of taxpayers' money—should simply be given away to satisfy the hope of international control. One of the first to stake out a position in this camp

was Jimmy Byrnes, Truman's Secretary of State and powerful right-hand man, and he kept company with Leslie Groves and Winston Churchill.[3]

President Truman started out as a fence-sitter. He dabbled with the idea of international control in the first months after the war, before he came to favor a more nationalist position. As a result of this dabbling, however, Truman approved a committee to examine the postwar development of nuclear energy, which would include the possibility of some sort of international control. The committee, chaired by Dean Acheson, included, among others, Byrnes, Groves, Bush, and Conant. To aid the committee with technical information, Acheson appointed a five-man team that included Charles Thomas, Henry Winne, Chester Barnard, Robert Oppenheimer, and David Lilienthal, head of the Tennessee Valley Authority. This group laid the foundation for what came to be called the Acheson-Lilienthal Report.[4]



President Harry S. Truman, Secretary of State James F. Byrnes, and Admiral of the Fleet William D. Leahy, on tour of Berlin, stop to view the ruins of the Reichstag building. Hitler had addressed his followers from the balcony of the chancellery in the background. James F. Byrnes Papers, Mss 90, negative 209344. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

Released in February and March 1946, the Acheson-Lilienthal Report championed the idea of international control of atomic energy. It proposed that the nuclear facilities needed to make atom bombs be spread around the world to ensure that no one nation could have a monopoly. The report also stressed the importance of open facilities and verification by all parties. The Acheson-Lilienthal Report found a lot of favor when it was released, and it became the basis of the Baruch Plan that Truman presented to the United Nations later that summer.[5]

The plan prepared by Bernard Baruch took its theme from the Acheson-Lilienthal Report, but it was more realistic about the problems of internationalizing atomic energy. It recognized that any international scheme would have problems with security, and stated baldly that world peace would be impossible without the force to back it up. The Baruch Plan was submitted to the United Nations for consideration in June 1946, but it was doomed from the start. The Soviet Union had no intention of opening its facilities to third-party verification, and over the next few months the Baruch Plan prompted counter-proposals that the United States found unacceptable. Before the end of the year, the plan was dead, and with it any realistic dream of international control.[6] The bomb would remain an American monopoly, for the time being at least, and the stage was set for an arms race that was not quite ready to begin.

LAST DAYS OF THE MANHATTAN PROJECT

In July 1946, while the Baruch Plan was being debated at the U.N., the Manhattan Engineer District (MED), in conjunction with U.S. military authorities, conducted the first

nuclear tests since the summer 1945. Scheduled as three tests, Operation Crossroads was conducted at Bikini Atoll in the Marshall Islands. The first shot, "Able," was an above-water test that yielded relatively minimal amounts of radiation. This was not the case with "Baker," an underwater explosion that generated more radioactivity than was expected. The third test, scheduled for deep water, was cancelled by Truman himself.[7]

Crossroads was one of the last stirrings of the Manhattan Project. Left without a clear mission since the end of World War II, the Manhattan Project had been depleted by the exodus of physicists in the months that followed the war. Oppenheimer himself left to become director of the Institute for Advanced Study at Princeton.[8] A MED committee did weigh in on the international-control controversy by urging the United States to maintain nuclear superiority,[9] but for the most part the Manhattan Project held its own, repairing the damage left by vacancies as best it could.[10]



Bernard Baruch, a native South Carolinian, was the author of the Baruch Plan that Truman presented to the United Nations in 1946 on international control of atomic energy. Here he (far left) is shown with Governor James Byrnes and Strom Thurmond (right) at the James Byrnes Testimonial dinner held at the Willcox Hotel, Aiken, South Carolina, April 16, 1955. All three South Carolinians would play a role in the shaping of atomic energy and its development, both in the state and in the nation. They were accompanied by (left to right) Mrs. Sarah Bush, Miss Elizabeth Nevans, Mrs. James F. Byrnes, and Mrs. Strom Thurmond. Strom Thurmond Collection, Mss 100, negative 1195. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

Companies also left, requiring the introduction of new firms to the nuclear fold. Monsanto Chemical replaced the University of Chicago as the prime contractor at Clinton Laboratory in the summer 1946.[11] Just as dramatic was the departure of Du Pont. Holding MED to its promise that the company could be relieved after the war, Du Pont relinquished operation of the Hanford Engineer Works on September 1, 1946. Groves enticed General Electric to take their place, which GE did with a one-dollar-profit contract similar to Du Pont's. In return, GE received a government commitment to help build a GE laboratory then under consideration just outside Schenectady, New York.[12]

Hanford had other problems. The wartime reactors were aging: Reactor B was shut down as a precaution, and D and F were forced to operate at lower power.[13] In 1946, MED planned to construct two additional plutonium reactors, in addition to two small test reactors at Los Alamos.[14] Even though the MED put these plans into play, it would not see them completed. By the Bikini Tests, legislation was already under way to place the nation's nuclear program under a civilian-controlled entity known as the Atomic Energy Commission.

CREATION OF THE ATOMIC ENERGY COMMISSION, 1946–1947

The U.S. Atomic Energy Commission, the direct successor of the Manhattan Engineer District, was the result of another controversy around the use of atomic energy. Closely tied with the dilemma of international control was another question: Should the U.S. atomic program remain under military jurisdiction, or be turned over to civilian control? Military control certainly had its supporters. A bill giving atomic power to the Army almost passed the House Military Affairs Committee in October 1945, and there were other attempts as well.[15] By 1946, however, the political tide seemed to favor civilian control, and almost all who had favored an international arrangement favored this option, including Truman.[16]

The push for civilian control came to a head in the summer 1946. At that time, the McMahon Act, also known as the Atomic Energy Act, sponsored by Senator Brien McMahon of Connecticut, passed Congress in July and was signed into law by Truman on August 1.[17] The Atomic Energy Act established a civilian-led U.S. government nuclear

monopoly known as the Atomic Energy Commission, answerable to Congress and the President. Nuclear information would be restricted, and no private companies or individuals could own nuclear materials or patent nuclear inventions. Without specifically stating it, the charter of the Commission gave it total control over atomic energy. The Atomic Energy Commission, or AEC as it was often called, was to take over all Manhattan Engineer District initiatives, properties, and programs on January 1, 1947.[18]

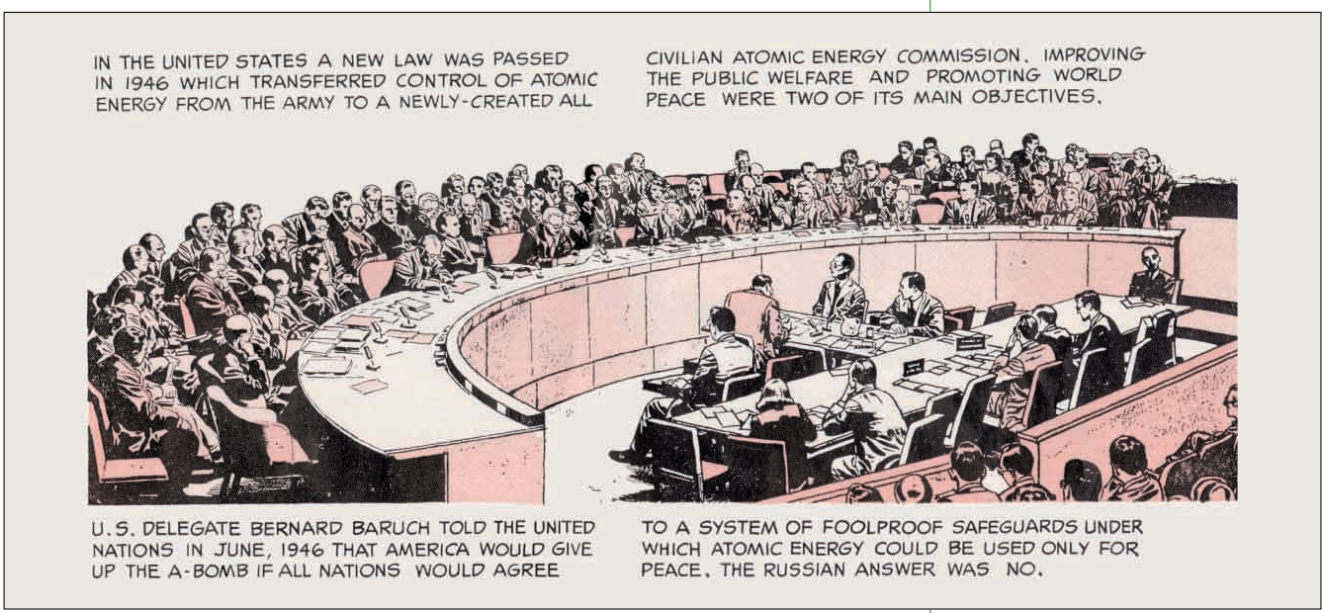
The Atomic Energy Commission consisted of five members, with one member designated chairman. All members were to be appointed by the President and approved by the Senate. Commission terms were to be five years, but the first five commissioners would have a fixed term of two years, plus an additional term of one, two, three, four, or five years, so that each subsequent commissioner would have his five-year tenure staggered by a year. This was to prevent an unwarranted accumulation of power within the commission, and allow smooth transitions within the AEC.[19] The Commission itself, however, was granted considerable leeway in the operation of its atomic program. It was given the authority to run the atomic program with government employees if it so chose, reversing the MED method of using private companies supervised by the government. The Commission was also exempt from Civil Service laws, allowing it complete freedom in dealing with its employees.[20]

The law also created a number of entities to serve the Commission. A General Manager would handle administrative and executive functions; like the commissioners, he would be appointed by the President and approved by the Senate. The law also established two essential committees to aid the Commissioners. The first, and most important in what was still a relatively new field, was the General Advisory Committee (GAC), designed to advise the Commission on all scientific matters. The committee was composed of nine members with six-year terms. GAC members would be appointed from civilian life by the President. The GAC was required to meet at least four times a year and to designate one of its members to serve as chairman, elected annually. The second committee was the Military Liaison Committee, which would coordinate the Commission's



Brien McMahon, Chairman of the Joint Committee on Atomic Energy. Courtesy of SRS Archives, negative M-364.

Cartoon taken from M. Phillip Copp, Booklet entitled *The Atomic Revolution*, 1957. Courtesy of SRS History Project.



work with the military's requirements. Below these two committees, the Commission would have various divisions to handle the production of nuclear materials and their assembly, and any other work the Commission deemed necessary. The law also established the Joint Committee on Atomic Energy, composed of nine Senators and nine Representatives, to oversee the AEC and its activities.[21] Brien McMahon, sponsor of the Atomic Energy Act of 1946, served as the first Joint Committee chairman.[22]

The commissioners appointed by Truman were David Lilienthal, Sumner Pike, Lewis Strauss, William Waymack, and Robert Bacher. The chairman of the AEC was a powerful figure, and few occupants of that position put more of a stamp on the organization than did the first, David Lilienthal. Appointed by Truman in October/November 1946, Lilienthal was a veteran of Roosevelt's New Deal administration, having served as co-director and later first chairman of the Tennessee Valley Authority in the 1930s and early 1940s.[23] As Lilienthal himself admitted, he knew little about atomic energy when he was pegged for the job. A strong proponent of civilian control, Lilienthal used his new position to stump for a greater appreciation of the peaceful uses of atomic energy, especially the potential for power generation and the creation of isotopes for scientific and medical research.[24] As if to underline this potential importance, the Clinton Laboratory (later the Oak Ridge National Laboratory) began dispensing radioisotopes to interested agencies around the world as early as August 1946, months before the AEC took over the American nuclear program.[25]



David Lilienthal, first chairman of the Atomic Energy Commission. Courtesy of the Tennessee Valley Authority.

Robert Oppenheimer was appointed to the General Advisory Committee in 1946, and was elected chairman of the GAC at its very first meeting in early January 1947. He too proved to be a powerful figure, and was re-elected chairman every year of his six-year term. Under Oppenheimer, the GAC chose not to conduct its business through a staff, but rather to keep its deliberations closed and work close to the vest. This work was highly classified. It soon developed that the chairman of the GAC would prepare a report that would go directly to the AEC chairman at the conclusion of each meeting. In addition, the GAC meeting minutes were provided to the Commissioners for further study.[26]

The MED holdings that the Atomic Energy Commission inherited in early 1947 were larger than those of the wartime Manhattan Project, but the terrain was still recognizable. In addition to the three government-run communities—Clinton (soon renamed Oak Ridge), Hanford, and Los Alamos—the AEC inherited MED plans for new reactors at Hanford, as well as the new national laboratories at the University of Chicago's Argonne site in Illinois, and at Oak Ridge.[27] The AEC also inherited General Groves' commitments for the Brookhaven National Laboratory on Long Island, as well as plans for new research facilities at Schenectady to be run by General Electric.[28] All of this, however, proved difficult to administer during the AEC's first year. The nuclear program was plagued with problems left over from the Manhattan Project, and the Commission itself had to sort out kinks in its organization.

The AEC inherited some of its biggest problems from a MED that was itself in transition after the war. These problems ranged the spectrum of the atomic program, from a chaotic situation at the laboratories, to dilapidated facilities at the three government towns and problems with the new prime contractors. As General Electric officials would admit in later years, their operation of Hanford in 1947 was not up to the standards of Du Pont. GE initially failed to recognize the scope of what had to be done at Hanford and did not put the requisite resources into the job.[29] At Clinton, there was friction between Monsanto

officials and the laboratory authorities left over from University of Chicago days.[30] Morale was low even at Los Alamos.[31] The situation was no better in the three atomic cities. Increasingly incongruous two years after the war, the residential facilities, substandard when they were built, were now completely run-down.[32] The worst of all was the state of the nation's nuclear arsenal. Lilienthal toured the AEC facilities in early 1947 and reported to a shocked Truman in April that the United States had no operable atomic bombs, just bomb parts.[33] Even after the scramble that resulted, there were only 13 bombs by the end of the year.[34]

The Atomic Energy Commission also had administrative problems. Unlike the MED, which was allowed remarkable autonomy, the AEC had to contend with a greater slate of issues, as well as Congressional oversight. Lilienthal was not confirmed by the Senate until mid-1947. In addition, the early commissioners were political appointees who lacked technical proficiency in the whole range of topics that would quickly come under the domain of the Commission. To address this deficiency, the AEC commissioners established new advisory committees responsible for certain key areas not foreseen when the Commission was created.[35]

The Atomic Energy Act authorized AEC divisions in Research, Production, Engineering, and Military Applications, each with its own director.[36] After the AEC began operation, it created additional advisory committees to handle Raw Materials, Biology and Medicine, Administrative Operations, and Reactor Development.[37]

The Atomic Energy Commission was still working out its organizational flaws when the Cold War, heralded since the beginning of 1946, took a serious turn in 1948 with the Berlin Blockade. From that year on, the Cold War became a steamroller that flattened many peripheral issues, including any doubt that the Commission might have had that its primary function was to produce nuclear materials for the military. A casualty of this development was the loss of a New Deal sense of openness and any immediate hope for significant peaceful uses of the atom.[38]



Along the Iron Curtain. Looking into communist East Germany from 11th Armored Cavalry Regiment observation post. Senator and Brigadier General in the U.S. Army Reserve Strom Thurmond, Representative Leroy Anderson, and Captain Harry Peters, 1957. Strom Thurmond Collection, Mss 100, Box 6, Folder 36, Photograph 1034. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

RISE OF THE COLD WAR, 1945–1948

The Cold War and the Nuclear Age developed side by side, but both had their beginnings long before Hiroshima. In this country, the Cold War was under way years before the end of the Second World War, even if that fact was not well recognized in the United States. Soviet operatives, who practiced industrial spying on a massive scale in the 1930s, found their way into the Manhattan Project during the war. Largely as a result of espionage, the Soviets knew how to make a plutonium bomb before the first devices were dropped on Japan. What they lacked was the industrial capacity to make the materials required, and that would take years to achieve.

On the diplomatic front, the first signs of discord between West and East were underlined at Yalta in February, 1945 in discussions of the postwar fate of Poland. As it became increasingly clear in the months to follow that Eastern Europe would remain under the domination of the Soviet Union, public opinion in the West began to shift. The Cold War formally began in early 1946, with war "declared" by both sides. Stalin's speech to the

Communist Party Congress on February 9th announced a resumption of the global anti-capitalist crusade and reaffirmed the Party's dominance in Soviet society. This marked the end of the relatively relaxed era of the Patriotic War. On the Western side, George Kennan's famous February 22nd telegram detailed the resumption of Soviet paranoia, and urged that Communism be contained. On March 5th, Churchill went further in his Iron Curtain speech at Fulton, Missouri, in which he envisioned an atomic arms race.

In 1946 and 1947, problems soon cropped up in Iran, where the Soviets were slow to leave their sphere of influence, and in Greece and Turkey, which were pressured to grant various concessions. The British dealt with most of these problems, since they had a traditional presence in the areas. Eastern Europe, however, on the critical western border with the Soviet Union, was swallowed whole.



Cartoon inscribed "Handle with Care" illustrates the conflict over possession of the atom bomb between the United States and the Soviet Union, circa 1945. Courtesy of the Collections of the Library of Congress.

Western leaders like Truman and Churchill knew that the Soviets were working on the atom bomb, but did not know how far the program had advanced. In 1942, Stalin had approved a research program to work on separating uranium-235 from natural uranium. In 1943, the main Soviet physicist, Igor Kurchatov, was shown the results of Soviet espionage in Britain and the United States, and work shifted toward plutonium. As a result of the espionage of physicists like Klaus Fuchs and Theodore Hall, the Soviets had the plans for the plutonium bomb, including the implosion device needed for detonation.[39]

The bomb effort became more intense when Lavrenti Beria, head of the secret police, was put in charge in 1945. The Soviets soon had their own version of Los Alamos at Sarov, 400 kilometers east of Moscow. It was there that the first Soviet reactor went critical, on Christmas Day 1946.

At this point, with Europe still in ruins, Communist parties throughout western and central Europe were gaining strength. Both to improve the European economy and forestall any further Communist advances, the United States put forth the European Recovery Program, known as the Marshall Plan, in the summer of 1947. The Plan was debated in Congress and throughout Europe in the second half of 1947 and early 1948, and was finally passed by Congress in April 1948. Although aid was proffered to all European nations, Stalin turned down the offer—as was expected—and ensured that the eastern European nations under his thumb did the same. When Czechoslovakia expressed interest in the Plan, the pro-Soviet but democratic government there was deposed by a Communist coup on February 25, 1948. When the Czech state folded into the Soviet camp, the Russians gained direct access to the Joachimsthal uranium mines.[40]

By this time, relations between the former allies had completely broken down. Unable to resolve the fate of a united Germany, both sides made plans to make nations out of the two halves. The German question came to a head with the Berlin Blockade, which began on June 24, 1948, and lasted almost a year, until May 1949. Stalin's prolonged attempt to force the Western Allies out of Berlin was the first direct confrontation between the United States and the Soviet Union, and it laid bare the full implications of a cold war that was just beginning. Before the end of 1949, the Soviet and American camps would be organized along a divide that would split Europe down the middle. The North Atlantic Treaty Organization (NATO), the logical next step after the Marshall Plan, stretched from Norway to Italy. NATO was opposed by the nations of the Soviet block, later known as the Warsaw Pact.[41] In Europe, at least, the lines of the new conflict were clearly drawn.

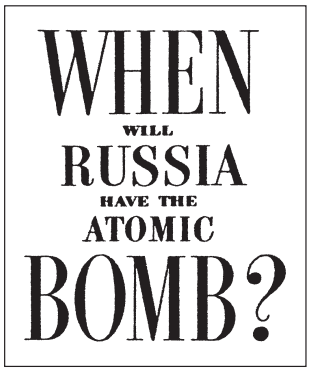
REORGANIZATION AND EXPANSION OF THE AEC, 1948

It took the Atomic Energy Commission well over a year to iron the kinks out of the atomic program inherited from the Manhattan Project, but some of the problems were of the AEC's own making. The AEC was a civilian organization, without a formal chain of command, and this problematic situation was compounded by the decentralized governing philosophy of the chairman, David Lilienthal. It was a philosophy seconded by the first General Manager, Carroll Wilson, who had served as an assistant to Vannevar Bush during the war.[42]

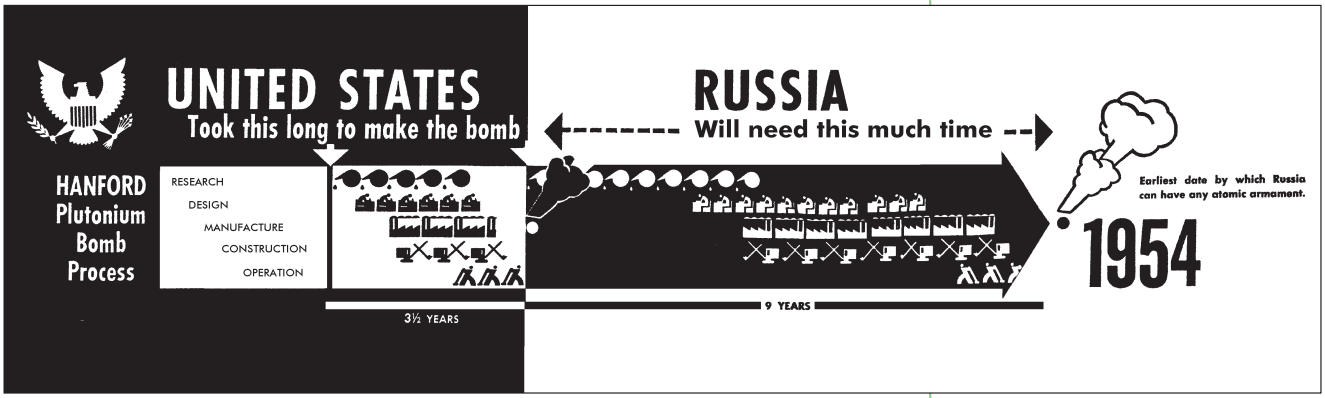
In what came to be called the "Lilienthal-Wilson Approach," the AEC was operated in this fashion during its first year and a half.[43] Lilienthal had used this approach in the operation of the Tennessee Valley Authority, and he thought it would work with the AEC as well. From the beginning, Lilienthal believed that the MED had been too centralized, with authority concentrated in Groves' office at Oak Ridge.[44] Lilienthal went the other way, with field-office managers at Los Alamos, Oak Ridge, New York, Chicago, and Hanford, all allowed considerable leeway in executing their duties. Each field-office manager reported to Carroll Wilson individually.[45]

One of the first agencies to see the flaw of this arrangement was the Industrial Advisory Group (IAC), established by the Commission near the end of 1947. Although its primary mission was to explore ways to increase the participation of private industry in the atomic business, it was also commissioned to review the AEC's organizational strengths and weaknesses.[46] The IAC discovered that the organizational links were too weak. Field managers not only had too much authority, but the arrangement was also too "geographical," with managers in control of little fiefdoms. Since they all reported directly to Wilson, the General Manager was overburdened. In addition, the group found that there was not enough attention devoted to the problems of production, and research and design.[47] To correct the organizational problem, at least, the group recommended a layer of administrators between the General Manager and the field offices.[48]

The AEC organizational problems came under increasing attack in spring and summer of 1948. It was then that the two-year trial period of the commissioners was scheduled to end, with each beginning staggered terms: Lilienthal, five years; Pike, four; Strauss, three, Waynack, two; and Bacher, one. This meant another round of confirmation hearings, which promised to be difficult. Even though the commissioners' terms were extended another two years in a compromise sponsored by Senator Hickenlooper, it was not before



(Above and Below) In the first years after World War II, it was assumed that it would take the Russians several years to develop the atom bomb. The unsourced newsclipping below projects a possible timeline developed in 1948, forecasting that Russia would need nine years to accomplish what took the United States 3 and a half years. Newsclipping, source unknown, dated March 16, 1948, courtesy of SRS Archives.



the AEC was raked over the coals for persistent fiscal problems and the dangerous autonomy allowed its field managers.[49]

Even the General Advisory Committee weighed in on this issue. In June 1948, the GAC, led by Robert Oppenheimer, launched a direct attack on Lilienthal and the commissioners. According to Oppenheimer, the Commission was too decentralized to provide the direction needed to keep the atomic program focused on urgent issues. As a result, the Commission was not able to make good use of the GAC's advice. Worse, the scientific community was starting to lose faith in the atomic program.[50]

In August and September 1948, Lilienthal and the other commissioners bowed to the inevitable and effected a general reorganization. The Commission's functions were centralized into four executive divisions: Research, Production, Reactor Development, and Military Application. Each of these divisions was equipped with its own program, budget, and planning department. Raw Materials, previously independent, was placed under Production; other areas of the AEC were similarly streamlined.[51] The office of the General Manager was strengthened, with more staff to handle the greater workload. From the evidence provided by the AEC General Manager's files, Carroll Wilson got the staff he needed to coordinate the various field managers.[52]

After the reorganization, the core of the new AEC was the Division of Production. Its main functions began with the procuring of raw materials, and continued through the processing of raw materials, the production of feed materials for the reactors, and the production of fissionable materials as a result of reactor operation. The Division of Production was also responsible for providing other materials needed for AEC operation. Its other functions included supervising the engineering and construction activities of the AEC, managing the AEC communities (Oak Ridge, Hanford, and Los Alamos), and providing management support for the other divisions. It even kept maintenance records on source and fissionable materials, prepared AEC mobilization plans, and administered all production facility licensing, source material licensing, and equipment export control.[53] The Director of Production was Walter Williams, who had served as Groves' production chief during the Manhattan Project, and was director of field operations before the reorganization.[54]

The reorganization allowed the AEC to operate more effectively, even as its facilities continued to grow. By the end of 1948, the AEC had increased its physical facilities in two directions: by adding to the older facilities inherited from the MED, and by building new ones. The AEC's empire included a headquarters in Washington, DC; the old Manhattan Project properties at Oak Ridge, Hanford, and Los Alamos; and a wide range of facilities that had been developed or enlarged since the war. These included the Argonne National Laboratory, which came out of the Metallurgical Laboratory; the Oak Ridge National Laboratory, which developed out of the Clinton Engineer Works Laboratory; and the new Brookhaven National Laboratory on Long Island. Under construction was the Knolls Atomic Power Laboratory in Schenectady, New York. Each main facility had ties to other institutions in the same geographic area.[55] These different nodes of the AEC were controlled through operations offices, generally centered around one of the major facilities. In addition to headquarters in Washington, DC, there were operations offices at Oak Ridge, Santa Fe, Hanford, Chicago, and New York.[56]

To operate these facilities, the AEC received tremendous sums of money through Congressional appropriations, and the appropriations increased every year. The budget for

fiscal year July 1948–June 1949 was $625 million.[57] From that sum, the AEC only spent $26 million on itself, which was used to pay five Commissioners, the General Manager, 21 administrative executives, and the 5000-strong staff in Washington and around the country. The rest, some 96 percent, went to the various private companies that operated the facilities under AEC supervision.[58]

Out of the 1949 budget, GE received a total of $208 million to run Hanford for the production of plutonium, as well as for the nuclear research facilities at Knolls, then under construction. The other prime contractors received considerably less money. Carbide and Carbon Chemicals got $60 million as the prime contractor at Oak Ridge, where gaseous diffusion was used to separate uranium-235. The University of California received $37 million to operate Los Alamos and the Radiation Laboratory. The University of Chicago received $35 million to run Argonne, the center for reactor research. Associated Universities, Inc., a consortium of Ivy League schools for the purpose of nuclear research, got slightly less for the operation of Brookhaven. Other large firms involved or associated with AEC operations included Allied Chemical and Dye, Dow Chemical, American Cyanamid, Kellex Corp., Westinghouse Electric, Monsanto Chemical, Tennessee Eastman, and Du Pont.[59]

The last two firms, Tennessee Eastman and Du Pont, had already retired from direct involvement with the government's atomic service. Tennessee Eastman left Y-12 at Oak Ridge in May, 1947, to the relief of both the government and Tennessee Eastman. Du Pont's case, however, was different. The former munitions—now plastics—firm had done an exceptional job at Hanford, and it was only at Du Pont's insistence that the company was let out of its contract in late 1946, before the AEC took over the atomic helm.[60]

In 1948, the main star in the AEC firmament was General Electric, the producer of plutonium. When Du Pont left Hanford, General Electric was enticed to enter the program with the promise of money for the new Knolls research facility that GE had already planned near its main headquarters in Schenectady, New York.[61] As a result of construction work, both at Knolls and at Hanford, much of the money GE received from the Commission was passed directly to the company's subcontractors.[62]

Hanford represented a big investment for General Electric. By the end of 1948, the plutonium plant accounted for 10 percent of GE's technical staff and 5 percent of its labor force, a very sizable investment for General Electric. This had not been the case during GE's first year at Hanford, where, by all accounts, the company underestimated the scope of the task, and operated without an adequate staff. In April 1948, former GE vice-president Roy C. Muir had been called out of retirement to correct the situation, and he had borrowed Du Pont employees to help him do it.[63]

None of these problems precluded new construction at Hanford, which was much larger than it had been in the summer of 1945.[64] Foremost among the new construction programs were two new graphite-moderated reactors, H and DR. Designed as replacements for the wartime reactors (B, D, and F), the new reactors were under construction by the end of 1948. H Reactor would go online in October 1949; DR Reactor would follow a year later.[65]

Construction was not as dramatic at the other former MED installations, but there were changes there as well. At the end of 1948, the prime contractor at Oak Ridge was Carbide and Carbon Chemicals, a subsidiary of Union Carbide. Carbide and Carbon had run K-25, the gaseous diffusion plant, since the early days of the Manhattan Project. By

1948, it also operated the other facilities, Y-12 and X-10. (Monsanto Chemical, which had operated X-10 and the Clinton Laboratory since mid-1946, retired from the job in March 1948). By the end of 1948, only K-25 was still used to separate uranium-235 from natural uranium. Since the war, improvements in the gaseous diffusion process made K-25 much more effective than Y-12, which was now relegated to making stable isotopes in concert with the X-10 pile, which solely produced experimental radioisotopes.[66]

One of the greatest problems for the AEC at the older facilities was the management of the government towns inherited at Hanford, Oak Ridge, and Los Alamos. Perhaps essential for the Manhattan Project, they were definite anachronisms in the postwar era. Each community had an AEC manager, and their reports to Wilson were filled with details of rent problems and other mundane issues that the General Manager would clearly have preferred not to address. By the end of 1948, it seems clear that the AEC was already looking for ways to divest itself of the government towns, and it certainly had no intention of creating new ones.[67]

In the new facilities planned and built by the AEC, government towns were not really an option, since none was a production center that would require a sizable workforce. For the most part, the new facilities were research laboratories. Brookhaven was already in operation by the end of 1948, and Knolls Atomic Power Laboratory would open in December of 1949. In the planning stage and soon to be approved (February 1949) was The National Reactor Testing Station that would encompass 890 square miles in Idaho. It would be operated by Argonne National Laboratory in Chicago and would test new types of reactors, including reactors for Navy submarines, as well as the materials and processes used in new reactors.[68]

The attention to research had begun to yield results. In 1948, the basic reactor was still what it had been in World War II, with uranium as the fuel and graphite as the moderator, but the range of fuel and moderator options was now much wider. Enriched uranium, uranium with a higher than normal percentage of uranium-235, could be used for reactor fuel and heavy water was now practical as a moderator.[69]

The development of heavy-water technology was one of the great achievements in reactor research after the war. It had long been recognized that heavy water had a better neutron economy than graphite, but logistical problems restricted its use during the Manhattan Project. The Argonne Laboratory concentrated its work on heavy-water-moderated reactors soon after the war, and by 1950 there were two such test reactors at Argonne: CP-3 and CP-5. This complemented the heavy-water-moderated NRX-Reactor in Canada, which had been in operation since July 1947. The tremendous problem posed by the limited supply of heavy water was at least partially resolved by a contract between the AEC and the Girdler Corporation. The contract called for a heavy-water pilot plant and production facility at the Wabash River Ordnance Works in Indiana, soon known simply as the Dana Plant. The process that Girdler used involved the "dual temperature exchange of deuterium between water and hydrogen sulfide gas." The process became known as the "S-process," or "GS" for Girdler sulfide. By the late 1940s, the AEC researchers clearly preferred heavy water for reactor moderation, even though the Commission did not yet have a single heavy-water production reactor.[70]

Other types of reactors were also explored. The atomic age began with production reactors, or reactors that produced the fissionable material essential for an explosive device. There was always, however, the possibility that power reactors could produce

electricity. As a civilian organization, the AEC was interested in peaceful uses of atomic energy, and the idea of a power reactor had great appeal. Physicists at both Argonne and Oak Ridge knew how to build such a reactor, but the catch was to make it profitable. Even though modern commercial power reactors burn uranium-235 and do so profitably, this was not thought possible in the late 1940s. So long as power reactors simply burned up valuable uranium or even more precious plutonium, it was widely believed that they could never be commercially viable.

For this reason, the AEC had long been interested in breeder reactors. As early as the GAC meeting of February 2, 1947, one of the three main priorities established for the AEC was to develop power-breeder reactors and high-flux reactors.[71] The possibilities of breeder reactors and the materials used in them would change over time. In the late 1940s, it was hoped that breeders would make fissionable uranium-233 from fission materials such as natural thorium. In this fashion, a reactor could produce fissionable material while it produced power. This was the only way thought possible to produce profitable electricity, and even this was not an imminent event. In 1948, the GAC stated that power from commercial reactors would not be economically feasible for another 20 years.[72]

As a way to save expensive uranium-235, the breeder reactor was long a favorite research topic for the AEC, with the first experimental breeder constructed as early as 1947.[73] This research would continue for years to come, but breeder reactors never became economically viable. One basic problem was that when reactors operated best for breeding, with fast neutrons, they were not in the best operational mode for power generation.[74] Despite this dilemma, what finally slowed the development of the breeder reactor was the discovery of vast new reserves of uranium throughout the United States, making the need for breeders less obvious.

THE PLUTONIUM PROJECT AND THE RETURN OF DU PONT

Concern for the expense of fissionable material led to improvements in production techniques as well, and these were more immediately successful. Methods were improved to save and recycle plutonium and spent uranium after they left the reactor. The standard process in the war had been to use bismuth phosphate to separate plutonium from the irradiated material. Bismuth phosphate, however, was not sensitive to uranium, and it was hoped that another process might be less wasteful of the spent uranium, much of which ended up in underground storage tanks. Since 1944, the Redox process had been known as a way to recover both plutonium and spent uranium simultaneously. Although it produced better results, it was also more expensive.[75]

These concerns led to the Plutonium Project in 1948–1949, an overall attempt to improve the Redox process and increase uranium recovery from existing waste tanks.[76] As Carroll Wilson put it, the project was an attempt to process plutonium so as to make the best use of uranium, still a rare commodity that usually came from the Belgian Congo. Because of the chemistry involved, and the company's good record at Hanford, the Plutonium Project was awarded to Du Pont.[77]

Although Du Pont was eager to get out of the atomic business at the end of World War II, and left Hanford in September 1946, it could be argued that it never really left the fold. Its Hanford work was too good, and the company knew too much, to be left out of

the inner circle. Throughout 1947, Du Pont's Wilmington office provided records and other assistance to General Electric, its replacement at Hanford.[78] Contracts were effected between GE and Du Pont in February, 1948 concerning the loan of Du Pont personnel for work on new reactor design and construction.[79] Du Pont even loaned personnel to Brookhaven National Laboratory for research on graphite reactors.[80]

Crawford Greenewalt, who had been in charge of Du Pont's work at Hanford, was asked to serve on a number of atomic energy committees. In 1948, his industrial background was required on a panel for the AEC Committee on Atomic Energy Research and Development, chaired by Robert Oppenheimer.[81] In late 1948 and early 1949, after Greenewalt had been made president of Du Pont, he still met with the AEC's Division of Reactor Development. This body reviewed, among other things, Oak Ridge National Laboratory plans for an experimental high-flux reactor.[82] In the Plutonium Project report of March–April, 1950, Du Pont concluded that uranium was indeed used inefficiently, and that new methods of uranium recovery, which had the potential for improvements on Redox, should be explored.[83]



Naval spectators wearing goggles watch explosion of atomic bomb during Operation Sandstone on the Enewetak Atoll, 1948. Courtesy of the Collections of the Library of Congress.

TACTICAL ATOMIC WEAPONS VS. THE HYDROGEN BOMB, 1948–1949

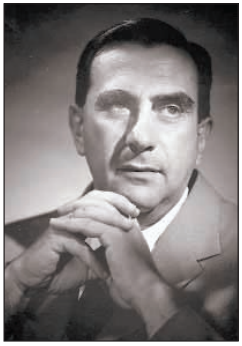
Despite pious disclaimers from Lilienthal and the other Commissioners, the main purpose of the AEC was not to produce isotopes for medical research or to study power reactors for electricity, but to produce fissionable material for the military. This led to fanciful projects like the Nuclear Energy for the Propulsion of Aircraft (NEPA), and to the highly successful submarine propulsion system studied by Westinghouse Electric for the Navy. For the most part, however, this work came down to producing and stockpiling atomic bombs.[84]

As the Cold War heated up in 1948 and early 1949, the AEC and the three branches of the military became embroiled in a controversy over the path to take in developing future generations of nuclear bombs. Tests conducted in the fall of 1948 demonstrated for the first time that small nuclear devices could be employed as tactical weapons on the battlefield. There loomed the possibility of the hydrogen bomb, dubbed the "Super," which had been studied during the Manhattan Project. The development of either option promised to be expensive, and both were fraught with moral dilem-

mas. Tactical A-bombs reduced the scale of destruction and made it more likely that atomic weapons would be used; the Super, alternatively, was much more powerful than anything produced by the Manhattan Project. Hydrogen bombs made it less likely that nuclear weapons would be used, but if they were, the destruction would be vast.

Ever since the days of Hiroshima and Nagasaki, it had been assumed that a fission bomb was simply too powerful to yield effective results on the battlefield. This meant that atomic war was reduced to massive annihilation, a prospect that troubled many of the physicists who had worked on the Manhattan Project. A bomb with a smaller yield, however, might be used in battle if the risks to friendly forces could be sufficiently reduced. Operation Sandstone, conducted on the Enewetak Atoll in April and May of 1948, demonstrated the practicality of mass production of bomb components.[85]

The "pacifist" wing of the AEC, which included Chairman David Lilienthal and GAC Chairman Robert Oppenheimer, championed the results of the Sandstone tests, and all that these results implied. Their enthusiasm, however, should be viewed in the context of the controversy over the Super. Neither Lilienthal nor Oppenheimer wanted to develop the hydrogen bomb, which they considered morally reprehensible. In hopes of heading off that development, they ordered that Los Alamos concentrate its efforts on developing tactical weapons. This decision was supported by both the Army and the Navy, which saw the new development as a means of harnessing atomic energy for their own purposes.[86]



Edward Teller, Hungarian-born physicist and atomic energy pioneer. Performed atomic energy research at Columbia University during WW II. He was pivotal in the successful explosion first U.S. hydrogen bomb. Between 1952 and 1960, Dr. Teller was the director of the University of California's Lawrence Livermore Radiation Laboratory. Courtesy of the Lawrence Livermore National Laboratory.

The Super also had powerful supporters. Edward Teller, who had worked on the idea of the hydrogen bomb since the Manhattan Project, believed it was essential for the nation's defense, and this position was supported by General Curtis LeMay and the Air Force, which had become tremendously influential in the years after the Second World War. With the military cutbacks since the war, the Air Force's Strategic Air Command (SAC) had become the nation's first line of defense, and atomic bombs were the cutting edge of that first line. The hydrogen bomb, in their view, would only sharpen that cutting edge.[87]

EARLY WORK ON THE HYDROGEN BOMB

The Super was based on a hydrogen fusion reaction more powerful than the fission of either uranium or plutonium. The basics of hydrogen fusion were known before the war—even before uranium fission. Ernest Rutherford and others explored hydrogen fusion as early as 1934. While experimenting with deuterium, an isotope of hydrogen, they discovered that two hydrogen nuclei would fuse if they were heated enough to overcome their electrical repulsion. Upon fusion, they released a great amount of energy.

To develop a fusion weapon, it would be necessary to develop a means to generate the high heat needed to ignite fusion fuel. As far back as the Manhattan Project, Fermi and Teller theorized that the fission bomb might be useful as a trigger for a hydrogen bomb. The Super thermonuclear bomb designed in the 1950s in fact involved a fission trigger, which produced tremendous compression, which in turn heated the fusion fuel to ignition.

By the time of the Manhattan Project, it was also known that fusion would work better with a combination of hydrogen isotopes: deuterium and the rarer tritium. Deuterium and tritium would fuse at lower temperatures than those required for deuterium alone, and tritium fusion could then be used to jump-start other deuterium reactions.[88] In a thermonuclear explosion, the fusion of these atoms would release heat, neutrons, and intense gamma radiation. Edward Teller was detailed to work on the Super, but because the fission bomb was the top priority of the Manhattan Project, he had to be content with theoretical work. Even this was daunting. The calculations required for the fusion bomb were much more demanding than those required for fission. One of the first computers, the ENIAC designed by the Moore School of Engineering at the University of Pennsylvania, was put to work at Los Alamos on the requisite calculations. In April, 1946, Teller and his associates at Los Alamos held a conference to summarize their work on the Super. Not only did they find the Super feasible, but they also recommended the production of tritium to advance further studies. Even though little came of the conference in the aftermath of the war, the physics of the Super, first studied during the Manhattan Project, continued to tease throughout the early years of the Atomic Energy Commission. When the Cold War became a harsh reality in 1948, interest in the Super was rekindled.

The development of the Super, however, would not be easy. A number of different processes had to take place within the bomb itself, almost instantaneously, to ensure a powerful fusion blast, and these defied understanding for a number of years. Almost as serious were the problems surrounding the physical production of tritium. The heaviest of the hydrogen isotopes, tritium had one proton and two neutrons, usually produced by the neutron bombardment of lithium-6. Not only was tritium highly radioactive, but it would require constant production. Unlike plutonium, with a half-life of 24,000 years, tritium had a half-life of only 12 years. Furthermore, the quantity of tritium needed would require additional reactors. Although small amounts of tritium could be manufactured in a plutonium reactor, this arrangement would not be suitable for mass production.[89]

INTERNATIONAL EVENTS 1949–1950

The full impact of the Cold War began with the Berlin Blockade in 1948. Even so, the emphasis of that conflict was in Europe. In 1949 and 1950, the conflict spread to Asia and became truly global. It began with the crumbling of Nationalist China in late 1948 and 1949 and the rise of Mao Tse-tung's Communists, first in North China and Manchuria, then throughout the mainland. By the time the People's Republic of China was proclaimed, on October 1, 1949, the American public was rocked by even worse news. Years before it was expected, the Soviets succeeded in detonating their first fission bomb on August 29, 1949.



Employee identification badge photograph of Klaus Fuchs, a German-born physicist and member of the British Mission to the Manhattan Project, confessed to being a Soviet spy in January, 1950. Courtesy of the Los Alamos National Laboratory.

The first Soviet A-bomb, known facetiously as "Little Joe," was exploded with virtually no fanfare.[90] A weather reconnaissance plane picked up the first traces of the blast's radiation, which was confirmed by other sources as the radiation spread eastward over the Pacific.[91] A shocked Lilienthal learned about the blast in mid-September, and Truman announced the Soviet achievement to an equally shocked American public on September 23.[92] To the dis-

may of the American physics community, it appeared that "Little Joe" was almost identical to the plutonium device first tested at Trinity.

Within a few months, the connection between Trinity and "Little Joe" would become clear. In January, 1950, British authorities arrested Klaus Fuchs, a German-born physicist and member of the British Mission to the Manhattan Project. Confronted with evidence of his espionage, Fuchs confessed to being a Soviet spy. In the weeks and months that followed, the web of intrigue that had penetrated the heart of the Manhattan Project's plutonium program at Los Alamos raised shock waves on both sides of the Atlantic. And matters only got worse. By the time Communist North Korea invaded South Korea in June, 1950, the Cold War was a full-blown national emergency worthy of almost unlimited financial resources. By this time, there was both the money and the will to develop the Super.

THE DECISION TO DEVELOP THE HYDROGEN BOMB

The Soviet A-bomb paved the way for the American hydrogen bomb. In October 1949, shortly after the announcement of the Soviet blast, the AEC approved an increase in the production of uranium and plutonium, while Edward Teller and the Air Force renewed the call for the development of the Super.[93] Development of the hydrogen bomb was not favored by either Lilienthal or Oppenheimer, both of whom did what they could to halt or slow the landslide. Oppenheimer's General Advisory Committee met to address this issue on October 29–30, 1949. The majority report favored additional research on tritium, but did not support an all-out push for the development of the Super, preferring instead to concentrate on tactical nuclear weapons.[94] In early November, despite the GAC report and his own opposition to the Super, Lilienthal had to report to Truman that a thermonuclear bomb could be built within three years.[95]

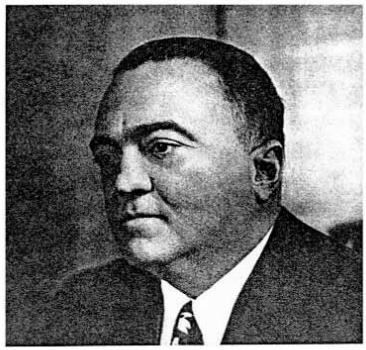
During this period, development of the Super was advocated by most of the nation's leadership, including Dean Acheson, the Secretary of State, and the Joint Chiefs of Staff.[96] The AEC itself had to fall in line. Even though Lilienthal was personally opposed, he reluctantly agreed to go along with the AEC majority report favoring the Super, if he could make a dissenting view directly to President Truman when the AEC presented its formal recommendations on January 31, 1950. Truman ignored Lilienthal's dissent and signed the AEC recommendations.[97] The Commission was directed to proceed with work on all forms of atomic weapons, including the hydrogen bomb; Congress would be asked to appropriate the funds later that year.[98] Implicit in this directive was the construction of a new facility to produce tritium.

Both Lilienthal and Oppenheimer would pay for their opposition to the H-Bomb. Rendered ineffective by his dissent, and increasingly irritated by the growing demands for secrecy within the AEC, Lilienthal resigned from the Commission on February 15, 1950, in the wake of the Klaus Fuchs revelations.[99] Gordon Dean, a supporter of the new direction, was made head of the AEC. Dean and General Manager Carroll Wilson clashed frequently in the months that followed, leading to Wilson's resignation on August 8, 1950. He was replaced by Carleton Shugg.[100] Oppenheimer was too valuable to suffer the consequences immediately, but he was increasingly isolated from the upper reaches of the AEC. Within a few years, at an AEC hearing, he would be stripped of his security clearance, effectively ending his usefulness to the atomic energy program.

Communism's Threat is Everywhere...

RUSSIAN SPY IN ATLANTA

By J. EDGAR HOOVER



J. Edgar Hoover

Sunday Magazine newspaper article emphasizing the communist threat to national security. This article, written exclusively for *The Atlanta Journal and Constitution* Magazine by the head of the FBI, J. Edgar Hoover, demonstrated the possibility that spies could be present on our homefront. Source: *The Atlanta Journal and Constitution*, circa 1950.



Alfred Dean Slack (left) is shown here as he was being jailed to face trial for spying. He lived in Atlanta in 1947; is now in Federal Pen.

In the meantime, an interagency committee chaired by Paul Nitze coordinated Truman's push for the Super; the committee's report, NSC-68, came out in April 1950. During this period, Congress took up the dispute between the development of the Super and the development of tactical nuclear weapons, a debate that was not resolved until the outbreak of the Korean War. After that, Congress simply decided to develop both. As a result, from 1950 to 1951, the Defense budget swelled from $13.5 billion to $48.2 billion.[101] All of this led to the creation or expansion of a number of nuclear facilities

designed to develop the new weapons. The Los Alamos Scientific Laboratory was renovated, and new facilities included the Lawrence Livermore Laboratory, long pushed by Teller as a new hydrogen-bomb research center. Among the proposed facilities was a new plant for the production of tritium.[102] At the beginning 1950, it was not yet known who would run the new tritium facility or where it would be located, but both of those questions would be resolved by the end of the year.



PART 2

Savannah River Project (1950–1956)

Reaction to the public announcement of the site selection on November 28, 1950, was jubilant in Georgia and South Carolina. Newspaper headlines clamored that Augusta would become a metropolis, Aiken a "fast growing city," and Barnwell and environs would quickly follow suit. In contrast, residents of the proposed site area listened sadly and carefully as U.S. Corps of Engineers (COE) officials outlined an eighteen-month staged evacuation of 1500 families.

The project had actually begun earlier. During 1949 and 1950, the Atomic Energy Commission and its statutory committees, national laboratory personnel, and government agencies worked in concert to plan the expansion of its production facilities in the nation's defense. When Du Pont came on board, the project moved from the planning stages to the banks of the Savannah River. The site selection process was carried out in relative secrecy until November 28. After that, the construction force and their families appeared in droves to participate in an industrial and engineering project that ranked with the construction of the Panama Canal. Urgent schedules, flexible design, safety, and security were defining forces in the construction of the plant.

The area's character changed. In the words of social critic Dorothy Kilgallen, "It is as if Scarlett O'Hara had come home from the ball, wriggled out of her satin gown, and put on a space suit." These changes only deepened in politics, education, and social relations as the newly arrived operations personnel settled into the area. With families in tow and degrees in hand, these atomic age homesteaders came to the Savannah River Valley from all over the United States, bringing diversity to the Central Savannah River Area. The economic impact of the project on the area was tremendous, with SRP becoming a major employer in the state with an average operating budget of over a hundred million dollars by 1960.

Part Two describes the genesis of the Savannah River Project, the site selection and land acquisition process and the construction of the plant. It also explores the social and economic transformations that resulted from the project and the start of operations across the state and region as atomic energy became part of the South's industrial profile.

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(Opposite Page) Thousands of helmeted construction workers attend a safety meeting in the heavy water production area in March 1952. Courtesy of SRS Archives, negative M-578-2.

4 The Large-Scale Gamble

Robert Bacher, AEC member and later consultant to the Commission, characterized the AEC's expansion program of 1950 as a large-scale gamble.[1] It was that on a number of planes. The country financially and philosophically backed a weapons-production program of incredible magnitude that was scientifically untested. Not only was the hydrogen bomb not a reality, but the production processes inherent in its making were also under development. The wartime sense of urgency had disappeared, and the scientific community that had been part of the bomb effort was divided on the direction the atomic energy program was headed. Unease and wariness took hold as the Cold War developed, and a fledgling civilian organization, rather than the military, began charting the future of the atomic energy program.

The AEC planned the expansion program. To them fell the responsibility of creating a path that was implied but not spelled out in the Truman directive. Working in consultation with the national laboratories and governmental and scientific advisory groups, they created the required conceptual framework. Minutes of the AEC meetings between January and June of 1950 indicate that they moved with speed toward consensus.

While most of the attention was riveted on weapon development at Los Alamos, the AEC's General Manager, Carroll L. Wilson, and production division head, Walter J. Williams, also kept the Commission and its statutory committees focused on production priorities. Several areas jumped out for immediate resolution. The first was how to achieve the new production goals without hampering the existing program. This area of concern soon evolved into a debate over a new reactor design. Multipurpose reactors capable of producing both tritium and plutonium almost immediately came under consideration. However, this reactor type and the proposed level of effort required not only a new site for the expansion of production facilities but also the resurrection of heavy-water research and production.

The second area of concern was selecting a contractor to execute the chosen design and any other process developments needed to ensure the expansion program's success. The AEC, practicing an old-fashioned form of risk assessment, chose Du Pont. Not only was there a shared history with the chemical firm, but there was also an ongoing technological dialogue between Commission members and the principals within the Wilmington-based firm, many of whom were veterans of the Manhattan Project.

Finally, the AEC chose two men from their ranks to manage the new installation who were ideally suited to shepherd the project. Both veterans of the Manhattan Project, Curtis

A. Nelson and Robert Blair brought considerable construction and engineering skills to the task at hand and also were familiar with the Du Pont firm. Nelson, through his work at Chalk River, would bring special skills to the new plant. At least as far as production processes were concerned, the risks involved with the long-range gamble were being transformed into obtainable objectives as the AEC began the decision-making process.

CONSENSUS

The special committee responsible for providing President Truman with a clear recommendation on whether the nation should pursue a thermonuclear program met at the Old State Department Building in Washington on the morning of January 31, 1950. Historians Richard G. Hewlett and Oscar E. Anderson Jr. note the perfunctory tone to the notes from the meeting; the sole course of action left for the committee was to provide a record "to support the only decision possible under the circumstances."[2]

David Lilienthal, Henry Smyth, Secretary of Defense Louis A. Johnson and Under Secretary Stephen Early, Chairman of the Military Liaison Committee Robert Le Baron, General James H. Burns, Dean Acheson, R. Gordon Arneson, Adrian Fisher, Sidney W. Souers, and James S. Lay gathered to draft a formal recommendation based on a study paper compiled by Arneson. The committee stated the need for public awareness of important decision-making, warned against over-reliance on a single weapon, and affirmed national goals of freedom and peace. The key recommendation, however, directed the Commission to continue with the development of all forms of atomic weapons, including the hydrogen bomb. Lilienthal, Acheson, Souers, and Lay informed Truman of their recommendation in an interview that lasted less than ten minutes. The White House made the decision public that afternoon and Joint Committee on Atomic Energy (JCAE) chairman Senator Brien McMahon conducted an afternoon hearing on the Hill to fashion a response to the President's directive. Henry Smyth attended, but Lilienthal begged off. His pending resignation, effective in two weeks, and his dissenting mindset made his presence unnecessary. He chose to inform the General Advisory Committee, which was meeting in Washington that day, of the morning's events. [3]

Chairman McMahon became the leading political proponent of the hydrogen bomb, contending that the Super offered a necessary military advantage from both physical and psychological perspectives. His speech in Congress on February 2 made clear the bomb's projected power and its perceived ability to protect the free world and prevent aggression. But he did not fully disclose the state of research on the new weapon.



Known in the press as the "Atomic Senator," Brien McMahon (D-Conn) was the chairman of the Joint Committee on Atomic Energy. Senator McMahon (right) visited the project along with Du Pont's Chief Engineer Granville Read on November 7, 1951. Courtesy of SRS Archives, negative M-364.

> Certain realities McMahon did not touch. The hydrogen bomb was not, as he suggested, a piece of hardware nearly ready for production. The bomb was an idea, tentative and glimmering—its theory based on bold thought reaching to the stars, and its slender stock of data largely unconfirmed by laboratory experiment. Despite McMahon's confidence, there was no assurance that Los Alamos could produce a nuclear weapon.[4]

To bring this "idea" into reality would require a great deal of problem solving. The scale and intensity of the effort on its development was to be determined jointly by the Commission and the Department of Defense, according to the President.[5] The speed dial set by the Department of Defense was on urgent, and the Military Liaison Committee journeyed to Los Alamos in late February to learn about the laboratory's efforts and to assess where the development of the weapon stood.

Norris Bradbury, the Los Alamos director, presented the laboratory's work on the fission weapon and then moved to the thermonuclear effort, bulleting the problems, materials needed, possible schedules, and initial solutions. For a thermonuclear reaction to occur, researchers had to identify a way to release energy by fusing the heavier isotopes of hydrogen. Deuterium appeared to have the most promise, as isotope-separation techniques had already been developed that would make sufficient deuterium available. The obstacle was that deuterium fusion was theoretically possible only when heated to a temperature of 400 million degrees, hotter than the temperature achieved in an atomic bomb. Los Alamos scientists needed to discover how to reach that temperature. Fusion of tritium mixed with deuterium was considered the possible path, where hydrogen isotopes would react at a lower temperature, releasing energy that would spur the fusion of deuterium. Bradbury continued on the project feasibility, noting the high cost involved and the sacrifices that concentration on the thermonuclear bomb would involve for the laboratory. Also, recruiting scientists was problematic and the wartime impetus was no longer there. The Military Liaison Committee accepted the laboratory director's frank analysis; Le Baron later commented that Los Alamos had "sold a program."[6]

OBTAINING NEUTRONS

The essential ingredient for success of the "program" was tritium, a radioactive isotope of hydrogen. Initial weapon design indicated that tritium was needed in large amounts, and the most direct way to produce tritium was to bombard lithium with neutrons. Hanford's reactors had produced small amounts of tritium during the Manhattan Project and in the postwar period as part of the P-10 Project.[7] This limited experience indicated that more neutrons were needed to produce a gram of tritium than a gram of plutonium. Also, tritium's short half-life of slightly more than twelve years would play into the decision-making as the Commission and its advisors sought short- and long-term answers to the military's agenda. In Robert Le Baron's view, the AEC should produce sufficient tritium both to support the testing program that Los Alamos would spearhead and to produce a stockpile large enough that such weapons could be immediately fabricated. A substantial change within the production program was needed.[8]

Initially, the Joint Committee on Atomic Energy and the Commission considered four alternatives.[9] Three possible technologies focused on reactors; the fourth considered a linear accelerator as a neutron source. The first possibility was continued and expanded use of Hanford reactors for tritium production was possible. Tritium production called for a different mix of fuels and targets than that used to produce plutonium; therefore a reactor would have to be dedicated for tritium production. Discussion centered on the use of H reactor, with the new reactor under construction, the DR-pile, to be used as a replacement for H in the plutonium-production program. Another option was refitting the DR-pile for use as a tritium producer for the stockpile. Ultimately, the use of the Hanford reactors was deemed undesirable as a long-term solution because it would interrupt planned plutonium production. Also, planners were cautioned by the General Advisory Committee that the use of current methods might not be efficient in the long term, and that new production processes might be needed to make the quantities of tritium needed.[10]

A second alternative was to construct a modified version of the materials-testing reactor (MTR) under design as a collaborative project between Argonne and Oak Ridge. Construction of the MTR began in June of 1950 at Idaho Falls. Oak Ridge had designed the 40-MW reactor with enriched fuel that was cooled and moderated by light water; Argonne designed the plant that would support it.[11]

A third route existed at the Berkeley Radiation Laboratory, which under Lawrence was studying a linear accelerator as a candidate, and had begun design studies to explore its feasibility.[12]

The fourth route under study, the so-called "North American Aviation" plan, was based on the heavy-water-moderated reactor constructed at Chalk River, Ontario, Canada, which went critical in 1946. The Canadian national research experimental (NRX) test reactor was built to conduct heavy-water reactor research, and was designed by a team of Canadian, British, and French scientists and engineers. The NRX was Canada's second nuclear reactor to go into operation. This option would involve modifying a test-reactor design for production. [13]

Carroll Wilson, general manager of the AEC and a MIT graduate, took a business-like approach to the problem. If both fission and thermonuclear weapons were needed, and the thermonuclear effort could not impact the progress of the plutonium program, then a decisive approach was needed to produce the additional materials. He established an ad hoc committee headed by George L. Weil "to consider which type of reactor would most efficiently produce tritium, given the uncertainties, and the urgent schedule." Weil, the chief of the Commission's reactor branch, had strong roots in atomic energy. He was one of the operators of Chicago Pile-1's control rods at Stagg Field for the first chain reaction, and he participated in the start-up of the X-10 reactor at Oak Ridge in November 1943.[14]

Weil's reactor group did not discount Berkeley's linear accelerator, but concentrated solely on reactors, as comparative data was available for evaluation. From that point forward, the type of neutron producer for the expansion began to take shape.

After analysis, George Weil submitted his findings to Wilson, who shared them with AEC Commissioner Carleton Shugg. The nation's reactor experts—Walter Zinn, Alvin M. Weinberg, C. Guy Suits, Eugene P. Wigner, and Chauncey Starr—were then asked to act as a review body for the Weil study. Carroll Wilson further moved the decision-making along when he requested that Oppenheimer submit the paper to the reactor group within



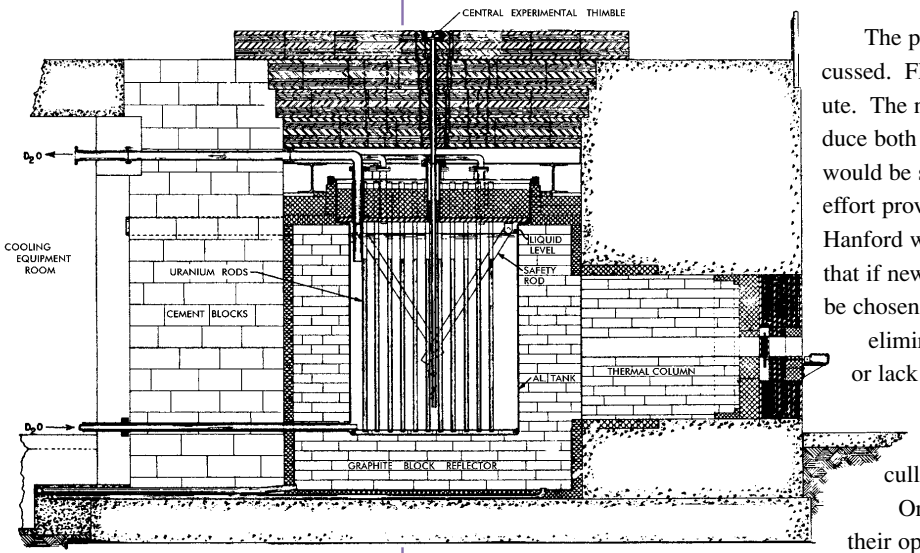
Eugene P. Wigner, a Hungarian scientist who came to America in the 1930s, played a principal role in the development of the atom bomb and nuclear science. As one of the nation's experts on reactors, Wigner also played a part in shaping the reactor technology to be used in the expansion program. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negative 201-8375.



Walter H. Zinn, director of Argonne National Laboratory (1946-1956) and a leading scientific figure within the Manhattan Project, was pivotal in the design and research of American heavy water reactors. His work lead to the design of the Savannah River reactor system. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negative 670-164.

the General Advisory Committee. Pulling from Wilson's diary, Hewlett and Anderson provide a sense of the discussion:

> As Wilson was making these arrangements, he began a series of gatherings in his office to study Weil's paper. Occasionally during the two days of discussions, Pike, Smyth, and Dean dropped in, but it was Wilson and his key staff who explored the possibilities. The goal was to obtain within two or three years the facilities to produce a large quantity of neutrons. Weil had tabulated the advantages and disadvantages of four reactor designs: a modified reactor by General Electric; a modification of the materials testing reactor by Oak Ridge and Argonne; a light water-moderated reactor fueled with slightly enriched uranium, a comparatively new reactor approach by the H.K. Ferguson Company; and the heavy-water-moderated, light-water-cooled reactor based on the Canadian NRX at Chalk River, but with modifications proposed by North American Aviation, Incorporated.[15]



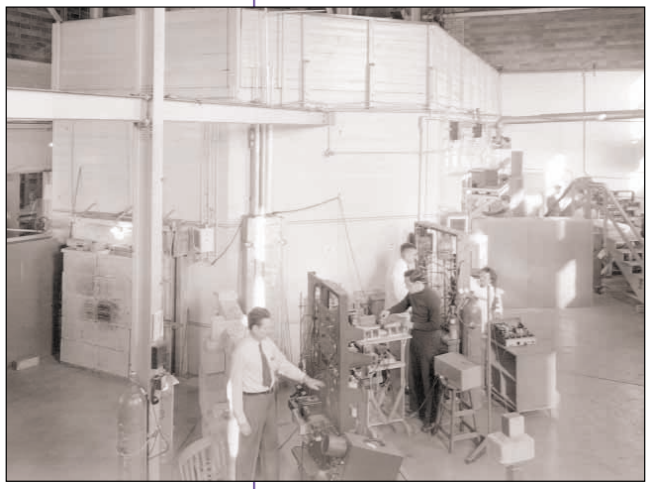
Vertical Section of CP-3, Heavy-Water Research Reactor, Argonne National Laboratory. Source: W. H. Zinn, *Design and Description of ANL Reactors (CP-3, CP-3', and CP-5*), Vol. II P/861, (Washington, DC: GPO), 456.

The pros and cons of each alternative were discussed. Flexibility was considered a critical attribute. The new reactor type needed to be able to produce both tritium and plutonium; this versatility would be sorely needed should the thermonuclear effort prove unsuccessful. The committee felt that Hanford was an immediate source for tritium but that if new reactors were needed, a new site should be chosen. Some of the reactor candidates were eliminated due to time needed for development or lack of flexibility. The North American Aviation reactor type appeared to be the front-runner at this point in the culling process.[16]

On March 30, Wilson's review panel had their opportunity to weigh in on the debate. Walter Zinn, Argonne Laboratory's director, had come prepared to present data on a modified materials reactor. When he learned of the commission's primary interest in a "flexible" reactor design capable of producing plutonium or tritium, he put aside his prepared notes. Instead, he spontaneously led the discussion, persuading all present that a reactor fueled with enriched uranium and moderated and cooled by heavy water was the correct choice. The reactor design he envisioned was an enlarged version of the proposed CP-5, a research reactor to be built at Argonne. CP-5 was described by Zinn as a natural successor to Argonne's CP-3, which began operation in 1944. The proposed design would provide maximum neutron flux for a given power, and this translated into economy in operation, as a reactor's power was a determining factor in operating costs.[17]

By April 12, Zinn submitted a proposal describing his reactor design to the AEC.[18] North American Aviation did likewise. Both proposals were presented in a meeting Weil

organized in May among reactor leaders. While Eugene Wigner cautiously suggested broadening their search, those who met deliberated over the two proposed designs for three days, "arguing over reactor physics and the definition of terms and constants."[19] Hewlett and Anderson note that the chief difference between the designs was their use of heavy water. The North American Aviation design used heavy water solely as a moderator, while the Argonne design used heavy water as a moderator and as a coolant. After lengthy discussion, the Argonne design pulled ahead. The main criticism lodged against it pertained to heat removal in the event of an emergency shutdown, whereas the flexibility of the North American Aviation design was questioned along with its potential for leakage and corrosion. While no definitive statement was made as to the preferred reactor type, both research groups were encouraged to study heat-exchange equipment and pumps. By month's end, the Commission had the conceptual framework in hand for the new reactors.[20]

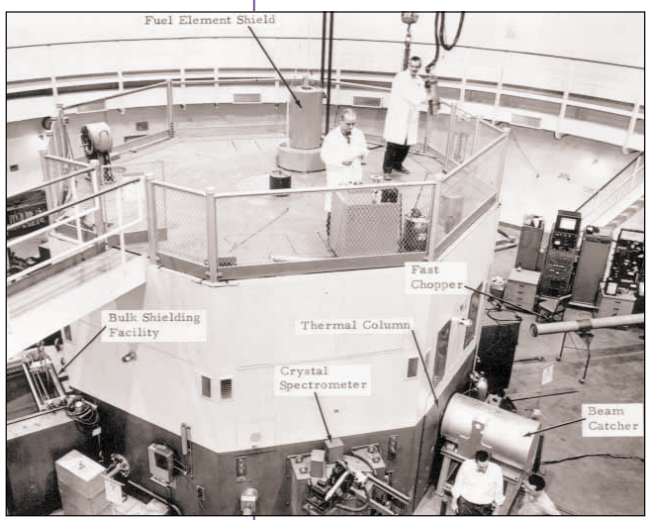


CP-3, Argonne's heavy-water research reactor, went into operation in 1944.

HEAVY-WATER PRODUCTION

Zinn's vision for a heavy-water-moderated and -cooled reactor for the AEC expansion program came with a companion problem. The design necessitated a large amount of heavy water, possibly up to 300 tons, for an individual reactor. And at this point in the program, the number and size of the proposed full-scale production reactor(s) was still undetermined. The world inventory of heavy water in 1950 was less than 50 tons.[21] Moreover, heavy-water production, code named P-9 during World War II, ended in the U.S. in 1945 with less than high marks for the distillation process that was used. Records show that as early as December 1949 the AEC was exploring possibilities within heavy-water production processes that had been researched and subjected to pilot studies during World War II.

CP-5, a heavy water research reactor to be built at Argonne, was the natural successor to CP-3. CP-5's design was the basis for Walter Zinn's proposal for the production reactors under consideration for the expansion program. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negatives 1-40 and 401-947.



WORLD WAR II RESEARCH AND THE DEVELOPMENT OF P-9 PLANTS

American research on heavy water as a moderator for reactors dates to the early 1940s, when different but parallel technological paths to the atomic bomb were under investigation. Both heavy water and graphite were considered potential moderators for reactor studies. However, Fermi's successful results with graphite and the absence of sufficient heavy water for experimentation moved graphite to the forefront of research and development. Heavy-water research would continue through the war years and beyond, but it was considered a second line of defense, needed in the event that the graphite option did not live up to its promise.

While the American program proceeded with graphite, British research was based on the heavy-water approach. Studies conducted at Cambridge by Hans Von Halban and Lew Kowarski convinced many scientists that heavy water had potential for "chain reaction studies" and that further tests should be made to investigate deuterium's capability as a moderator. A team of American scientists headed by Compton reviewed Halban's work and were encouraged, but not convinced. A duplication of the British experiments using heavy water produced in a pilot plant was needed, and the experiment they had in mind would require as much as a ton of heavy water.[22]

Harold Urey of Columbia University, the discoverer of deuterium, had kept abreast of research concerning chain reactions. Learning of Halban's success, he began to study how heavy water could be mass-produced. He also sought out Pegram and Fermi's advice. While Fermi remained confident that graphite was a better moderator than deuterium, he also thought heavy water might be useful at least as a coolant. Urey sought and won sufficient funding from the Uranium Committee to set up a pilot plant in Louisiana operated by the Standard Oil Company. The pilot plant was charged with studying the liquid–gas phase exchange reaction under high pressure while Urey worked on developing a catalyst.[23]

Heavy-water research continued, but the effort moved from Louisiana to Canada. In a cooperative effort between the United States, Britain, and Canada, Harold Urey worked with Halban, who was to head a heavy-water research program for the British. The program was sited at Trail, British Columbia, near the American-Canadian border. Consolidated Mining and Smelting Company of Canada LTD (Cominco) owned and operated a hydro-powered, electrolytic-hydrogen plant for ammonia production at Trail. Cominco management was persuaded to convert a loop in their ammonia plant for heavy-water production. The conversion was slow going, but by mid-June the plant had produced enough deuterium for Fermi to make measurements. Six months after CP-1's success, the new studies proved that deuterium was an excellent moderator. [24]

When the Trail plant went into operation it produced 40 pounds of deuterium oxide per day. This was adequate for testing, but tons would be needed to make deuterium oxide a viable alternative to graphite. Research quickly focused on how to produce heavy water on an industrial scale. The difficulties involved with bringing heavy-water production online were brought to the attention of Du Pont, the prime contractor for chemical separations at Clinton Laboratories and at the Hanford Engineering Works. General Groves had requested that the chemical firm compile a feasibility study on the design and construction of a new large-scale nuclear materials plant. The Du Pont report presented in November 1942 reported favorably on the feasibility of heavy-water-moderated reactors and advised that the construction of large-scale heavy-water production units should be considered.

This recommendation was duly noted by Groves, but the American reactor program during World War II was based on graphite-moderated reactors. Heavy water was relegated to an understudy role, despite some scientists' belief that it far outshone graphite in its efficiency. To quell further discussion, Groves contracted with Du Pont to make advances in heavy-water production.

Heavy-water historian Per Dahl notes, "Du Pont was asked to forego sophisticated schemes based on catalytic exchange or electrolysis, and proceed with deuterium production by the crude but more direct method of fractional distillation of steam, based on the slight differences in the boiling points of heavy and ordinary water, augmented by electrolysis for a final concentration stage."[25] The chemical firm used excess steam from existing

Department of Defense facilities at Morgantown, West Virginia; Childersburg, Alabama; and Newport, Indiana, to operate three P-9 plants between 1943 and 1945. An electrolysis unit for final concentration and purification at Morgantown served all three plants. The Du Pont facilities operated for two years, producing collectively 2,400 pounds of 99.8% heavy water each month. Dahl states the plants produced about 23 tons at a cost of $28 million, or 1.4% of the total budget for the atomic bomb program. The P-9 plants supplied the 6.5 tons of heavy water used in CP-3, the first heavy-water reactor designed by Walter Zinn at Argonne. And Canada also used heavy water produced under the MED program in the development of their reactor program.[26]

The importance of the P-9 plants to the events of 1950 cannot be overstated. They demonstrated that heavy water could be produced on an industrial scale. They also set the stage for better decision-making regarding future production paths. While the heavy-water plants were under construction in 1942, Du Pont continued to investigate better technologies to produce heavy water. Two alternative production paths, dual-temperature and hydrogen-distillation processes, were considered. The latter was shelved because it involved too many obstacles. The dual-temperature process had promise. This approach entailed the use of two towers in which water and hydrogen sulfide were placed in counter contact at two different temperatures. This observation made by Du Pont was not immediately acted upon. However, in 1950, it would help set the direction for the heavy-water production needed for the expansion program.

HEAVY WATER FOR THE 1950 EXPANSION PROGRAM

As reactor specialists leaned toward the development of heavy-water-moderated reactors should new reactors be necessary, the AEC's request of the Girdler Corporation in December 1949 seemed prescient. The firm was requested to study the feasibility of converting the old Du Pont P-9 facility at the Wabash River Ordnance Works (WROW) to a low-pressure dual-temperature production plant. The AEC's New York Operations Office would manage the work. Given that the WROW facility was designed for vacuum operation, it could not be converted into a high-pressure production system. It was estimated that the converted plant could produce 2.5 tons of heavy water per month at lower pressures. In their report, Girdler recommended that a new, more efficient, high-pressure facility could be constructed at the same cost as converting the existing facilities. [27]

While Girdler's studies were ongoing, the AEC also funded work with the hydrogen-distillation process, requesting that Hydrocarbon Research, Inc., design a plant based on this process. On March 1, 1950, the commission approved construction of a pilot plant. In this design, hydrogen gas would be cooled to liquid temperatures, and fractional distillation would be used to separate deuterium from the gas. [28]

The production division of the AEC quickly pressed for a second pilot plant. Previous estimates for heavy water were beginning to look low, and reliance on one method of production appeared risky. Between 1942 and 1950, Harold Urey of Columbia University and Jerome S. Spevack researched the dual-temperature or "GS" process (Girdler sulfide process), which involved the dual-temperature exchange of deuterium between water and hydrogen sulfide gas in alternately placed hot and cold mixing towers. The Commission approved a second pilot plant using the "GS" approach on May 11, 1950.

The Girdler Corporation, a Louisville, Kentucky-based firm that had conducted the feasibility study for converting the WROW plant facilities, received the contract for design, erection, and operation of a dual-temperature process pilot plant and an associated laboratory to study the process. The pilot plant, to be located at WROW, was designated the Dana Area. Reuse of the federal property and some of the facilities would substantially reduce costs that had heretofore been considered prohibitive.[29] If the pilot plant at Dana was successful, then the facility could be expanded. Initial construction was to begin on June 26, 1950.

NEGOTIATIONS WITH DU PONT

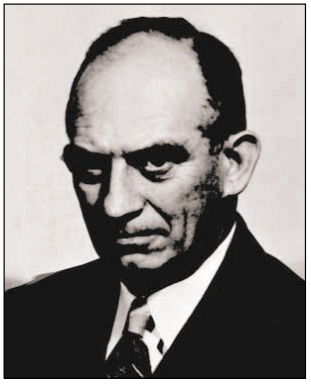
The proposed design alternatives involved in tritium production, code-named P-10 production, were on the agenda of the AEC's May 5, 1950 meeting.[30] However, the meeting minutes show consensus rather than debate on the choice of a heavy-water reactor system. AEC commissioner Smyth in conjunction with Robert Bacher, now a Commission consultant, approved of the heavy-water program because reactors moderated by heavy water appeared to be versatile and because neutron economy was desirable for both tritium and plutonium production. Heavy water was perceived as a win–win proposition. The commissioners and their advisors drafted a proposal to that effect to the Military Liaison Committee.

Walter Williams, the AEC's director of production, preferring decisions rather than discussion, commented that it was his understanding that the problems inherent in the heavy-water approach were mainly engineering problems rather than theoretical problems and could be "presumably solved by an aggressive and well-supported organization."[31] One week earlier he emphasized that if heavy-water-moderated reactors were to be used, then heavy-water plants needed to be built. AEC historians Hewlett and Anderson state that Williams believed that a new production site, a new operations office, and another major contractor were warranted.[32] The aggressive and well-supported organization he had in mind was Du Pont, echoing the April recommendation of the General Advisory Committee. The General Advisory Committee, at their April meeting, had agreed with Zinn's argument in favor of a natural-uranium, heavy-water reactor. And they went one step further, advising the Commission to contact Du Pont to provide further study for the heavy-water design for the production reactors.[33]

Du Pont was aware of the direction the AEC expansion was taking and that it would lead to Wilmington. As discussed earlier, Du Pont's exit from atomic energy affairs after World War II was nominal. Key Du Pont staff members and company principals acted as advisors during the postwar years, and the firm had authored design feasibility studies for the commission for separation processes. More importantly, their corporate experience included all facets of the proposed project. Du Pont built and operated Hanford reactors, Oak Ridge's early separation's facilities, and three heavy-water production units under the government-owned contractor-operated (GOCO) system for MED during World War II. The choice of Du Pont for the job was almost inevitable.

Hewlett and Anderson noted that Carleton Shugg kept R. Monte Evans, Assistant General Manager of Du Pont's Explosives Department and a Hanford veteran, apprised of the general discussion as it evolved. With reactor design in place, negotiations began in

R. Monte Evans, Assistant General Manager of Du Pont's Explosives Department. Evans maintained ties with the AEC's Carleton Shugg who kept the Du Pont executive informed on the development of the expansion program. Courtesy of SRS Archives, negative 3016-5.



earnest in April 1950.[34] This early consultation was necessary to the success of the proposed expansion, as there were interlocking problems to be solved between reactor design and heavy-water production. By May 5, an AEC paper was already in draft summing up "tritium negotiations" with Du Pont and the possible "construction of an additional heavy water plant using a different process."[35]

On the morning of May 15, Carroll Wilson briefed his fellow commissioners on his visit to Wilmington. The commissioners' response to the Du Pont visit was guarded. Smyth saw Du Pont as reluctant, and their insistence on contractual flexibility until after an internal evaluation was perceived as a challenge to the AEC's authority. Gordon Dean, cognizant that Du Pont was the front runner, inquired about other firms and their experience. Walter Williams noted that Union Carbide, Monsanto, The Dow Chemical Company, and American Cyanamid were available.

Carleton Shugg reminded everyone of the delays involved in re-opening investigations of firms that had already been eliminated from consideration and squelched further inquiry into these firms. Williams cemented the Du Pont candidacy, replying that none of the mentioned firms could match Du Pont's experience in the design and construction of reactors and chemical separations facilities. To Wilson, Shugg, and Williams, the Wilmington firm was uniquely qualified to design and construct large-scale tritium facilities and had a proven track record in keeping difficult schedules.[37] The phrase, "uniquely qualified for the job," became a Du Pont mantra that would resurface in contracts, letters, and public relations documents in the future.

As negotiations proceeded through May, the critical need for further heavy-water facilities was recognized. Carroll Wilson stated that the availability of heavy water and progress on the construction and operation of new heavy-water production facilities might well pace the whole tritium production program. He further suggested that the construction and operation of the new heavy-water facilities might be subsumed under the Du Pont contract. Heavy water was too essential to the program not to be included under the main contractor's responsibility. The minutes of the AEC meeting for May 15 suggest that Crawford Greenewalt of Du Pont reacted cautiously to the heavy-water production choices that had been selected by the AEC without Du Pont input. He apparently called for further review, but Walter Williams of the production review team held sway, stressing that while such a review would be helpful, it should not postpone design work and construction for "the Spevack process" proposed for Dana. [38]

This shift in arrangement would make Du Pont responsible for estimating the heavy-water requirements in relationship to reactor time schedules, evaluating heavy-water production processes, and meshing reactor program requirements with construction schedules for a heavy-water plant. They would end up working with Girdler cooperatively on heavy-water production at Dana.

The wariness exhibited by the commissioners must have been outweighed by Du Pont's experience. On June 12, AEC Chairman Sumner T. Pike asked Du Pont to review technical aspects of a new atomic energy production center. This request was considered preparatory to a contract that would be let for all phases of the proposed project, including the site selection and survey.

TRANSFERS FROM CHALK RIVER AND WASHINGTON

Just as Du Pont began to look to within its ranks for personnel for the new project, the AEC followed suit, selecting Curtis A. Nelson, a native of Bristow, Nebraska, as the first local manager for the new operations office and Robert C. Blair as its deputy manager.



SROO Manager Curtis A. Nelson with South Carolina Governor Jimmy Byrnes at Savannah River, circa 1953. While Curtis Nelson brought strong construction experience to his job, he was also an adroit manager with strong "people" skills. Courtesy of SRS Archives, negative 2015003.

Nelson, a civil engineer educated at the University of Nebraska, brought a wealth of construction experience to the proposed project that he had gained as a member of the U.S. Army Corps of Engineers, the Civilian Conservation Corps, and the Federal Works Agency. He had supervised large-scale building construction projects—dams, lake restoration, river diversions, and railroads—during the 1930s. As Captain Nelson, he was assigned as constructing quartermaster to Joliet, Illinois, where he was responsible for the construction of the Ordnance Plant in 1941. With ten years' active duty with the U.S. Army and a reserve commission as colonel in the U.S Army Corps of Engineers, he was eminently suitable for the managerial position.[39]

His qualifications went beyond construction, however. Nelson's direct experience with atomic energy began late in 1943 when he was assigned to Oak Ridge under the Manhattan Project. At Oak Ridge, he served under District Engineer Lt. Col. Kenneth D. Nichols as Construction Officer, Control Officer, and Personnel Director. In this capacity, he helped to solve the labor disputes between CIO leaders and Union Carbide at Oak Ridge. Nelson was awarded the Legion of Merit for his service to the nation during the war. [40]

After the war, Nelson was assigned to Canada's nuclear facility at Chalk River, Ontario, as U.S. liaison. During his three years at Chalk River, he was responsible for preserving and protecting American property and for negotiating information exchanges between the American, British, and Canadian atomic energy programs.[41] The Chalk River site, on the Ottawa River about 130 miles west of Ottawa, emerged from a World War II Anglo-Canadian technical cooperative program. Home to the Zero Energy Experimental Pile (ZEEP) reactor, the Canadian facility was remotely sited. Its scientists and their families resided in the adjacent community of Deepwater. The ZEEP, a zero-power heavy-water-moderated reactor, went critical in September 1945, a week after the end of World War II.[42]

Built for heavy-water reactor research, the ZEEP was followed in the postwar period by the NRX, an experimental heavy-water test reactor that went into operation in 1946. Nelson was on hand in 1947 to view the Canadian operation and to learn first-hand the technology these reactors represented and what they might have to offer for the American expansion program. He was the first American to serve in this position, and his tenure at Chalk River gave him a view of the atomic energy program on the international level. At Deep River, the Nelsons became part of an international community that included high-level British, Canadian, and American scientists and engineers and their families.[43] The position at Chalk River ended in June of 1950 when Nelson was notified that he was to manage the new production plant.



Chalk River Laboratories, Ottawa River, Province of Ontario, Canada. Small building in forefront housed Canada's Zero Energy Experimental Pile (ZEEP), the first reactor outside of the United States to achieve a self-sustained nuclear reaction. Photograph courtesy of Atomic Energy of Canada Limited.

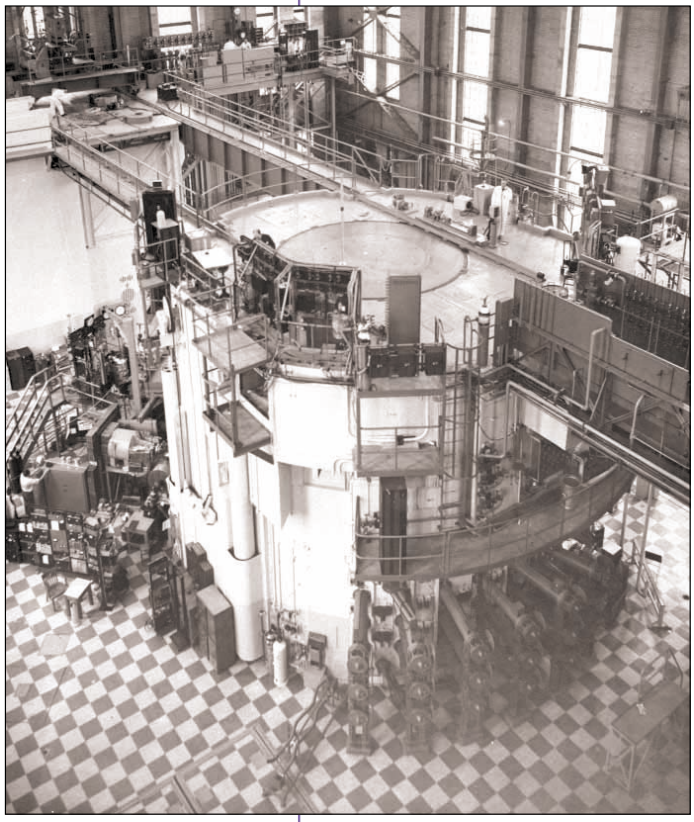
Robert C. Blair, hired by the AEC in 1949, was named Deputy Manager for the new production plant. A native of Urbana, Illinois, Blair had followed a similar career path to Curtis Nelson. He studied civil engineering at the University of Illinois, after which he served with the U.S. Army Corps of Engineers in Tennessee and at the St. Louis District. At the outbreak of World War II, he was Head Engineer of the Syracuse, New York, District. He entered military service in 1942 and was one of the first chosen by Col. James C. Marshall, District Engineer, for the MED. Blair was promoted to lieutenant colonel in 1943, and an organization chart for April 1943 shows him third in command as Executive Engineer of the MED. He continued in this post through the summer of 1943, participating in the site-selection process for Oak Ridge. When the leadership of MED changed in July 1943, Blair and others of the "old guard" under Col. Marshall left the MED and went overseas.[44]

At the close of the war, Blair was in the Southwest Pacific Theater as commander of the 5222 Engineer Brigade (Construction), Headquarters and Headquarters Company in the Philippines and Japan. For his war service he was awarded the Bronze Star and the Legion of Merit.[45]

During the postwar years, Blair initially returned to the Corps of Engineers but left for the private sector, joining an American engineering firm based in Argentina. On his return to the U.S. in 1949, he accepted a position with the Military Application Division of the AEC in Washington. From that job, he was transferred with Nelson to the new operations office.

Nelson and Blair were a formidable managerial team. Both men were well versed in the organization of the AEC and how it did business. In addition, Nelson was already familiar with Du Pont and its corporate mindset through their work at Oak Ridge. His work in industrial relations at Oak Ridge was also an asset. Both men had impressive credentials in construction and management, having headed up scores of Army Corps projects. They also had international experience. In Canada, Nelson was exposed to heavy-water reactor technology and to an international scientific society. Blair's construction work overseas shaped his experience, providing perspective from both the contractor and federal agency's side.

View of NRX reactor. Courtesy of SRS Archives, negative 3057-1.



In July 1950, Curtis Nelson moved to Wilmington where he could better manage the new operations office in tandem with Du Pont. The site-selection process was beginning and where the new plant would be located was still unknown.

PRODUCTION GOALS DEFINED

Truman received a letter written jointly by the Commission and the Military Liaison Committee that summed up their recommendations for the expansion program. Hanford would be responsible for short-range tritium production, and the Washington State facility would supply Los Alamos with the tritium needed for a test of thermonuclear principles slotted for the spring of 1951. Long-range production goals would be met by a new facility that exhibited "improved technology" with two heavy-water reactors. It was further recommended that Du Pont design, construct, and operate the new facility. Truman responded quickly to the recommendations, approving negotiations with Du Pont.[46]

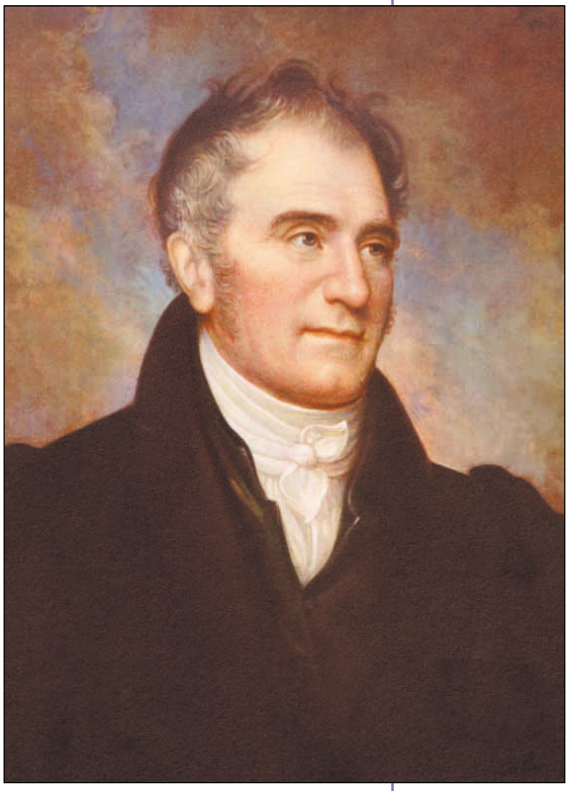


Deputy Manager Robert C. Blair (right) and unidentified colleague viewing physiographic model of the Savannah River Plant area, circa 1953. Courtesy of SRS Archives, negative M-508.

When the plan for the expansion program was approved on June 8, the Du Pont–AEC contract had been mostly outlined, allowing Pike to formally request the company to accept the work on June 12. The scope of work penned by the commission, but tempered by Du Pont, included responsibility for the site survey, design, construction, and operation of a "new reactor installation" and for review of the technical analyses for the reactors and the proposed heavy-water processes.[47] The AEC had chosen their staff for the new installation. The scale and the rate of effort for the thermonuclear program were defined at last, and the conceptual framework on major processes and reactor types was set to realize the objectives. The next business on the agenda was a firm commitment from Du Pont so that the site-selection process could begin.

5 Like Picking Babe Ruth In His Prime

Eleuthère Irénée du Pont. Painted by Rembrandt Peale. Source: E. I. du Pont de Nemours and Company, Inc., *Du Pont: The Autobiography of an American Enterprise* (New York: Charles Scribner's Sons, 1952), frontispiece.



The design of the Savannah River Plant, from its physical layout to the structure of its management and organization, would be derived in large part from the philosophy of its builder, Du Pont. Du Pont's history, like the history of the AEC and nuclear science, would influence the strategies used to build the plant and its administration. Du Pont went through two distinct phases in its growth prior to the Savannah River Plant, and aspects of each would come in to play in the approach to Savannah River. The first lasted for a century, during which time Du Pont was owned and managed by a succession of family members who expanded the firm's manufacturing capabilities and capacities. The second began in 1902, when a company crisis caused a change in organizational policy and management philosophy, and the resulting reorganization allowed Du Pont to acquire the experience and administrative techniques that enabled its managers to take on projects like the operation of Savannah River.

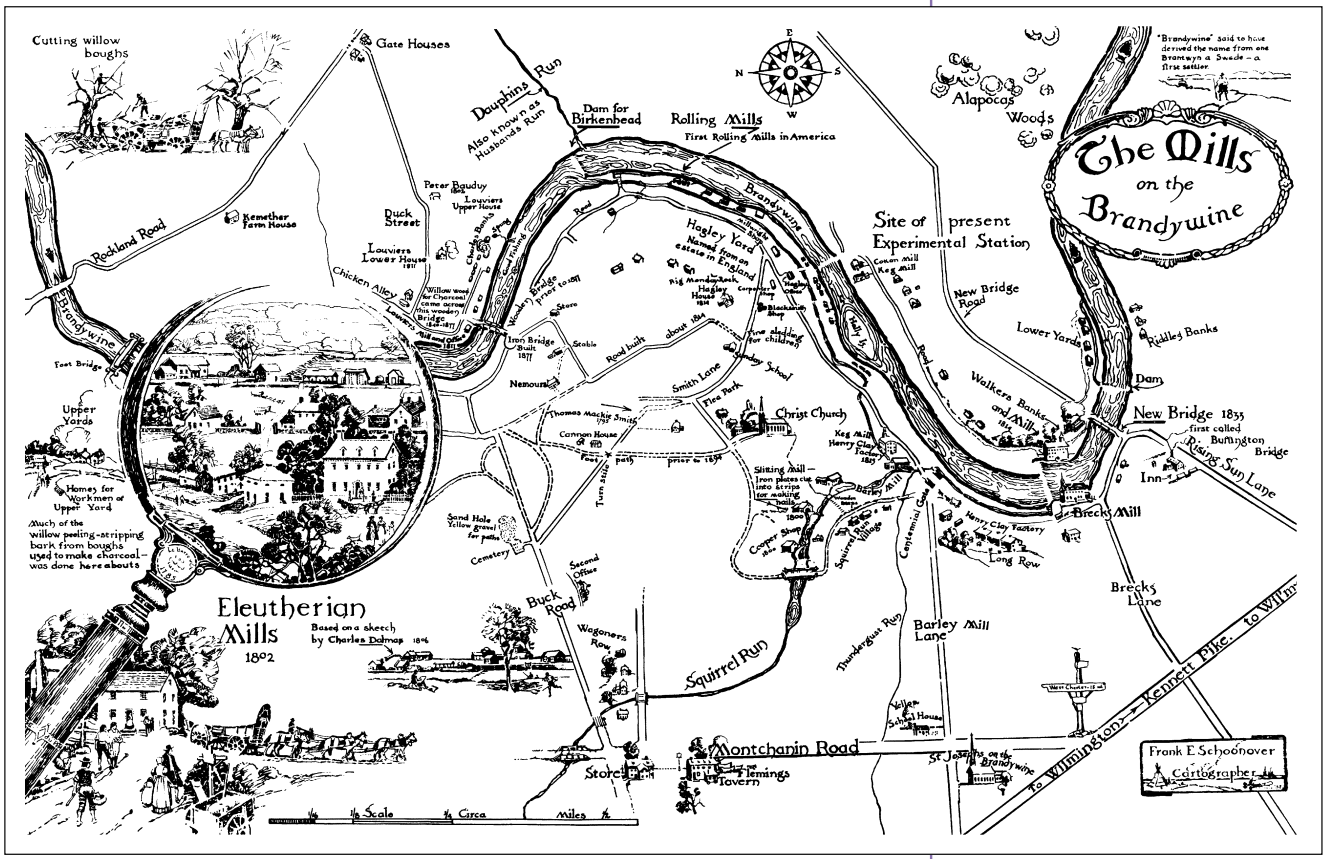
Since the founding of the company in 1802, Du Pont had made efforts to distinguish itself within the American business community, and to become a valuable component of American enterprise-—not only prospering commercially, but becoming an essential element of society as a whole. Through public relations campaigns and advertising strategies, the company built an image of itself as a corporation that balanced the privilege of profit with its responsibilities to society. The firm saw the operation of Savannah River as one of those responsibilities. The company's business philosophy was well-expressed by company president Lammot du Pont Copeland: "Business is a means to an end for society and not an end in itself, and therefore business must act in concert with a broad public interest and serve the objectives of mankind and society or it will not survive."[1] Such perspectives helped define Cold War relationships between Du Pont and the government, and in turn between the government and many of its contractors.

THE FIRST GENERATIONS

The founder of the Du Pont company, Eleuthère Irénée du Pont, was born in Paris in 1771. He was the youngest son of economist and states-

man Pierre-Samuel du Pont. Influential and active in politics, the elder du Pont contributed to the trade clause in the Treaty of Versailles, and served time in jail during the French Revolution for his support of Louis XVI and the royalists, an experience that helped influence the family's move to the United States.[2]

Irénée studied chemistry in his youth, serving as an apprentice to the French chemist Antoine-Laurent Lavoisier. In 1775 Lavoisier was placed in charge of the gunpowder plant at Essone, and it was there that Irénée first learned to make the compound that would later become synonymous with the du Pont name. When Irénée was 23, Lavoisier was sent to



E. I. du Pont drew these plans for the layout of the original millworks in 1802. Irénée initially thought to call the new factory the Lavoisier Mills, in homage to the teacher that had made the endeavor possible. But he changed his mind and settled on Eleutherian Mills, the word a reference to "freedom" and perhaps associated in his mind with the colony he had originally wished to establish. Courtesy of the Hagley Museum and Library.

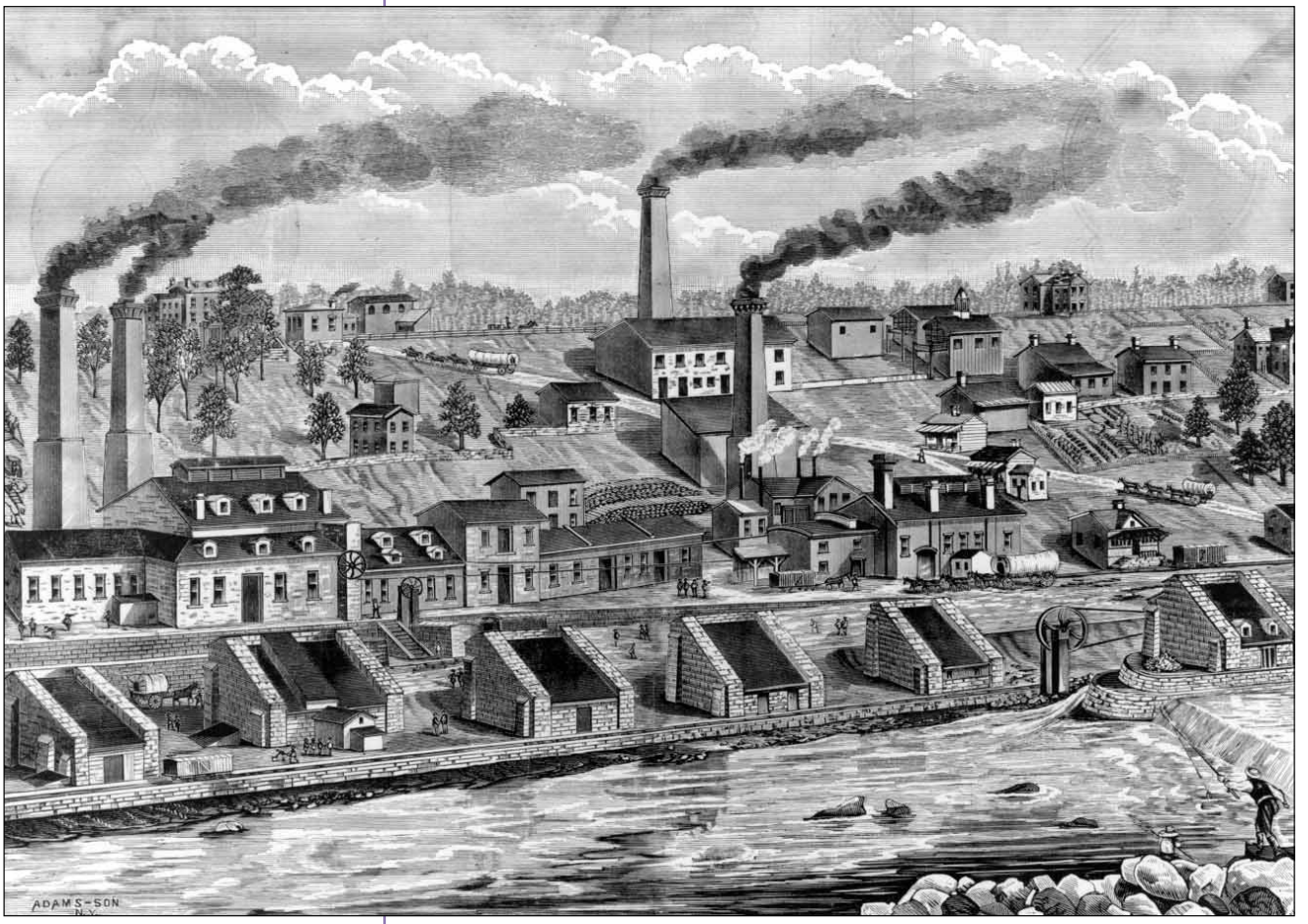
the guillotine. Irénée's gaze turned from the instability in France and he, with the rest of his family, decided to immigrate across the Atlantic to the newly founded United States.

The du Ponts—Pierre-Samuel, Irénée, Irénée's older brother Victor-Marie, and their families—arrived in the United States on New Year's Day of 1800 and immediately became involved in the political, social, and commercial development of the nation. On a hunting trip shortly after his arrival, Irénée du Pont noticed the inferiority of American gunpowder compared to what was being produced in Europe, and first realized that European powders were prohibitively expensive for most Americans. It was clear to him that there was a substantial need for quality powder at a reasonable price. A tour of powder plants in the United States at that time convinced him that powder production could be a profitable undertaking.

Irénée du Pont located his first powder mill on the Brandywine Creek, near Wilmington, Delaware. Construction began in 1802, and the first mills were in operation at the end of 1803. Du Pont gunpowder went on sale the following spring. The first year of production du Pont's Eleutherian Mills turned out nearly 45,000 pounds of powder; the next year the mills produced three times as much. By 1808, they were the largest gunpowder manufacturer in the United States.

Du Pont was ahead of his time in the organization of his business. Much like today's managers–and unlike those of du Pont's day–Irénée tried to continually upgrade both his product and the process by which he manufactured it. Because of the close attention paid to his work and the quality of production, powder from the mills soon became so common in the United States that black powder and lead shot were known as "Du Pont and Galena."[3]

Two notable items from this period helped define Du Pont attitudes toward safety, and relations between managers and their employees. Both are still mentioned by Du Pont employees, and both reflect the idea that privilege is accompanied by responsibility. The first notable item was that the du Pont household was located next to the powder yard—if the employees risked their lives in their work, management could do no less. The second was the explosion that occurred in March 1818, which heavily damaged the mills and



"The Mills on the Brandywine," a composite drawing incorporating maps of the Eleutherian Mills area dating from before the establishment of the mills to the 1950s. Drawing by Frank E. Schoonover. Courtesy of the Hagley Museum and Library.

killed 40 employees. Although not legally required to, nor expected to by practices of the day, Irénée considered it the company's responsibility to take care of the families of the employees that were killed. The widows were given pensions and furnished with living quarters, and the company paid for their children's education and medical costs. Conscientious attention to the human and monetary costs of unsafe operations helped instill a long lasting safety culture in the company, a distinctive feature of their operations at Savannah River.

By 1834, Irénée du Pont was producing more than a million pounds of powder a year. Although the company coffers remained filled with notes instead of profits, it had greatly expanded facilities and laid the foundation for growth into a major United States enterprise. The founder of the company died in 1834 at age 63.

Alfred Victor du Pont, Irénée's eldest son, became the senior partner of Du Pont after his father's death. Alfred Victor was more at ease conducting experiments with chemicals and developing machinery than with the daily routine of business administration, but under his leadership the company continued to grow, and held its own against increasing competition in the powder manufacturing industry. Henry was the third du Pont to administer the family corporation, running the company from 1850 until his death in 1889.

During the 1850s, Lammot du Pont, a grandson of founder E. I. du Pont, set up a laboratory at the family mills to work on process and product improvements. One of his developments was soda powder. The new compound, although not of the quality needed for firearms, was well suited to blasting purposes; Du Pont's "B blasting powder" was the result of the development, and it quickly became a standard for mining and blasting because of its lower cost. Lammot's research efforts also set a far-reaching precedent for the company.

All production was converted to the Union cause during the Civil War, and the Federal forces used Du Pont powder at a rate of nearly a million pounds a year. In conjunction with the Army Ordnance Department, Du Pont developed Mammoth Powder, a special powder that made heavier artillery feasible to use for the first time. Soda powder and Mammoth Powder pointed out the accomplishments possible through a company research program.

After the war, Du Pont expanded its explosives interests by buying into the Repauno Chemical Company, a dynamite producer. Heralding future Du Pont efforts to diversify and to expand its business through product development, Repauno was set up not only as a production site but also as a research facility. Lammot du Pont established a laboratory there, and from its scientists and technicians came many improvements in both the products of the du Pont family enterprises and the means of manufacturing them.

Eugene du Pont, another grandson of E. I. du Pont, was the last family member to head the company before the major reorganization of 1902 and 1903. He became president at the death of Henry du Pont in 1889 and held the office until his own death in 1902, the result of pneumonia that may have been brought on by overwork. The year 1902 marked the one-hundredth anniversary of the founding of Eleutherian Mills by Eleuthère Irénée du Pont, and very nearly marked the end of the company as well. After the death of Eugene du Pont, the selection of a new president proved to be a problem. Each of the partners in the enterprise disqualified himself from taking the position. Only a matter of months before the anniversary date, the partners voted to sell the company to the highest bidder.

A NEW BEGINNING

> At a side table in the Café Savarin, in the old Equitable Building, New York City, coffee cooled in three cups. The trio of young men were [sic] too preoccupied with their conversation to notice. First cousins, each was a great-grandson of E. I. du Pont de Nemours. The prospect before them was, therefore, an exciting one. They were planning the purchase—buildings, assets and good name—of the century-old family business. It was quite an undertaking for Thomas Coleman du Pont, 38,… Alfred Irénée du Pont, 37, and Pierre Samuel du Pont, 32.[4]



The first buildings at Du Pont's Experimental Station were built in 1903. The concept of conducting fundamental research for product and process development, as was done at the Experimental Station, was a great asset to the Du Pont company, and has helped shape modern concepts of business development. Courtesy of the Hagley Museum and Library.

When Alfred du Pont heard of the owners' decision to sell the business, he moved to keep the company in the family. He contacted two of his cousins, and the three younger du Ponts presented the older generation of partners with an offer to buy the company themselves, paying for it with $2100 in cash and stocks to be issued when the cousins reorganized Du Pont into a new corporation—E. I. du Pont de Nemours, Incorporated.[5]

The eldest cousin, Thomas Coleman du Pont, became the first president; his main duties were to lead administration and expansion. Coleman, with Arthur Moxham (the future manager of the Du Pont Experimental Station), had managed the railway equipment manufacturer Johnson and Lorain Steel Company, so he had been exposed to relatively new management trends in the railroad industry. Alfred du Pont was to rely on his many years of experience in the powder yards to help him in his new position as vice president and chief of production. The youngest member of the trio, Pierre du Pont, was made treasurer. One of their first actions was to organize the Executive Committee, a group of seven knowledgeable Du Ponters who would provide broad guidance concerning the operation of the business and the smaller companies owned by Du Pont but not yet consolidated under a central management.[6] The assignments of the Executive Committee at its inception were to shape overall company policy, formalize the pension plan, and set up a bonus program to reward achievement and encourage company ownership by employees and managers through the distribution of stocks as part of a benefits program.[7] The practice of committee decision-making would reverberate in many future undertakings.

Soon, all the separate companies administered by Du Pont were consolidated, and operations were divided functionally into the black powder, high explosives, and smokeless powder departments.[8] This allowed the chain of command to become much more vertical, flowing from the president and Executive Committee to the department directors to the facility operators. The new organization made it easier to bring purchasing, sales, legal, and other administrative and support functions together so they could be accomplished more efficiently.

The three cousins took over the company at a transition point in American business practices. Innovative ideas were helping determine the shape of modern management.

The new organization of the company reflected modern trends, but the new ground the cousins and company were treading was not just managerial. Science, and its relations to manufacturing, industrial research, and the military, was changing as well. The era of what has come to be known as "big science" was at hand.[9] Big science depended on the efforts of teams rather than individual inventors; these teams dealt with complicated issues, and were generally backed by expansive funds, often supplied by the government. Du Pont would play an important role in the twentieth-century history of big science.

Between 1902 and 1911, Du Pont began placing greater emphasis on research and development. The du Pont cousins established their first formal research facility at the Repauno Chemical Company. Completed in 1902, the new facility was called the Eastern Laboratory. Hamilton Barksdale, the general manager of Repauno, set out a broad mandate for the laboratory, charging it with improving explosives and manufacturing techniques. The laboratory itself was placed under the direction of chemist Charles L. Reese, who quickly proved that research could show an impressive return on investment. Process improvements reduced manufacturing costs and increased yields of nitroglycerin, which in turn reduced raw materials costs.[10]

In 1903, Du Pont extended its research capabilities by establishing the General Experimental Laboratory near the mills on the Brandywine. Scientists at this facility—better known by its later name, the Experimental Station—would pursue a wide range of development work that broadened the Du Pont product line. The initial successes of the Eastern Laboratory had played a role in encouraging this extension into more research, but the original commitment to the Experimental Station was cautious. Before too many years, however, the ideas of the Executive Committee vis-à-vis research at its newest laboratory grew to be "grandiose."[11]

During the next decade, differences in opinions between the managers of the Eastern Laboratory and the Experimental Station pulled Du Pont research in opposing directions. Hamilton Barksdale, head of the Eastern Laboratory, favored decentralized research, with each department of the company undertaking its own investigations, improving its own processes, and developing its own products. Francis du Pont and Arthur J. Moxham of the

Evolving Management Practices—Merging Ideas

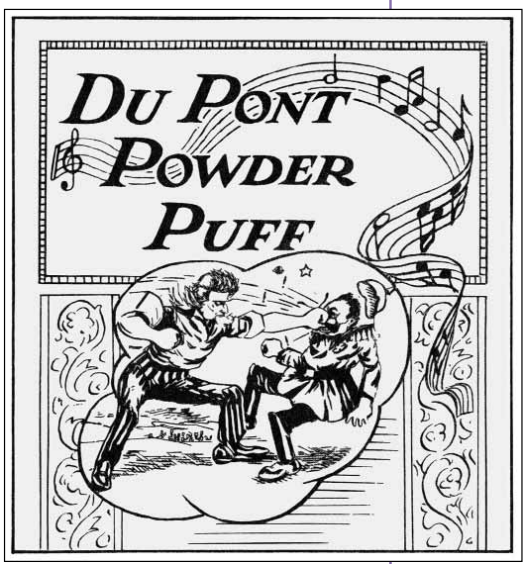
In the 1890s, engineer Frederick W. Taylor introduced his concept of "scientific management," which further developed the idea of functional division in production enterprises. Taylor's ideas significantly influenced the three du Pont cousins in their 1902 reorganization. Thomas Coleman had even hired Taylor to install cost and control systems at the Johnson and Lorain Steel Company.

During the last decades of the nineteenth century, businesses generally grew either by adding marketing and purchasing offices to their existing enterprise, or by acquiring other firms. The latter is generally called "horizontal" combination, and this was the path that Du Pont had typically chosen prior to 1900. In strict horizontal combination, firms were brought under the umbrella of the parent organization by purchase or trust agreement, but were not truly consolidated with the parent firm. The acquired businesses usually continued to handle their own sales, purchasing, support, and other general administrative functions as separate entities. "Vertical" organization was one way to embrace the new management techniques that were becoming essential in competitive business. Unless such horizontally growing companies integrated their new acquisitions vertically by consolidating management functions into a coordinated, centralized administrative effort with clear lines of authority and responsibility from upper management to the production floor, horizontal expansion did not prove to be viable over the long term. Du Pont was one of the companies that grew first horizontally, then turned to vertical integration to manage its extensive assets.

Experimental Station believed, to the contrary, that a general laboratory would be better suited to these tasks, and could undertake and coordinate work as directed by department heads or the Executive Committee more efficiently. The Executive Committee initially sided with Barksdale,[12] but requested that the laboratories communicate with each other about projects so they could limit duplication. The latter proved to be of limited utility since the two laboratories competed directly on projects.[13]

By 1905, three-fourths of the explosives industry in the United States was managed by the Du Pont Executive Committee. Growing profits allowed the company to invest heavily in research activities, and in 1907 the annual budget for research at Du Pont was nearing a quarter of a million dollars.[14]

Although business development was placed on hold when tensions between the Allied and Central powers exploded in the summer of 1914, there were benefits for Du Pont. The firm was again called upon to produce powder for war use, and the expansion program required to meet powder demands from the Allies resulted in the most rapid growth period the company had experienced. The war was highly profitable for Du Pont, and larger receipts soon presented an excellent opportunity for the further expansion of research efforts.[15]



The song "Du Pont Powder Puff," sung to the tune of "Coming Through the Rye," was popular among World War I-era employees at Du Pont's Old Hickory smokeless powder plant in Tennessee. The song's lyrics included: "Old Hickory plant is working nights to make the real stuff, To paste upon the Kaiser's nose - a Du Pont Powder Puff. Source: E. I. du Pont de Nemours and Company, Inc., *Du Pont: The Autobiography of an American Enterprise* (New York: Charles Scribner's Sons, 1952), 78.

Thomas Coleman du Pont relinquished his position as president of the company in 1915, turning the job over to Pierre Samuel du Pont, the second of the three cousins to hold the office. The change took place in part because of disagreements between Coleman and Pierre Samuel over the use and promotion of upper-level personnel.[16] Pierre would hold the position for only four years, but during his term Du Pont expanded their operations into dyes, paints, acids, and other chemicals by purchasing firms involved in these industries, and the company began selling it own nitrocellulose-based plastics.[17]

From the last year of World War I through 1919 research expenditures increased greatly, but these efforts were scaled back beginning in 1920 because of an economic recession. The recession served to focus the Executive Committee on company organization, which had grown increasingly problematic during the last ten years of diversification. Pierre Samuel retired in 1919, passing the leadership role to Irénée du Pont. One of the most important actions of Irénée du Pont was to further strengthen the power of the Executive Committee.

Du Pont had reorganized three times between 1911 and 1920, and an important consideration during each of these reorganization efforts was the company's research strategy. Throughout the decade, there was a trend toward greater centralization of research, which was gradually brought under the direction of the Chemical Department, headed by Charles Reese. But an important company reorganization in 1921 reversed this trend, creating autonomous manufacturing departments that were run as separate businesses controlled by general managers. Directors of these more independent departments demanded control of their own research efforts partly because they believed doing so was necessary to carry out their new responsibilities, but also because they generally perceived that the Chemical Department had been unresponsive to their needs.[18]

The Chemical Department might have been abolished at that time except for the efforts of Charles M. A. Stine, who convinced the Executive Committee that not all research fit neatly into a departmental scheme, and that there was value in general, long-

range research that may not reveal immediate commercial applications, research that even investigated scientific fundamentals that appeared to have no commercial value. Stine became head of the Chemical Department in 1924 and embarked on the patient cultivation of a broad "pure science" research endeavor within the department.

Upon his retirement in 1926, Irénée turned the presidency over to Lammot du Pont, who held the position for the remainder of the years between the wars.[19] At the end of 1926, Charles Stine began to work more actively toward his vision for the Chemical Department by submitting a memorandum to the Executive Committee called "Pure Science Work." The memorandum vaguely outlined a broad program he hoped to undertake, and presented four arguments he felt justified backing research along pure science lines.[20] Stine felt that expenditures in pure science were justified even if there were never any commercial discoveries, but he believed that commercial products would naturally evolve from fundamental research. During the months that followed, Stine refined his arguments to show the committee that the seemingly diversified and unrelated products manufactured by Du Pont were actually related by common bases in science. Better understanding of the scientific fundamentals would lead to profits, but basic research was not being done, and would not be done, under the fragmented system that concentrated on short-term departmental goals. A strong and centralized research capability was needed.

The Executive Committee voted to back Stine's vision, and approved a budget that included the construction of a new laboratory for fundamental research. Stine's pure science laboratory was nicknamed Purity Hall.[21] One of the researchers contributing to the memoranda Stine used to sell his ideas was Crawford H. Greenewalt, who would later play important roles in the Manhattan and Savannah River projects. Greenewalt had been transferred to the Experimental Station in the mid-1920s, and had just been appointed as a group leader when Stine called on him to suggest potential research topics concerning high-pressure technology and chemical engineering. "In his report to the Executive Committee, Stine drew heavily upon Greenewalt's suggestions."[22]

By the end of 1927, Stine had hired eight men to work on several lines of research at Purity Hall. But finding scientists who were willing to work for a commercial rather than an academic entity was not an easy task, especially when it came to the organic chemistry group. Stine had not hired one person for that group by the fall of 1927, and he was only able to hire one by the end of the year. That one person hired was Wallace Hume Carothers, who led the organic chemistry group to the discovery of neoprene synthetic rubber and nylon; Carothers initially turned down an offer to leave Harvard University, where he was then teaching, but was convinced to do so near the end of the year. Although Carothers took the job only after repeated assurances from Du Pont that he would be able to continue his theoretical pursuits—pure science with no strings attached—he very quickly outlined his ideas about polymerization that later bore such important commercial fruit for Du Pont.[23]

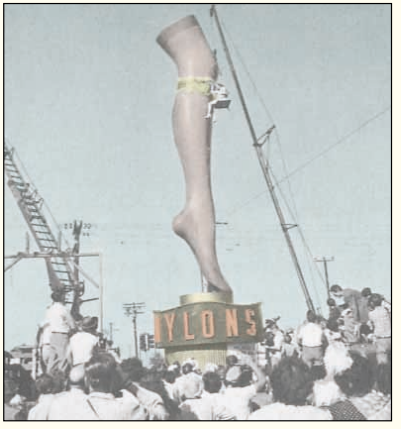
Carothers was able to pursue research as he wished until 1930, when in the same month his group stumbled upon both neoprene synthetic rubber and the world's first completely synthetic fiber. Both showed great promise as commercial products. Only a few months after these discoveries, Charles Stine was promoted to the Executive Committee, and Elmer K. Bolton took his place as head of the fundamental research program. Bolton did not agree with Stine's perception that fundamental research was in itself of value to Du Pont; he believed that its value was held in products the efforts developed.[24] With his

assistant Ernest B. Benger, Bolton strongly encouraged Carothers to refine the fiber the group had discovered into a product that had commercial value, but the work bored Carothers, so he drifted back to his theoretical interests. He returned to the study of the synthetic fiber in 1934, and by spring of the following year had found several variations

Nylon Development, a Model for the Future

Du Pont managers ". . . believed that they had developed an ideal approach to managing research and development—from fundamental research all the way through commercial development. Nylon became a model, an archetype for Du Pont's research and development on large projects, including that leading to the Hanford Engineer Works of the Manhattan Project."

The actual commercial development of nylon began less with Wallace Carothers' work than with an Elmer Bolton veto of a recommendation by Carothers. From his research, Carothers felt that the variation of the polymer most suitable for commercial production was what was known as a 5-10 polyamide, which was easy to polymerize. Bolton disagreed, arguing that an intermediate compound needed for the production of the 5-10 polymer was far too expensive, and that a 6-6 polymer, which could be made from abundant benzene, would be more cost effective to produce, even if the process was more difficult. With this decision, nylon development became a crash program undertaken jointly by several departments to produce the first synthetic fiber.



"The development of nylon has probably played a greater role in shaping the post-1940 history of Du Pont than any other factor or set of factors. . . . Nylon has served not only as Du Pont's most successful product, but also as a model for the corporation's research and development programs."

Bolton's fast-track program pushed nylon from laboratory curiosity to marketable commodity in less than five years. The effectiveness of his effort can be attributed to two decisions: first, the company clearly defined its goal as the development of an alternative to quality silk hosiery; second, they focused on a single means of achieving each step in the production process. These two decisions were gambles that could have had disastrous consequences, but the edge offered by the skills of the company's managers to make the appropriate choices of goals and processes, and the capability of the research force to develop workable solutions proved the gamble to have an enormous payoff. Nylon could have been employed in a wide variety of products, from yarns to coatings to films and plastics, and Du Pont could have tried to capture markets on many items concurrently. But company managers selected only one and focused all their attention there. Regarding the second of the two nylon-model decisions, a more cautious approach would have involved investigation into competing production process steps to determine which were most economical and suitable to plant-scale operations. With nylon development, major process decisions were made early and were not questioned; process researchers persevered in their work until successful. In the end, "no major lines of work had to be abandoned."

To select the processes and coordinate the work of the various research groups, Bolton set up what he called the Steering Committee, which was also responsible for "freezing" design elements when they were deemed good enough. The committee met twice a week after 1935, and attendance was mandatory. Bolton also insisted that manufacturing processes be tested in intermediate-scale plants, or semi-works. Bolton drew from Stine's precedent here; Charles Stine had played an important role in making the semi-works plant an integral part of scaling up to plant scale.

In its original application, the nylon model was tremendously successful. Nylon earned approximately $20 billion for Du Pont. The model would be applied to numerous other Du Pont projects, some with great success and some with disastrous results. Applications that were enormously successful, such as the World War II plutonium production facility, gave the company confidence in the strength of the model. But the later development of Delrin resin and other products would show it was not universally applicable. These failures would lead not only to the dethroning of the nylon model but to the curtailment of Du Pont's fundamental research commitments in the mid-1970s.

Source: E. I. du Pont de Nemours and Company, Inc., *Du Pont: The Autobiography of an American Enterprise* (New York: Charles Scribner's Sons, 1952), 109.

that were candidates for commercial production. The development of nylon was under way.[25]

By 1931, Lammot du Pont had led the firm to become a broadly diversified chemical company with products ranging from explosives to organic chemicals, and from rayon to photographic film. By then, the company was also one of the largest in the nation. But the Depression and a battle with antitrust accusations brought an end to the Du Pont way of doing business that began with the 1921 reorganization.[26] Post-World War I antitrust hearings took the form of a Senate investigative committee headed by Gerald P. Nye, called the Senate Munitions Inquiry.

The investigation, which began in the spring of 1934 and continued into 1936, was prompted by requests from the American Legion and a March 1934 article in *Fortune* magazine that resonated with growing isolationist preferences and increased public sentiment against the munitions industry. The best-selling book *Merchants of Death* that appeared a month after the *Fortune* article has become indelibly associated with the armaments industry, the Nye investigations, and Du Pont. Although the book apparently did not prompt the investigation, the committee did investigate the premise put forth therein—that an international munitions ring involving companies in Great Britain, Sweden, France, Czechoslovakia, Germany, and the United States existed and possibly influenced the war. Although the Nye committee found little to indicate such an organization existed, the stigma of being called before the committee as a "merchant of death" stayed with Du Pont, and encouraged the cautionary stance the company has taken in its government contracts from that time forward.[27]

During the difficult times of the depression era, Du Pont introduced neoprene (1930), synthetic rubber (1931), and nylon (1938); at the same time, it expanded its product lines into plastics, photographic film, and agricultural chemicals. Although the decade of the 1930s held many significant problems for the company, it was also a very productive period. To the American public, Du Pont ranged from being a munitions manufacturer that used its influence to increase profits during World War I, to the harbinger of an exciting and modern new world through its invention of nylon and other man-made materials. The Du Pont exhibit at the World's Fair of 1939, held in New York, was entitled "The Wonder World of Chemistry" and it attracted five million people during the summer of that year.[28]

WORLD WAR II

As with World War I, the military forces fighting in the Second World War relied heavily on the industrial organization and production capabilities of the Du Pont company. But the Executive Committee hardly welcomed the situation, nor the potential that any role they played could bring on another round of congressional investigations and further "merchant of death" associations. The Executive Committee also felt that increasing smokeless powder production was a step in a direction opposite company objectives of diversification pursued during the previous decades.[29]

Regardless of Du Pont executives' wishes, the company was approached by the Anglo-French Purchasing Board to build the first World War II munitions plant on United States soil in 1939. The company took on the construction of that plant, then many more for the American government. During the next five years, Du Pont would devote a majori-

ty of its efforts to the mobilization program, building—and in some cases operating—8 of the 77 ordnance installations constructed in the United States during World War II (not including Hanford Engineer Works), more than any other entity.[30]

Involvement in the war effort forced Du Pont to set aside many commercial projects. About 25 percent of the Chemical Department research staff were directly involved in specific war-related research between 1942 and 1945, and many of the remaining researchers were conducting investigations for other departments undertaking projects that were war- or critical-materials-related.[31] The Manhattan Project would further drain Du Pont research resources.

The War Department Office of Scientific Research and Development initiated what became the Manhattan Project, but turned the effort over to the Corps of Engineers in 1942 when they realized their staff did not have the experience to handle an undertaking of such magnitude. The architectural-engineer firm of Stone and Webster Engineering Company was asked to design and construct the pilot facilities for the project, but grew increasingly uneasy with the responsibility as the project grew. In October 1942, General Leslie Groves, then in charge of the Manhattan Project, entered negotiations with Du Pont to take on part of the Manhattan Engineer District project.[32]

The invitation from Groves concerning yet more war involvement was not gladly received by the Du Pont Executive Committee.[33] A lack of information from Groves and others in the Manhattan Project—a result of security restrictions—discouraged Du Pont executives from making a commitment. In late November, key personnel at the company were allowed a close inspection of the entire effort by way of membership on a project review committee. Admittance to the committee allowed the Executive Committee to determine for themselves the chances for the success of the project, and gauge whether Du Pont could feasibly undertake the work. They committee decided the job was feasible and communicated to Groves their willingness to become involved. Groves issued a letter of intent on December 1.[34]

Early in 1943, chemists, engineers, production specialists, and other Du Pont personnel began being quietly siphoned away from regular duties to unnamed locations. The destination of these persons would be only given as "TNX," the name of the secret Du Pont department created to undertake the nuclear program. TNX was a division of the Explosives Department, headed by Roger Williams. Williams pulled R. Monte Evans from the Ammonia Department to help him; Evans would later be in charge of Hanford operations. The Executive Committee selected Crawford Greenewalt to lead the TNX research effort. Hundreds of other upper level and promising Du Ponters would disappear into the shadows of TNX during the war, their work not revealed until late in the summer of 1945.[35]

Du Pont successfully applied the model it had established for the production of nylon to the development of the Hanford Engineer Works. Like the nylon development effort, the Hanford project also incorporated semi-works plants for intermediate process development, a steering committee for project organization and direction, and the concept of parallel development. Personnel that played important roles in nylon development were inserted into key positions for the Hanford project. Crawford Greenewalt, who had served on the immensely important Steering Committee Bolton set up to direct the nylon effort, was one of three research supervisors and "played a particularly important role because of his chemical engineering background and his 'take-charge' personality."[36]

Application of this commercially successful model did not please all who were involved in the project, however. The physicists argued against the need for semi-works plants, and many bristled at the control of their endeavors by a corporate entity, anathema to the loose and informal organization they were accustomed to in academic departments.[37] But Arthur Compton, who was directing the work of these scientists, liked and adopted Greenewalt's suggestions that the laboratory conduct its work under a management hierarchy that included a laboratory director and research managers, that a committee review system be used to assess research progress, and that other controls be put in place to better gauge and direct the work.[38]

Du Pont stood its administrative ground during the Manhattan Project, adhering to the limits that they saw as encompassing the immediate needs of the war effort. They objected to expanding development efforts to explore heavy-water reactors because they were confident of the success of a graphite pile (the nylon model showed that a firm decision should be made and adhered to; Du Pont viewed the graphite pile as a "frozen" decision). In the spring of 1945, when Du Pont was specifically requested to load reactors with bismuth slugs to produce polonium, Greenewalt made his objections clear. Polonium was used in neutron triggers for nuclear devices, and thus was necessary to the nuclear weapons effort. The Clinton reactor was producing polonium, but it might not have been

Crawford H. Greenewalt

One of the engineers who disappeared into the shadows of the TNX Department was Crawford Greenewalt. Greenewalt had clearly demonstrated an ability to make critical decisions in his nylon work, and in the words of one supervisor of the day, E. K. Bolton, he held "to an unusual degree a combination of research and executive ability."

The du Pont family began keeping an eye on the management potential in Greenewalt at least as early as the 1930s, but Greenewalt himself was apparently content with his work as a research chemist. That contentment worried the du Pont family because they wished to continue the tradition of family management (Greenewalt's aunt, Ethel Hallock, had married William K. du Pont, a brother of the one of the cousins who bought the company in 1902, so he was considered family). In 1942, the Executive Committee placed Greenewalt in the difficult position of director of the Grasselli Chemicals Department, asking him to resuscitate its neglected research program. But after less than a year in that position, Greenewalt was made technical liaison between Du Pont and the University of Chicago Metallurgical Laboratory. He excelled in the task, quickly grasping the physics that underlay nuclear fission well enough that he could interact intelligently with the Chicago physicists. One well-known story illustrates Greenewalt's growing grasp of nuclear physics. During the startup of the first Hanford reactor, xenon gas built up in the reactor core and kept it from becoming self-sustaining. Diagnosis of the problem stumped many of the physicists, but John Wheeler and Enrico Fermi eventually worked out the cause; Greenewalt had come to the same conclusion independently. What is less well known is that both Fermi and Massachusetts Institute of Technology president Karl T. Compton were impressed enough with Greenewalt to offer him positions in their research programs after the war. Greenewalt declined, although not without consideration of the offers since he was at that time unsure of his future with Du Pont.



Crawford Hallock Greenewalt was an important figure in the twentieth-century history of the Du Pont company. He served on E. K. Bolton's nylon development steering committee, supervised semi-works development for nylon, excelled as technical liaison between Du Pont and the University of Chicago Metallurgical Laboratory scientists for the Manhattan Project, and was president of the company from 1948 through 1962. Source: E. I. du Pont de Nemours and Company, Inc., *Du Pont, The Autobiography of an American Enterprise* (New York: Charles Scribner's Sons, 1952), 88.

able to meet the war demand. Greenewalt conceded there was a need, but his objection illustrates that Du Pont wanted no wider involvement in the project than was absolutely necessary. The irradiated polonium-containing slugs were not allowed to be processed at Hanford and had to be sent to Los Alamos for refining.[39]

The operation of the Manhattan Project Hanford reactors and separations facilities provided the scientists and the military with just enough plutonium to build an experimental atomic device and one plutonium bomb, detonated over Nagasaki in August 1945. By September, the Du Pont Executive Committee was asking Groves when they could expect a replacement operator.[40] Du Pont's reluctant first brush with the nuclear industry was nearly over.



Du Pont's H. E. Jackel waves to the guard as he leaves the Wabash River Ordnance Works, in Indiana, for the last time. Jackel was the last of 37,000 Du Pont employees to leave the seven explosives plants built and operated by Du Pont during World War II. Source: E. I. du Pont de Nemours and Company, Inc., *Du Pont: The Autobiography of an American Enterprise* (New York: Charles Scribner's Sons, 1952), 119.

POSTWAR DU PONT

For Du Pont, the Second World War was similar to the earlier great war in that it too became a watershed in the company's history. Du Pont entered the war after having done surprisingly well during the depression, and after having consolidated its earlier acquisitions under a capable and stable organizational structure and management system. But the pace of change in technology driven by the war effort quickly altered the business environment in the United States, and the chemical industry grew much more competitive in the postwar era. "These factors combined to shake the house of Du Pont and force its executives to chart a new course for the corporation in the next generation."[41] The trend to rely on in-house research and development was strengthened by the postwar environment.

According to Du Pont's 1952 "autobiography," the months following the surrender of Japan were exciting times for the Executive Committee since, with the war effort behind them, they were preparing to embark on an ambitious expansion and modernization program. In the five years following the war, Du Pont would spend more than a half billion dollars on these efforts. The company added production capacity for its products that had come out before the war, expanded its research capabilities, and doubled its research staff during the most intensive period of growth in its history. By approximately five years after the war, the facilities that were built during the expansion effort produced goods accounting for 35 percent of Du Pont sales.[42]

Although its wartime work gave Du Pont unique experience from which it could have attempted to move into commercial nuclear ventures, the company had little interest in pursuing business in that direction. Their stated position from the beginning of their involvement in the Manhattan Project was that the company had no interest in the field, but the Executive Committee did ponder the possibilities. E. K. Bolton first raised the issue of commercial involvement in postwar nuclear physics in February 1943; he, Greenewalt, and Williams agreed that the best preparation was education and exposure to the field, so they used as many Chemical Department employees as possible in the TNX effort to build a base of expertise. Greenewalt discussed commercial possibilities with Fermi and other Manhattan Project scientists, but vacillated in his opinion on whether Du Pont should enter the field after the war; regardless, Roger Williams and Greenewalt urged

Precedent For Cooperation—The Hanford Contract

Du Pont approached the Hanford project with caution. This caution had an important impact on postwar public and private-sector collaboration in military-related research and industrial endeavors, establishing precedents for cooperation and for the contractual vehicles used to govern such joint efforts. Du Pont's cautious approach was derived from prior accusations of being a "merchant of death" and political difficulties that had grown out of the company's dominant role in the explosives industry. Du Pont entered into a contract agreement via a letter of intent on October 3, 1942, to design and build a pilot-scale separations plant at Clinton Laboratory, Tennessee, the intent of which was to ease Stone and Webster of some of its weighty design and construction responsibilities at the facility. Pleased with Du Pont's performance in other World War II efforts, General Leslie Groves quickly moved to extend the company's involvement in the Manhattan Project, but the Executive Committee was hesitant. In December, only after being allowed a close examination of the project, Du Pont agreed to take on a much larger role that would include the design and construction of the Hanford Engineer Works.

The cost-plus-fixed-fee contract that was later issued to cover the work was a refinement of a form used prior to and during World War I called a cost-plus contract. A cost-plus contract paid the government subcontractor a fee that was a percentage of the cost of the work undertaken by the subcontractor—the greater the cost of the work, the greater the fee. The cost-plus contract tended to encourage cost inflation and discourage subcontractor efficiency, and for these reasons was abandoned for most military construction after 1918 in favor of a type of fixed-fee contract. The attractions of the cost-plus contract were that it allowed the military to bypass time-consuming competitive bidding requirements in emergency situations, and that it helped secure subcontractors in instances where the scope of work was not defined clearly enough for them to assess the fee amount. Legislation used to justify this use of the cost-plus contract had been in place since 1861. In mid-1940, a law was passed that allowed government agencies to bypass competitive bidding requirements in the negotiation of cost-plus-fixed-fee arrangements with subcontractors. This form of contract was used for much of the World War II mobilization effort.

However, the cost-plus-fixed-fee contract that was negotiated and agreed to by Du Pont and the Corps of Engineers had distinct qualities that have continued to impact government contracting long after World War II. The reasons that caused Du Pont to hesitate to become involved were not completely eliminated. Their existence allowed a closer examination of the project, which only eliminated their justification for staying away. There was still the issue of public reaction against the company due to the immense destructive power promised by nuclear weapons. One way they chose to counter the potential public-relations problem was to refuse to accept a profit from the work; the fixed fee was set at one dollar. The company would be paid an allowance to cover overhead in installments, but amounts above actual expenses would be returned to the government. Du Pont waived any patent rights that might arise from their work on the project, specifying that all patentable discoveries would become the property of the government. In return, the company asked for indemnity against losses or liabilities that might result from the work. Details about the reimbursement of overhead and administrative costs would drag contract negotiations on for years at Savannah River, but within the secrecy of the Manhattan Project Du Pont was able to set some important precedents.

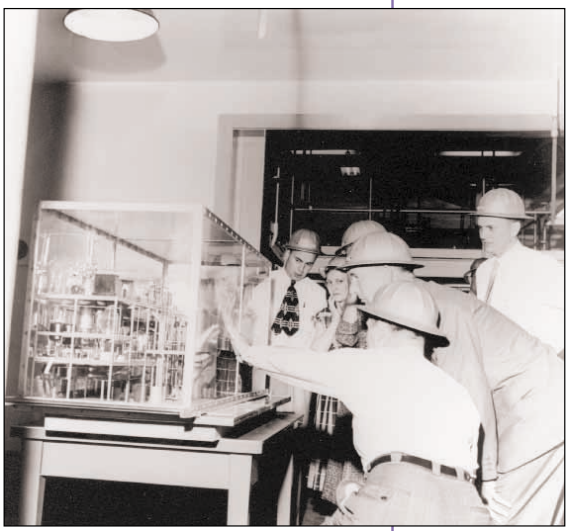
In the contract, Du Pont specifically requested that pay for its personnel—a reimbursed cost—was to parallel pay going to persons in like positions in Du Pont's commercial work. The company had learned a lesson in the summer of 1942 when employees were loaned to the University of Chicago and placed on university salary, which was much less than they would have gotten from Du Pont but was comparable to pay rates for government technicians and engineers. Corporate salaries of the time were significantly higher than these salaries, so these Du Pont employees who contributed to the Chicago work did so at a personal financial cost. If Du Pont had to follow government pay scales, it might be difficult to convince good employees to transfer from commercial work to the government project, so the company insisted on using its own pay scale. On top of that was the bonus system. Du Pont insisted also that bonuses be repaid by the government under the Manhattan Project contract, and they were. These bonuses were not small—they could amount to more than a year's salary for a top manager. Under some fee-based contracts with other government subcontractors, bonuses were considered administrative or overhead costs covered by the fee paid to the subcontractor. Thus it could be argued that Du Pont was in fact paid a fee over and above the one dollar stated as the official figure.

All of these issues and solutions set important precedents for government and private industry cooperation during the Cold War. And, some items such as bonuses would long cause points of contention, argued over in future contract negotiations.

> "As you recall, we took on the Hanford job without fee. We did that at that time because we felt that there was nothing in the way of background knowledge—specific experience—that the du Pont Company could bring to that effort. It was a field that was completely new to us, as indeed it would have been new to anybody, and we felt it was completely inappropriate for us to take a fee when we had nothing, as it were, in the way of technical experience to bring to the job."

—Crawford Greenewalt, to the Joint Committee on Atomic Energy, August 4, 1950.

Crawford Greenewalt looking at Dacron Prototype model in Seaford, Delaware, 1952. Courtesy of the Hagley Museum and Library.



Compton to explore non-military uses for reactors at the beginning of 1944.[43] By approximately the end of 1944, Greenewalt appears to have decided that the field was unlikely to be profitable in the near future, but Charles Stine was still enthusiastic and convinced the Executive Committee to allow company research to include nuclear physics. In early 1945, Stine withdrew to a more cautious stance, suggesting that the company eschew extensive research in the field but make efforts to not lose what had been learned.[44] Opportunities to keep a finger on the pulse of nuclear physics developments presented themselves during the next five years, and the Savannah River contract offered a means of keeping in touch with the field at less cost to the company than doing so under only its own initiative.

During the postwar era, growth by acquisition was effectively disallowed by the politics of the time. Fundamental research generated avenues for growth within, and the nylon model presented a vehicle to take research from the laboratory to the marketplace in an effective way. Thus the postwar strategy was to generate what Crawford Greenewalt called "new nylons" by expanding both the central research facilities and the industrial departments' laboratories, the latter of which were encouraged to increase their emphasis on basic research. Greenewalt pursued the new-nylon approach in spite of warnings from both Charles Stine and Elmer Bolton that the model should not be emphasized too greatly.[45]

During this period, the fabric of research was being altered on a national scale, changing the efficacy of the nylon model. Much more money was being pumped into research and development programs by the government as part of the persevering Cold War economy. And many large United States companies were expanding their fundamental research efforts. When nylon first began to score immense rewards, Du Pont was pioneering fundamental research in commercial industry. After World War II, the company found itself a player on an increasingly crowded field, competing not only with private-industry rivals but with the public sector as well.[46]

In the summer of 1946, Crawford Greenewalt became a member of the Executive Committee, and soon thereafter began serving as vice chairman to Walter Carpenter, an apprenticeship position intended to prepare him for the presidency. Carpenter relinquished his position as president in January 1948; Greenewalt became the next president of Du Pont at age 45. Greenewalt proposed two principles of growth and development: The company would seek diversification in any chemical industry to which it could make a substantial contribution, and would concentrate research and manufacturing in areas that required large resources of technical ability and money.[47] The nuclear industry was potentially just such an area.

THE SAVANNAH RIVER INVITATION

As it was with Hanford, Du Pont's involvement with Savannah River progressed through stages of involvement. By 1950, the company had turned down several government requests that it take on the operation of defense works, still reluctant to be associated with the "merchant of death" image.[48]

General Electric took over the operation of Hanford from Du Pont, but asked Du Pont for assistance when the Atomic Energy Commission decided to expand Hanford in 1948. Du Pont loaned to General Electric about 30 persons who had been involved in the Manhattan Project. The loan of personnel was viewed as an alternative to undertaking the entire expansion project, which Greenewalt described as "too horrible to contemplate."[49] Later the same year, the Atomic Energy Commission asked Du Pont to conduct a survey of the status of research and operations capabilities related to the chemical processing of plutonium in the United States, a survey the company undertook at its own expense.[50] Greenewalt felt that more requests for assistance would be forthcoming, and wrote as much to Carpenter in early 1949. The turning point and the decision to build a tritium production facility came with the escalation of activities in Korea.[51]

General Electric's World War II contributions to the Manhattan Project gave General Leslie Groves sufficient satisfaction to justify approaching them for the postwar operation of Hanford, but General Electric was not considered when the Atomic Energy Commission began planning what would become the Savannah River facility.[52] It should be pointed out that General Electric had not been enthusiastic about operating Hanford, but had taken the project on after being urged by General Groves to do so. According to Atomic Energy Commission general manager Carroll L. Wilson, the companies considered for constructing and operating a new production reactor site were Union Carbide, Monsanto, Dow Chemical, American Cyanamid, and Du Pont. But only one candidate stood out.[53] As noted earlier, the Atomic Energy Commission's Wilson, Carleton Shugg, and Walter J. Williams felt that "the DuPont [sic] Company was uniquely qualified for the design and construction of large-scale tritium production facilities, particularly in view of the urgency of the project. Mr. Wilson recalled that the desirability of drawing the DuPont [sic] Company back into the program on a major project had been under discussion for several months."[54]

Rear row: Monsanto Chemical's Executive Vice President Charles S, Thomas, Harvard's James B. Conant, Physicist Arthur H. Compton, Standard Oil Development Co.'s President E. V. Murphree, Du Pont's Greenewalt. Front row: Manhattan Project's Major General Leslie M. Groves, M.I.T.'s Dr. Vannevar Bush, Physicist Enrico Fermi, Colonel Kenneth D, Nichols (Groves' deputy), Columbia's Physicist George B. Pegram, U.S. Bureau of Standards' Lyman J. Briggs. *Time Magazine*, April 16, 1951, 102.



On January 31, 1950, President Truman announced that the U.S. would develop hydrogen weapons. It took a few months for the Atomic Energy Commission to interpret and plan how to react to the announcement, but by May the project was sufficiently developed to begin the search for a contractor to build and operate the new facilities that would be needed. On May 12, Carroll Wilson and Carleton Shugg traveled to Wilmington to meet with Crawford Greenewalt. At the meeting Greenewalt set conditions for taking on the project: Du Pont would have full responsibility for design, construction, and at least initial operation. The company would not make any commitment until they could review and assess the various heavy-water reactor designs and estimate the feasibility of meeting the Atomic Energy Commission's desired schedule. And finally, they wanted a letter from President Truman stating the national security necessity of the project. The commission was wary of handing over so much control to Du Pont.[55]

On June 2, Truman asked that the Atomic Energy Commission go forward on discussions with Du Pont. Over the next three days, the commission contacted Greenewalt by telephone and sent a draft of the letter inviting Du Pont participation (AEC 262/30) to

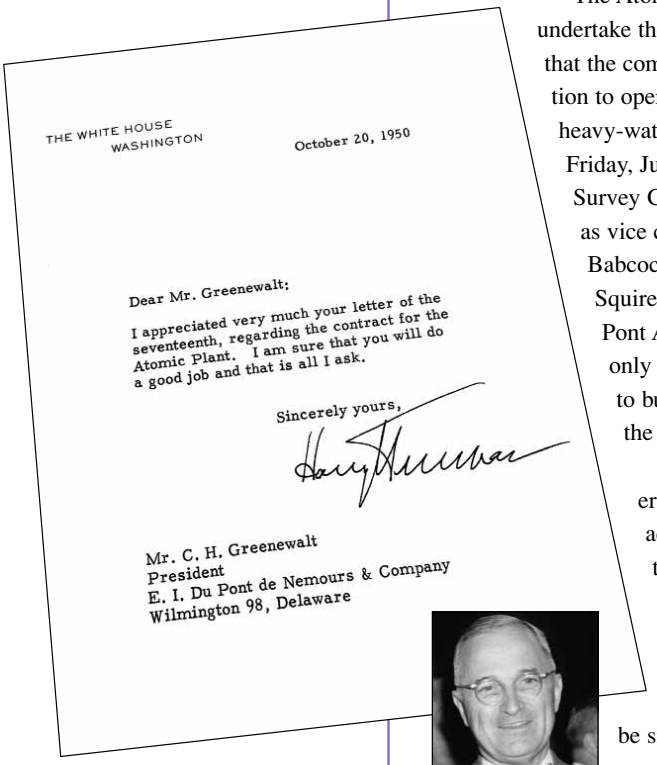
him. Greenewalt made a few suggestions for changes, and reiterated that Du Pont would not accept a fee for the project and expected to be the operator of the new installation.[56]

The Atomic Energy Commission then made its formal request that Du Pont undertake the project via a letter from Sumner T. Pike dated June 12, stating that the company could have responsibility for project aspects from site selection to operation, including review and assessment of reactor design and heavy-water production processes. The letter was dated on a Monday; by Friday, June 16, the Explosives Department had created the Atomic Energy Survey Committee, with R. Monte Evans as its chairman and B. H. Mackey as vice chairman. The other members of the committee were D. F. Babcock, F. M. Burns, Jr., G. P. Church, J. E. Cole, W. C. Kay, Lombard Squires, V. R. Thayer, C. W. J. Wende, and Hood Worthington.[57] The Du Pont Atomic Energy Survey Committee would be short lived, intended only to study the feasibility of the Atomic Energy Commission proposal to build heavy water reactors and various aspects related to undertaking the new effort.[58]

The Monday after the creation of the survey committee, the general manager of the Explosives Department, Harry Brown, was accompanied by Evans, Mackey, and Squires to Washington, where they discussed initial steps: conduct a technical survey of the project as then proposed, develop terms of a contract, and begin the search for a site.[59] On July 25, Truman complied with the request that he make a statement regarding the national security need for the project. Although a letter contract covering the project would be signed on October 17, it would be years before a final contract was agreed upon.[60]

Du Pont organization of the project would be based on the structure that worked in its commercial operations, particularly drawing from the nylon model. Management would be the responsibility of the Explosives Department, and at the beginning of August, a new division was established as the managing entity. It was named the Atomic Energy Division; at the same time, R. Monte Evans became assistant general manager of the Explosives Department, and Bill Mackey was made manager of the new division. Other initial members of the Atomic Energy Division were D. F. O'Connor, administrative assistant to Evans; W. C. Kay, Director of Manufacturing; F. M. Burns, Jr., Control Division manager; Lombard Squires, Technical Division manager; J. E. Cole and Hood Worthington, both Technical Division assistant managers.[61]

The Atomic Energy Division would develop the scope of work for the project, and the Engineering Department would work from that scope as the architect-engineer for construction. Auxiliary departments contributing assistance would be the Legal, Purchasing, Service, and Treasurer's departments. They would depend heavily on other entities for information and data. Initially, Argonne National Laboratory was chosen to provide data for both reactor and separations facility design, and negotiations with Argonne were begun on August 2, 1950. On a suggestion by F. K. Pittman of the Atomic Energy Commission, Du Pont began considering Oak Ridge National Laboratory for help in the chemical separations work, and near the end of August Lombard Squires visited the Oak Ridge facilities with that consideration in mind. Squires was impressed with their capabilities and willing-



THE WHITE HOUSE
WASHINGTON

October 20, 1950

Dear Mr. Greenewalt:

I appreciated very much your letter of the seventeenth, regarding the contract for the Atomic Plant. I am sure that you will do a good job and that is all I ask.

Sincerely yours,

Harry Truman

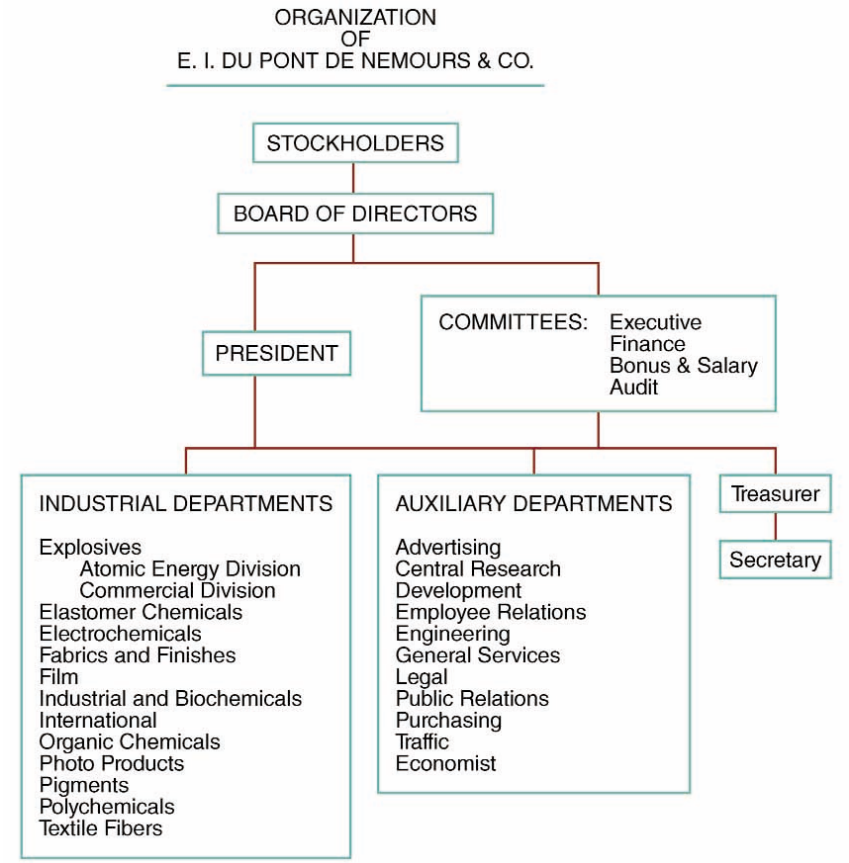
Mr. C. H. Greenewalt
President
E. I. Du Pont de Nemours & Company
Wilmington 98, Delaware



Greenewalt stipulated that a letter from President Truman was a condition for Du Pont taking on the Savannah River project. Although the company has long promoted the letter as an urgent personal request from the highest national office specifically for Du Pont's participation, and company promotion of the letter has firmly established the document as such in site folklore, the text of the letter clearly attributes the choice of Du Pont to the Atomic Energy Commission. Greenewalt's stipulation to the commission was that Truman simply affirm the project was important to national security, as is stated in the final sentence of the brief correspondence. The letter was not issued until about five weeks after the commission had extended its request and Du Pont had begun organizing for the project. Courtesy of the SRS Archives. Inset of President Truman, James F. Byrnes Papers, Mss 90, negative 209233-S. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

ness to become involved in the effort; thus the focus on separations development and training for chemists was shifted to that facility. Du Pont and Oak Ridge reached an agreement on cooperation soon thereafter.[62]

In September, the Atomic Energy Division began filling supervisor and technical positions. Transfers were accomplished on a voluntary basis working from lists submitted by the managers of the various departments, with Atomic Energy Division managers requesting permission to approach individuals they felt especially qualified. Management felt that an acceptance rate of more than 90 percent of the offers made would indicate excessive inducement, but thought an 80 percent acceptance rate could be expected.[63] The Du Pont work culture stated that one was expected to volunteer when such offers were made. The new division was concentrating its recruitment efforts among younger men with one to five years of service with the company, feeling that these persons would be better suited to the moving and training that would be required, as well as other aspects of the work. In an indication of upper management's attitude toward the longevity of the project, offers made to employees were specifically described as long-term positions, and potential recruits were told that they would receive approximately 10 to as much as 15 percent increase in pay as compensation for moving and increased responsibility. One aspect that made recruitment difficult was that the work to be done was as yet secret.[64]



Du Pont saw the recruitment of these initial personnel as one of the most significant problems it would face in getting the installation going. Commercial business was booming, offering attractive opportunities for recognition and advancement in the company, and there was no wartime emergency to encourage company service for patriotic endeavors; employees would have less incentive to take on work that might seem to offer a less lucrative career. Nor would it be in the interest of department heads to let go of their best personnel. To make positions attractive, the company offered salaries and other benefits that were no less than what the employee could expect in commercial work. The objective of long-term involvement in atomic energy was also stressed so that employees would be less likely to view the work as a diversion from career objectives. Management also emphasized that Du Pont planned to run the atomic energy site in a progressive manner that would allow employees use of and recognition for their ingenuity and initiative. It was partly to achieve this last point that Du Pont requested the scope of work to include research and development facilities for the installation.[65]

The management style attributable to large project organization experience in general and the nylon model in specific could be seen from the beginning of the work. Large decisions that gave shape to the installation—the general size and arrangement of the production areas—were set before details were worked out. Site preparation and infrastructure development began soon thereafter; the designs for known facilities were frozen as research continued and remained fluid for buildings housing processes still to be worked out; and the whole of the effort was orchestrated with an eye to how the choices of one day narrowed the alternatives of the next.[66] Regarding the Atomic Energy Commission role in these efforts, authors Rodney Carlisle and Joan Zenzen note that the commission took a very hands off approach. "It seemed the Commissioners established control only by setting the conceptual design and the general parameters; within those parameters Du Pont made almost all the detailed choices with the help of a scattering of AEC-paid contractors at other facilities."[67] That was certainly expected by Du Pont since the terms under which they took on the project explicitly stated as much.

THE CONTRACT: ANOTHER MODEL

Du Pont Contract Number AT(07-2)-1 covered the development, design, construction, and operation of the Savannah River installation, which included facilities for the production of heavy water and nuclear materials, and the purification of those products. The contract was of the cost-plus-fixed-fee type often used by the government and with which Du Pont was familiar from World War II. The stated fee, in this case, was one dollar.[68]

The primary contract negotiators for Du Pont were H. F. Brown and R. M. Evans, general manager and assistant general manager of the Explosive Department. They were assisted by F. W. Bradway (Explosives Department), A. C. Nielsen (Treasurer's Department), C. A. Rittenhouse, and H. K. Clark (both with the Legal Department).[69] The model used for the contract was Contract Number W-7412-Eng.-1, which had covered the Hanford Engineer Works design, construction, and initial operation. Both Du Pont and the Atomic Energy Commission felt a similar contract would be acceptable in general with slight modifications. The Atomic Energy Commission specifically noted "hold harmless" clauses as a problem area, as such clauses had resulted in "unusual arrangements" with

Bendix, Western Electric, and General Electric in the postwar era. But the commission felt a similar contract would be acceptable if Du Pont would accede to modifications concerning primarily overhead distribution, insurance, and various employee benefits. For its part, Du Pont had questions about the commission's legal authority to enter a contract concerning work for which funds had not been appropriated, and of course they had specific conditions under which they would take on the project.[70]

The first meeting was held in Washington on July 31, followed by an August 11 meeting to discuss a revised draft letter contract prepared by Du Pont. Two differences of opinion emerged at these meetings. The first concerned assurance by the Atomic Energy Commission that the final contract would provide no less protection for Du Pont than had the Hanford contract—a hold harmless clause. Du Pont presented this as a desire "that the Company and its employees be protected from suffering tangible loss as a consequence of faithful work under the contract."[71] The Atomic Energy Commission negotiators felt this would excessively restrict their pursuit of desired modifications to the Hanford contract. What was viewed as a compromise was reached on September 28, allowing modifications to be made to requirements specifying types of records to be kept, the duration of the contract, and the auditing of indirect expenses. The second point of contention was related to the Atomic Energy Commission authority to enter such contracts, which was not clearly granted by the Atomic Energy Act of 1946. Du Pont asked that President Truman grant approval of the contract in advance of its negotiation, as was allowed by the act. The Atomic Energy Commission objected because of the precedent it would set and the doubt that might be cast on contracts already in place.[72] The commission agreed to attempt to introduce legislation that would clarify its authority and, if that was not possible, to grant Du Pont's request for presidential approval. Presidential approval was granted on September 27, 1950.[73]

Although the intent was that the parties would work out a final contract (called the Definitive Contract) by the end of the year, at which time the letter contract expired, that did not happen. The letter contract was extended 11 times, to the end of September 1953. Even before the final contract was discussed, changes were made to the letter contract concerning liability coverage, the method of reimbursing employee bonuses, and specifics about the monthly allowances.[74] The first meeting to discuss the text of the final contract took place on March 19, 1951, when a partial initial draft was reviewed. During the remainder of the year, a basic disagreement over responsibility and control for the project hindered progress on substantive issues. The Atomic Energy Commission felt that they should have broad control, whereas Du Pont felt that "maximum accomplishment was possible only when du Pont [sic] controlled the manner and means of carrying out the work. Otherwise, the value of du Pont's contribution would be, to a considerable degree, nullified and it would retain responsibilities without [the] required authority to implement them."[75] A compromise was finally reached on January 21, 1952. Each party recognized the interest of the other in controlling the project without conceding that control to the other, agreeing instead to keep the other well informed about significant performance-related issues and to make all reasonable efforts to resolve differences of opinion as they arose.[76] By January 1953, Du Pont and the Atomic Energy Commission had worked out other terms of the contract and the Definitive Contract was signed on September 30, 1953.[77]

6 Boomers, Boosters, and Economic Statesmen

Choosing a site for the new reactor facility was a complex task. Although President Truman advised AEC Chairman Gordon Dean to choose the new location solely on its merits, other forces would play into the selection process.[1] While AEC and Du Pont records scrupulously describe the steps, based on strategic, operational, and tactical concerns, which led the survey team southward, forces within the Central Savannah River Area were already at work to entice federal dollars into the area. A carefully fabricated welcome mat for industrial development, over a hundred years in the making, was waiting by the river.

BRIDGING THE RIVER - INDUSTRIAL HERITAGE, REGIONAL COMPETITION

> What was Augusta's role in the South's destiny? Simply put, it was to lessen the South's dependence upon New England by becoming a manufacturing center.[2]

The first decades of the nineteenth century in Augusta were punctuated by a series of highs and lows as the meaning of the city shifted from entrepot, to the western frontier, to the great piedmont tobacco port, to the urban focus of a region whose population had largely migrated westward. With this western expansion, Augusta's riverine commerce took on less importance. However, the advent of the railroad secured Augusta's prominence as a regional transshipment point throughout the century. The role the railroad would play in Augusta's future was well demonstrated in 1834 when the Charleston and Hamburg line, the world's longest railroad when established, "annihilated time and space." By leaving Charleston at 6:00 a.m. and arriving at Hamburg, South Carolina, at 3:30 p.m., the "Edgefield" steam car won over Augusta's business community, and the organization of the Georgia Railroad followed quickly.[3] Cotton overtook tobacco as the major cash crop, and the Georgia and South Carolina piedmont east and west of Augusta served as the heart of short-staple cotton agriculture from the 1820s onward. By the 1850s, the Mississippi delta and the black belt of Alabama assumed that role.

The South was an agrarian region in 1840, with the exception of a slice of land that traced the fall line in the Savannah River Valley in both Georgia and South Carolina. Within this slice of land, the perception of the agrarian South was changing. William

Gregg's call for an industrial South and the success of his industrial ventures on the South Carolina side of the Savannah at Graniteville during the late 1830s influenced the thinking of Augusta's and South Carolina's capitalists and politicians. Gregg, and other local proponents of the New South, argued that industrial manufacturing would lessen the South's dependence on the North, and further strengthen the southern economy by converting southern raw materials (primarily cotton) into finished goods. His call was taken up by the Augusta press, which published Gregg's "Essays on Domestic Industry" as a tool to push industrialization in Augusta. South Carolina's newspaper editors were also supportive of Gregg's crusade.[4]

The plan worked. In 1844, an ambitious plan to build a canal along the Savannah was launched to fuel industrial development in Augusta. The Augusta Canal was completed in 1846. It provided the motive power for the city's premiere textile manufactory, the Augusta Factory, as well as flour mills and other manufacturing firms that quickly became the foundation of the city's pre-Civil War economy. Some 25,000 bales of cotton were shipped into the city annually along the canal, while Augusta's products were exported to

"Giant Signboard erected by the Savannah Valley Booster's Assn., on Atlanta-Augusta-Columbia highway outside of Elberton, Ga., provided by Valley's civic minded business men and state leaders." Source: *The Anderson Daily Mail*, February 20, 1952.

"Individuals below sign are: Gradus T. Christian, publisher, *Elberton Star*; Georgia State Senator Peyton T. Hawes; Z. W. Meeks, and H. G. Anderson, representing the Anderson, S.C. Chamber of Commerce, Louie L. Morris, member of the *Hartwell Sun* and owner of radio station WKLY which carries Savannah Valley Booster progress reports; Tom Wigginsworth of the Southeast Power Administration; Mayor W. C. Johnston, Anderson and brother of United States Senator Olin D. Johnston from South Carolina; T. O. Tabor, prominent Augusta civic leader and past president of the Augusta Merchant's Assn.; Lester D. Moody, veteran of 25 years in Savannah Valley progress, secretary of the Augusta Chamber of Commerce, and Georgia Chairman of the Savannah Valley Booster's Assn.; T. S. Mason, REA leader, from Hartwell, Ga.; Hubert Dyar, Jr. publisher, *Royston Record*; Burton J. Bell, public relations officer for the U.S. Corps of Engineers, Atlanta; the Hon. Clark Gaines, Secretary of Commerce for the State of Georgia; Clifford D. Davenport, Executive Secretary, Savannah Chamber of Commerce; I. V. Hulme, Reese Hart, representing the South Carolina Research, Planning and Development Board; Wilton E. Hall, publisher of the *Anderson Independent and Daily Mail*, owner of radio stations WAIM-WCAC, former chairman of the Hartwell Dam Steering Committee and former United States Senator, and South Carolina Chairman of the Savannah Valley Booster's Assn.; Barton Stephens, representing the Elberton Granite Association; Wilbur H. Hoover, president of the Elberton Chamber of Commerce and others."



regional and international markets via an established network of rail lines and steamboats that connected Europe to the Mississippi Valley.[5]

Historian Edward Cashin notes that the canal and its tandem industries contributed to a larger picture in which Augusta was perceived as a player in the South's search for economic independence from the North. It became a manufacturing center despite critical scrutiny from its agricultural neighbors who still clung to plantation ideals. The city newspaper lauded the efforts of its mid-century industrialists in 1849:

> "Augusta mechanics who are turning out beautiful Steam Engines, locomotives, carriages, and a thousand other articles are doing more for the South than all its sectional politicians put together." The newspaper went on to challenge those who saw industry as a threat to the social order, arguing that slaves should be employed in factories and that Augusta's varied industrial experience and river-port heritage had already shown that black workers were skilled at a variety of trades. Augusta's cosmopolitan mindset, focused on industrial and commercial growth, had room and opportunity for both whites and blacks, free or enslaved.[6]

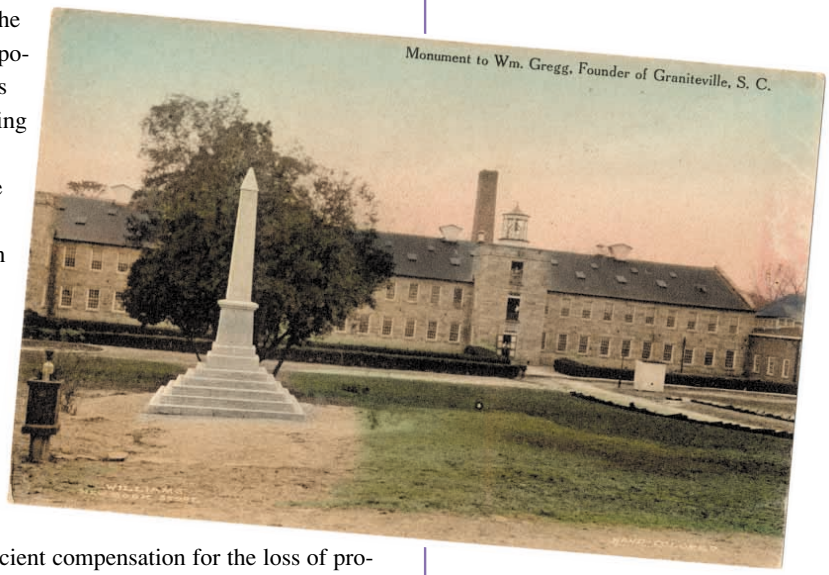
South Carolina's counties along the Savannah River were mostly rural, dotted with small towns. Agriculture drove the economy with some notable exceptions. The chief competition to Augusta's commercial dominance on the river was the town of Hamburg. Located across the river on the South Carolina side of the bridge, Hamburg was laid out as a rival port to Augusta by Henry Shultz, an early nineteenth-century German entrepreneur and developer. Shultz and his business partners built the Augusta Bridge, the city's first wharf, and incorporated the Georgia Steamboat Company. In 1819, after tremendous financial success, Shultz pulled out, selling his interests prior to his planned return to Germany. His leave-taking was thwarted by his partner's bad business dealings that resulted in the Bank of the State of Georgia owning "his" bridge. He spent the rest of his life trying to recover control of the bridge through legal means. For spite, he created a rival to Augusta across the river, igniting interstate competition over the very structure, the Augusta Bridge, which joined the two states.

In 1822, Shultz's city had approximately 135 residences, a wharf, market, warehouses, and a brickyard. He was a master developer and a commercial genius. Shultz was the first to conceive of direct commercial trade with Europe; he formed a company that brought goods from Hamburg, Germany to Hamburg, South Carolina. Augusta merchants followed his lead. While Hamburg would eventually lose its commercial vigor over disputes for rights to the bridge, the levying of tolls, and flooding, it was a phenomenon in its early challenge to Augusta. It also gave South Carolina a taste of the potential commercial benefits a developed port on the Savannah River could garner.

If Hamburg was Augusta's commercial competition, William Gregg's Graniteville Mill near Aiken was the Augusta Factory's industrial counterpart. Gregg's mill, which he operated from 1846 to 1867, was a model for New South industrialists. Gregg initially earned his livelihood as a jeweler and silversmith, but after a brush with cotton manufacturing at a family mill in Madison, Georgia, he purchased stock in the Vaucluse Mill located in South Carolina's Horse Creek Valley in 1837. His establishment was ambitious: the

two-story granite mill housed 9,245 spindles and 500 looms, and an equally impressive mill village was laid out around the factory building.[7]

As noted above, Gregg was an ardent writer, "the region's best known industrial publicist."[8] After touring New England's mills, he earnestly advocated other southerners to follow his example by placing factories in southern fields. The strength of his advocacy and his operation of the mill gave him the reputation of "the father" of the southern textile industry. His writings advocated mill placement in isolated, rural settings where a work force of poor white families, self-contained in a mill village, would be "uplifted" by factory life. He was antiurban; according to one source he refused to invest in Augusta mills that were contemporaries of his Graniteville operation. Cashin suggests otherwise, stating that Gregg was hopeful of operating Augusta's first textile mill along the new canal, but sufficient roadblocks were placed in his way that he chose a site in South Carolina. In Cashin's words, "There is little doubt that restrictions were placed in his way. The canal was built by Augustans and Augustans wanted to be the first to profit from it."[9]



Graniteville, located in South Carolina's Horse Creek Valley, was a model for New South industrialists. The two-story textile mill building shown in this postcard housed 9,245 spindles and 500 looms.

Postcard, "Monument to Wm. Gregg Founder of Graniteville, S.C." Courtesy of J. Walter Joseph.

The economic rivalry between Augusta and South Carolina's Hamburg reached the status of a war when the South Carolina Railroad requested a permit to cross into the city. James Gadsden, president of the South Carolina line, made an offer of $100,000 for the right to cross into the city. The offer was refused as it was not considered sufficient compensation for the loss of projected revenue from tolls. Gadsden characterized the Augusta response as blackmail and threatened to build his road to Tennessee through Rabun Gap in northeast Georgia. Heightening the tension, Hamburg residents erected a new tollgate on their side of the bridge, resurrecting the Shultz claim to the bridge as their mandate. The Augusta City Council slapped a toll increase on their end of the bridge in response to the Hamburg insult. The battle was on.

After much negotiation and flat-out refusals, the South Carolina line gained access to the city. The ante went up $50,000, but Gadsen's line was permitted to cross the river. The South Carolina firm was also permitted to construct a passenger depot and a freight terminal in the downtown area, albeit at separate locations. This requisite allowed Augusta to remain in control of the hauling trade that would emanate from the new line. The change in Augusta's position was most likely a product of the times as well as the additional concessions that were added to sweeten the deal. Rail lines built with private funds, by big businesses, and or by state governments were girding the South, and their connection had momentous consequences for the region. Forward-thinking Augusta would have wanted in on this reshaping, and it is possible that the economic impact of Gadsen's threat to bypass the city may have sunk in. Once the decision was made, the economic rivalry between Hamburg and Augusta subsided, with only one more revival of toll warfare. The rail line achieved sufficient importance in the town fathers' eyes that, when the piles were driven for the railroad's bridge in 1858, the need to incorporate a draw to allow steamboat traffic to pass was ignored. Instead, the lack of definition of a channel and the costs

involved with the construction of a city drawbridge forced the city to limit steamboat traffic to the docks below Fifth Street, thus avoiding the problem.[10]



Historic view of Sand Bar Ferry with railroad bridge in background.

Postcard, "Sand Bar Ferry near Augusta, Ga." Courtesy of J. Walter Joseph.

While the admission of the South Carolina line to Augusta brought limits for river traffic, it was a significant step toward forging a regional identity. Antebellum Augusta was truly unlike many other southern cities. Its economy was strong and based on industry and commerce, its population was culturally and economically diverse, and its city government was lively and progressive. These factors empowered Augustans to move toward their destiny, lessening the South's economic dependence on the North. While the South Carolina counties on the Savannah River remained mostly agricultural, an appetite for commerce and industry—whetted by the Hamburg experience and fueled by industrialists such as William Gregg—was a catalyst for change. The infighting between Augusta and Hamburg over the shared bridge and river that had characterized the antebellum period had been a detriment to development. The economic potential of a transcontinental railroad and the creation of regional rail networks changed all the stakes. Differences were shrugged off as the South acquired a "sense of empire," and by the 1850s communities such as Augusta and Hamburg took stock of the larger picture that was taking shape across the region.

It was this unified region that went to war in 1860 and survived the Reconstruction Period. Lessons learned from both this age of empire and the Civil War and its aftermath would come into play as the Central Savannah River Area emerged as an economic force in the twentieth century, but the genesis of that entity perhaps begins with Shultz's bridge over the river.

"PROGRAM OF AMBITIONS"

The 1880s witnessed exponential growth and expansion in a variety of areas from industry to tourism to education to sports. Industry prevailed after the Civil War, and canal improvements were at the heart of the invigorated economy that spread over to South Carolina.

By enlarging the canal, Charles Estes permitted the dream of Henry H. Cumming, the Father of the Canal, to come true. An explosion of industrial growth took place. The old Augusta Factory quadrupled its looms and spindles. In addition to the Enterprise, Sibley, and King Mills, three other factories began operations: Algernon, Sterling and Warwick cotton mills, Arctic Ice Factory, Cotton Seed Oil Company, Lombard Iron Foundry, Georgia Chemical Works, Sutherland Manufacturing Company and the Augusta Lumber Company. These large industries spawned the growth of over sixty other subsidiary operations, railroad shops, boiler repair shops, lumber mills, compresses, brickwork and the like. The Horse Creek Valley across the Savannah River shared in the boom as Augustans invested in the Langley Manufacturing Company at Warrenville and the Clearwater Bleachery and Manufacturing Company at Clearwater.[11]

Unfortunately, this growth dissipated by the turn of the century. Changing race relations, unhappy farmers, different land tenure patterns, changing politics, and hard times were ahead. Augustans were no longer in financial control of their transportation systems or their factories. Northern capital had infused much of the expansion and the business leadership reflected that fact. Moreover, the cast of Augusta's industry changed as tourism began making inroads into the city's economy. The city that considered itself the "Lowell of the South" was in the process of transforming itself into the "Saratoga of the South."[12] The Exposition of 1889 and the new Bon Air Hotel were products of this movement, spurring similar enterprises.

By 1910, Augusta's civic leaders were pounding the streets searching for ways to invigorate the economy. This period of self-promotion, which continued through the 1930s in the Augusta area, occurred across the country. In some regards, Augusta was successful in bringing new faces to the area. Extolling its assets, it tried to sell itself as the "City with the Golden Future." Advertisements were circulated to lure aviation schools, luxury hotels, National Guard encampments, and any industry that would pump money into the city's economy. Georgia was selected for two National Guard camps, Camp Wheeler in Macon and Camp Hancock in Augusta.[13] The city had placed a successful bid with the Army, and a special Chamber of Commerce committee was authorized to oversee Augusta's part of the contract with the military—namely, to supply water and housing within a two-month time frame. While the camp was never fully extended to the proposed 90,000 troops, the numbers of soldiers sent to the installation taxed Augusta's reserves, making it difficult to live up to its contractual agreement.[14] The city bought the camp in 1927, and renamed it Daniel Field.



The Bon Air Hotel, located in Summerville on Augusta's hill, opened for business in 1892. Linked to the Bon Air Golf Club organized in 1897 and later the Country Club of Augusta, the Bon Air became a tourist destination for the Georgia city attracting visitors as well as golf enthusiasts. During construction of SRS when housing was at a premium, some of the construction personnel were housed at this Augusta landmark.

Postcard, "The Bon Air – Vanderbilt Hotel. Augusta, GA." Courtesy of J. Walter Joseph.

1927 brought a recommendation from the Army Corps of Engineers that a lock and dam be built below Augusta to provide a steady depth of water at Augusta's wharves, and the dredging of a river channel was also proposed. A monster flood occurred in 1929, breaching the levee that had protected the city since 1913. The levee built under the direction of City Engineer Nisbet Wingfield and sponsored by a Flood Commission had saved the city from previous inundations. There was debris on Greene Street and the city was so devastated by the flood that, in Cashin's words, "it made the stock market crash look like small news."[15] What was left of Hamburg was washed out.

Flood control was now a critical issue for Savannah River Valley residents; Augustans who had thought the levee made them invincible from flood damage were particularly affected. Flood control was a critical issue nationwide according to Congress, which tasked the Army Corps of Engineers with undertaking studies of the nation's rivers to identify solutions on a national scale. While the central study was of the Mississippi and its tributaries, other river systems were similarly studied. Scores of reports were generated for over 200 of the nation's rivers, showing how they might be managed to serve multiple purposes—flood control, navigation, irrigation, and power generation. Congress accepted



(Above) Portrait of Lester Moody, Secretary of Augusta's Chamber of Commerce, at his desk in 1977. Courtesy of Fitz-Symms Studio, Augusta, Georgia.

"It is the binding duty of the leaders of every community to teach their fellow citizens, by precept and example, to think unselfishly and to think together for the common good; to teach them that the joy of community work is also an opportunity for greater service; that what they do for each other and their own community they are doing directly for their country. In this way, and only in this way, can we maintain a good state, a good nation, and a good world."

– L. S. Moody

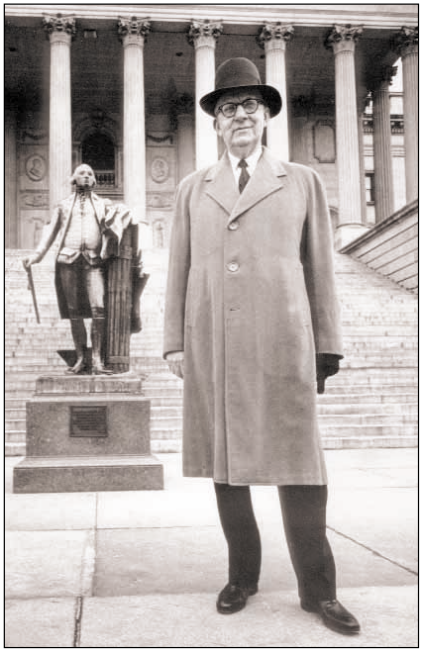
Source: *Building Augusta and the Central Savannah River Area*, Vol. 1, September 1951.

(Inset) Senator Edgar Brown strikes a pose on State House steps in Columbia, South Carolina. Edgar A. Brown Collection, Mss 91. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

responsibility for flood control and, in a series of laws that culminated in the Flood Act of 1936, defined flood control as a "proper activity of the federal government." Over 2,000 projects in a variety of states were approved.[16]

Two men who passionately believed in the economic potential of the Savannah River Valley were hard at work planning the future of the river and its communities. Augusta's Lester Moody and South Carolina's Edgar Brown, premier economic statesmen, saw opportunity in the federal government's proposed program for flood control. Development of navigation on the Savannah River between Augusta and Savannah was their objective, and the Clarks Hill Project was necessary to the achievement of their goal. As Lester Moody stated later, "We made the Savannah River the keystone in the program of ambitions for Augusta. We were looking for a foundation on which to build economic power and that foundation was the river."[17] The Clarks Hill Project, conceived as a multipurpose project that would afford flood control, better river navigation, power generation, and recreation, was a gift from the federal government that would take all of Moody's energies and that of his South Carolina counterpart, Edgar Brown, to pull off.

Lester Moody signed on as Secretary of Augusta's Chamber of Commerce in 1926 and, as historian Edward Cashin notes, no single individual would contribute so much to Augusta's progress over the next three decades.[18] Moody's years of work promoting the Augusta area and the development of the Savannah River earned him the title the "Father of the Savannah."

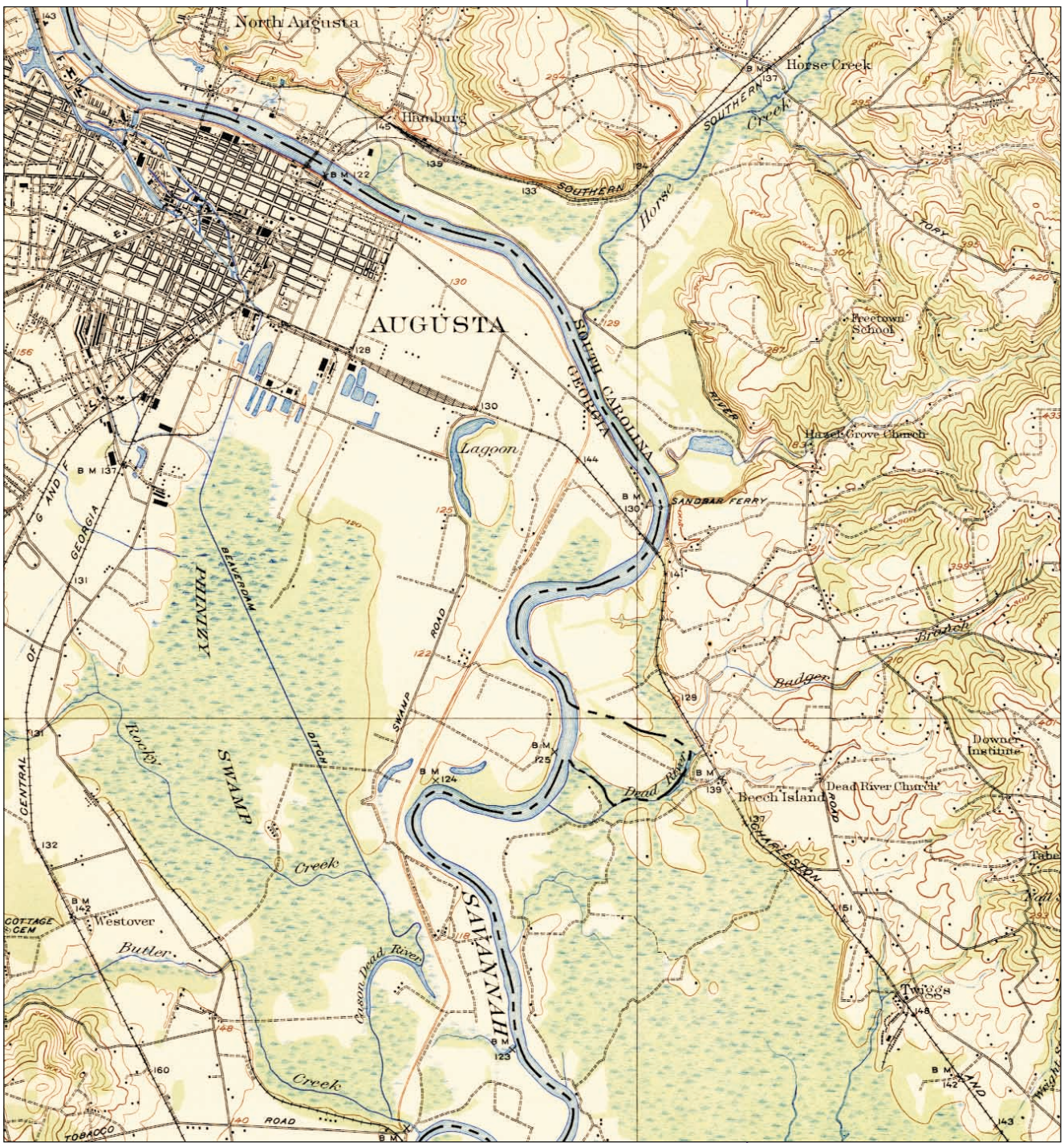


Edgar Brown of Barnwell, who had served in the South Carolina State Senate since 1929 and was chairman of the Senate Finance Committee from 1942 to 1971, championed South Carolina's interests in the development of the Savannah. Working hand-in-hand with Lester Moody to complete the Clarks Hill Project, Brown would become a consummate booster for river development, later involving Governor Strom Thurmond in the endeavor. Brown, who also strongly encouraged economic development in his home county of Barnwell, was known by a number of nicknames such as "Mr. Big," "That Man Brown," and the "Bishop of Barnwell." From the efforts of these two men and others like them, a chain of federal projects came to the Savannah River Valley. The Clarks Hill project was the first in that chain.

CLARKS HILL PROJECT

Lester Moody's acceptance of the job at the Chamber of Commerce in 1926 coincided with the application of the Savannah River Electric Power Company to the Federal Power

Detail from 1921 USGS Topographic Quadrangle showing most of Augusta and the undeveloped area on the city's eastern perimeter. North Augusta, Hamburg, and Horse Creek Valley are shown on the South Carolina side of the river. Below Augusta, only the Sand Bar Ferry and the Charleston and Western Railroad Bridge north of Beech Island crossed the Savannah River. Source: USGS Topographic Quadrangle, Augusta, GA., 1921. Courtesy of New South Associates, Stone Mountain, Georgia.



Commission for the right to construct a dam and power plant at Clarks Hill, South Carolina. The Federal Power Commission issued a permit to the Savannah River Electric Company in 1928 for the construction, operation, and maintenance of a hydroelectric project at the Clarks Hill site. However, the company surrendered its license in 1932; the project did not appear feasible due to unfavorable economic conditions. The South, like the rest of the country, was in the throes of the depression, and the local firm forecast a decrease rather than an increase in the demand for power.

The power company's decision had larger ramifications. Developing navigation on the Savannah River between Augusta and Savannah was a shared goal between the City of Augusta, its Chamber of Commerce, and the State of South Carolina. If Augusta could become an inland port, South Carolina's Hamburg, a colonial port town no longer in existence, could be resurrected to share in the benefits of freight rates and shipping interests. Clearly the basin areas on both sides of the river had an interest in the economic benefits a navigable Savannah River represented. While Congress had authorized a number of projects, none to date had corrected the low water depths that the river experienced seasonally. To create a year-round channel on the lower Savannah River, upstream storage capacity was needed to discharge into the lower river when needed. The Clarks Hill project would have created this storage capacity as well as produced power.

The surrender of the Savannah River Electric Company's permit in 1932 spelled trouble for the river developers, who had counted on benefiting from the power company's project. After ascertaining that the local company had no future designs on the site, Moody and Brown began their drive to involve the federal government in the construction of Clarks Hill in the interest of navigation, power, flood control, and recreation for the region.[19]

In August, Lester Moody announced that the Clarks Hill Project had earned the attention of President Roosevelt and that a commission had been appointed to study its feasibility and impact. By March 1936, the vote was in and the commission endorsed the construction of the Clarks Hill Dam. The Flood Control Act of 1944 approved the construction of the Clarks Hill project, as the first in a series of eleven dams.

It is clear from a 1946 brief co-authored by Lester Moody and Edgar Brown on the project that men on both sides of the river were involved in this important drive:

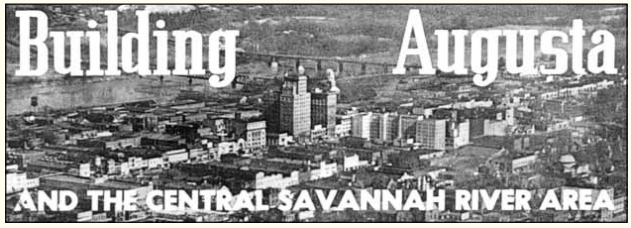


Historic aerial view of Clarks Hill Dam, circa 1950. The construction of Clarks Hill Dam was a major factor in the selection of the Savannah River Site. Courtesy of U.S. Army Corps of Engineers, Savannah District.

The people of the Savannah River Basin, both in South Carolina and Georgia, are intensely interested in the complete development of the area. The Savannah River is a great potential asset to all of the South Atlantic States. Here is a river with abundant water supply and ample power sites, centrally located in a region blessed with raw materials and labor. If developed, this river cannot help but be instrumental in increasing the prosperity of the people. To best accomplish such a development, water transportation, protection from floods and ample power must be available.[20]

Lester Moody—"Father of the Savannah"

Between 1926 and 1964, Lester S. Moody served his community as Secretary of Augusta's Chamber of Commerce. In historic photographs of local booster clubs or groups of Augusta notables, he is typically in the second row or background, suggesting that he was not interested in the limelight. However, the twentieth-century history of the region and the City of Augusta shows him to be a pivotal figure in the area's development. A native of Jacksonville, Florida, Moody was a master at forging alliances with those in political power to further the city and region's goals.



When he drove to Augusta from North Carolina to accept his new position in 1926, no paved roads lead to Augusta. "It took nearly three hours to drive from Aiken to Augusta. I was so impressed that I made highway paving my very first ambition, and Chamber members enthusiastically backed me up." Road improvements were followed by other campaigns to improve the city. After a severe flood in 1929, he led a campaign for the construction of new bridges at Fifth Street, Thirteenth Street, and Sand Bar Ferry. The latter bridge was named in his honor in 1968, and his name was etched onto the westbound bridge's abutment. He would later play a role in the construction of Fureys Bridge located about 15 miles north of Augusta. The location of Camp Gordon, Bush and Daniel Fields, and the Savannah River plant in the CSRA were the results of his labor to bring industry to the area. Other campaigns spearheaded by Lester Moody included his promotion of the city's resort industry in the 1930s, road improvements, and the development of a poultry industry. He served on the Committee of 100, the Savannah Valley Boosters Association, and other organizations that sought to encourage business and industry in the CSRA.

His work in the development of the Savannah River's potential was his greatest accomplishment, spanning four decades.

He provided leadership for the region, not just the CSRA, in finding congressional support for river improvements. The lock and dam project below Augusta, built to guarantee Augusta access to a deep-water port was a result of his efforts.

He was instrumental in the construction of the Clarks Hill and Hartwell dams. The Clarks Hill Dam project was a strong factor in the selection of the South Carolina site for the Savannah River Plant.

He was also a champion of a nine-foot channel on the Savannah River. This navigation channel was dredged between Augusta and the deep-water port at Savannah, with the intent of linking Augusta by inland waterway with ports all around the North Atlantic seaboard to the Mexican border at Brownsville, Texas. A cross-Florida canal, which was never built, was needed to make the plan work.

Moody was a director of the National Rivers and Harbors Congress, acted as chairman of the Bureau of Water Resources of the congress, and was a member of the U.S. Study Commission, Southeast River basin, a group dedicated to long range development of land and water resources in the Southeast. He retired from the Augusta Chamber in 1964, having the honor of receiving the U.S. Army's highest award for civilians, the Decoration for Outstanding Civilian Service. He was the first individual from the Southeast to receive that award. In 1966, the Willard J. Breidenthal Medal, a national award for water conservation, was awarded to Lester Moody. The citation for the medal honored him as the "Father of the Great Savannah River."

Source: Paul Garber, "City Booster's Influence Felt In Many Areas," *Augusta Chronicle*, www.augustachronicle.com/history/moody. (Inset) Source: *Building Augusta and the Central Savannah River Area*, Vol. 1, September, 1951.

The Clarks Hill Project was completed in 1954 despite setbacks stemming from legal suits over the earlier license. It was the first Corps of Engineers Flood Control Project in the Savannah River Basin. The dam, renamed after South Carolina's J. Strom Thurmond in 1988, spans 5,860 feet and measures 200 feet in height. Built at a cost of $79 million, the dam impounds a lake that stretches 40 miles up the Savannah River and 26 miles up the Little River.[21] Its power output was estimated at 53,000 kilowatts. Hartwell, the second Corps of Engineers Flood Control Project in the Savannah River Basin, followed Clarks Hill. Hartwell's dam, completed in 1963, spans 18,000 feet and impounds a lake that stretches 49 miles up the Tugaloo River and 45 miles up the Seneca River. It was hoped that these projects would finally do what the new Savannah locks and dam, completed in 1937, had not done, allow August to become an inland port. Lester Moody enthusiatically predicted Augusta's future as an inland port would finally occur with the completion of Clarks Hill.[22]

Lester Moody, Edgar Brown, and the other local politicians who supported the Clarks Hill Project derived invaluable experience from brokering the deal. Their cooperation was an admission of regional goals. A sense of regional identity was displayed, a glimmer of what would be later recognized as the Central Savannah River Area. It was also an astute recognition of how their states and constituencies could garner federal support. With the federal government's statement of responsibility for flood control that was encapsulated in the Flood Act of 1936, they were able to get the Clarks Hill Project onto the federal gov-

Edgar A. Brown

Edgar Brown of Barnwell, was actually a native of adjacent Aiken County. Born in 1888 to Augustus Abraham Brown and Elizabeth Howard, he grew up on a small Aiken County farm. At about the age of 12, he got a job in Graniteville as a textile worker and saved enough money to pay his expenses at Graniteville Academy. Later he traveled to business school in Augusta to learn shorthand, a skill necessary for a stenographer. Brown first worked as a stenographer in the law offices of Colonel Daniel S. Henderson where he began to read the law under Henderson's tutelage. At 20, Edgar Brown succeeded Jimmy Byrnes as court stenographer of the 2nd Judicial Circuit; Judge Robert Aldrich of Barnwell appointed him to the position. Byrnes had just been elected solicitor and Brown moved to Barnwell as a consequence.



Brown's career of public service was marked by a number of achievements. He served in the South Carolina State House between 1921-1929, acting as Speaker of the House from 1925-1926. He began his long career as a State Senator in 1929, serving as President Pro Tempore in 1942 until his retirement at the end of the 99th General Assembly. He was also Chairman of the Senate Finance Committee. "Considered by many to be the most powerful man in South Carolina politics," Brown worked hard toward the industrialization and modernization of his home state and was a major force in shaping state government. State road improvement was an early coup for him and his fellow supporting senators. A later achievement was his work on the Clarks Hill Authority and the bringing of the Savannah River Plant to his home county of Barnwell and neighboring Aiken. James Long, would later refer to Brown in 1962 as the one who started it all, as he and other South Carolina politicians bartered for future projects with the Atomic Energy Commission building on the foundation that Brown had made. Edgar Brown and Sol Blatt, the Chairman of the House Ways and Means Committee during World War II and his political cohort also from Barnwell, were such a strong political team that they were referred to locally as the "Barnwell Ring."

Source: Edgar A. Brown Collection, Mss 91, Finding Aid. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina. (Inset) Edgar A. Brown Collection, Mss 91. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

ernment's drawing board. Their actions placed both men and their home states on the national scene where large federal projects were unfolding. They and their fellow economic statesmen learned the ropes of how to attain economic power, lessons they would hone in the decade to come.

THE PHOENIX EFFECT

The New South programs of the 1880s and 1920s were eclipsed by the amount of industrial change that World War II brought to the South. The military-industrial complex developed to win World War II would amount to a "virtual affirmative action program" for the American South.[23] The federal government spent about seven billion dollars on military bases and industrial plants in the South during the war; another billion dollars of new business was generated in the private sector. Southerners left their rural homes in the millions to take advantage of the job market now open to them, and began to rub elbows with the over six million non-Southerners who came south as part of the military influx or in search of jobs.[24] Statistics show that between 1939 and 1972 the number of southern factories rose 160 percent and that the number of workers in them increased 200 percent. The per capita income reflected this industrial expansion, rising 500 percent between 1955 and 1975.[25]

The boomers and boosters who espoused the New South in the earlier periods would have been proud of the next generation of industrial "statesmen" who created World War II success stories and built upon them. Newspapermen, chambers of commerce officials, and state development boards offered financial enticements to bring industry below the Mason-Dixon line. These enticements ran the gamut from tax reductions or exemptions, to offers of public funding for construction costs, to start-up programs for new industry.



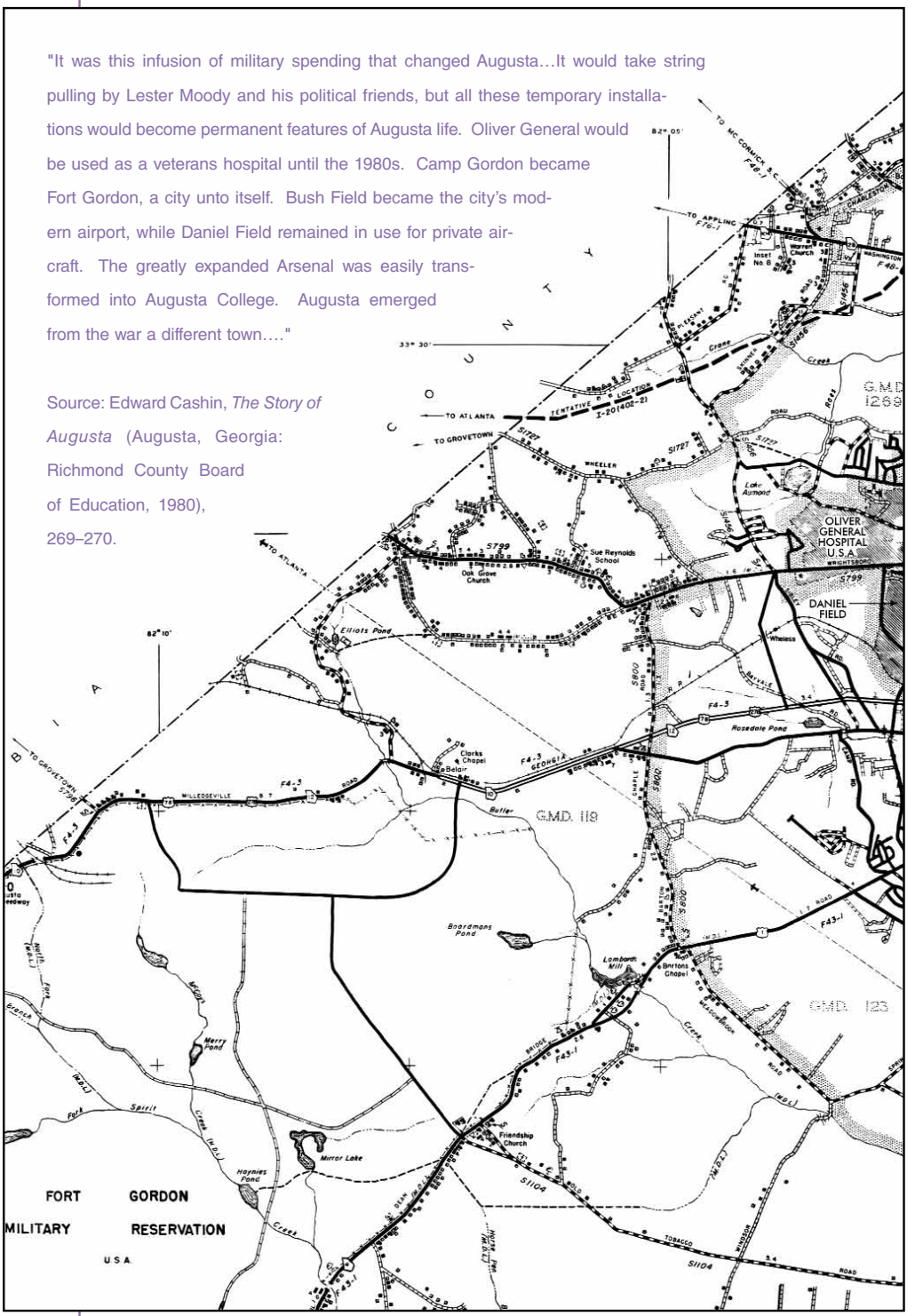
Burnet R. Maybank, a Byrnes protégé, New Dealer and Santee Cooper Project backer, moved from the mayor's office in Charleston to the governor's house in 1938 then later represented South Carolina in the Senate. The photograph is signed "Best wishes to my good friend Ed Brown a real fellow and outstanding democrat." Edgar A. Brown Collection, Mss 91. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

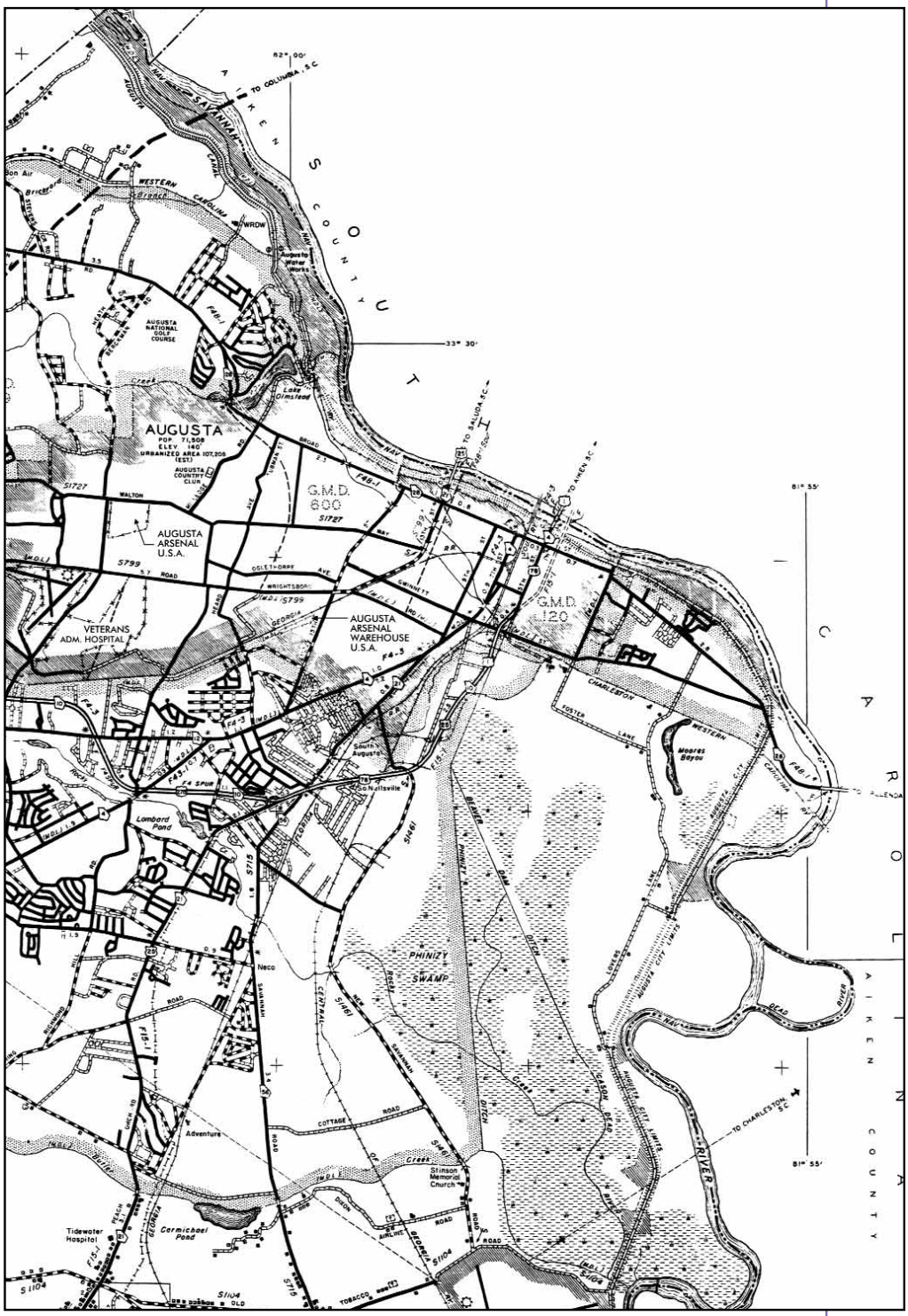
On the Senate floor, Senator Burnet B. Maybank of Charleston attributed the South's incredible industrial expansion to the economic statesmanship of the its industrialists. Maybank, in a response to Senator John F. Kennedy's statements on the decline of industry in New England, told other regions to learn from the South's example:

> Can it be that such regions are paying the penalty of failure or inability to translate their scientific progress into lower prices for the buyers of their products? Is it perhaps possible in their zeal to promote expensive social welfare schemes, they have stifled industrial initiative by running up the costs of doing business? If so, it is hardly fair for them to point a finger of scorn, and to shout "unfair" at those regions where business foresight has permitted technological progress to be passed on in good measure to the consumer in the form of lower and competitive prices for products?[26]

"It was this infusion of military spending that changed Augusta…It would take string pulling by Lester Moody and his political friends, but all these temporary installations would become permanent features of Augusta life. Oliver General would be used as a veterans hospital until the 1980s. Camp Gordon became Fort Gordon, a city unto itself. Bush Field became the city's modern airport, while Daniel Field remained in use for private aircraft. The greatly expanded Arsenal was easily transformed into Augusta College. Augusta emerged from the war a different town…."

Source: Edward Cashin, *The Story of Augusta* (Augusta, Georgia: Richmond County Board of Education, 1980), 269–270.





Detail from 1950 Richmond County Highway Map showing post-World War II Augusta and the physical impact of the War. The northern section of Fort Gordon is shown as well as Oliver General Hospital, the Augusta Arsenal, the Augusta Arsenal Warehouse, and Daniel Field. Bush Field is not shown. Source: General Highway Map Richmond County Georgia. Prepared by the State Highway Department of Georgia, Division of Highway Planning, in cooperation with U.S. Department of Commerce Bureau of Public Roads, 1957. Courtesy of the Map Collection, Science Library, University of Georgia, Athens, Georgia.

Maybank's speech affirmed his home state's success. The South was in the process of being reborn, while New England was reaching old age. The catalyst for this rebirth was World War II.

The drive for American rearmament began in 1940 after Hitler's invasion of Belgium, the Netherlands, and then France. Substantial military appropriations were made to cover the cost of increasing the Regular Army, remodeling the nation's arsenals, developing new munitions plants, purchasing equipment, and constructing airfields, service schools, tactical stations, storage facilities, and seacoast defenses. The dollar figure for the mobilization program was as unprecedented as the events happening in Europe, and the Army Corps of Engineers found themselves at the heart of the storm. The big permanent camps such as Fort Bragg in North Carolina, Fort Benning in Georgia, Fort Lewis in Washington, and Fort Knox in Kentucky were to be expanded to accommodate the Regular Army divisions. Smaller installations such as Fort Jackson in South Carolina, Fort Riley in Kansas, and Fort Ord in California were also a focus of expansion. New camps for the National Guard troops and for unit and replacement centers, new airfields for the Air Corps, and new munitions plants were needed within a year to eighteen months. In the words of Army historians Fine and Remington, it was a construction man's nightmare.[27]

The criteria used to select sites for the new camps and airfields were fairly similar, with weather conditions playing a large role within the selection process. From a military perspective, training camps were needed in a variety of climates, to ready the soldiers for whatever might be ahead. This mandated camps in both the North and South. However, the South's weather, plus vast acreage available for continuous training and maneuvers, made it a prime location. In addition, Army Corps of Engineer planners were given a budget for camp construction that allowed only $400 per man. This figure was based on the assumption that all training camps would be located in the South where tents could be used for housing.[28] The newly selected ground force's sites stretched over thirty states, but the majority of training camps did end up in the South. The Air Corps, which had priority for new sites, was also in need of training facilities in locales with favorable weather that permitted flying throughout the year. Again, the South would benefit.[29]

The geography of the new camps and airfields reflected these strategic and operational concerns as well as political and social agendas. The proposed construction program presented an avenue for the Roosevelt administration to provide economic relief to areas in need, influencing some of the site choices. Many municipalities took matters in their own hands and came to Washington to bid on the proposed defense projects. State senators and representatives lent their voices in support of projects for their constituencies. And the red carpet would be laid out for War Department site boards when they visited to collect data on proposed sites. Typically, cities that wanted civil airfields proposed leasing city land to the government for a dollar a year and promised to extend power and water lines to the site. Many municipal airports were selected, saving the Army some construction costs.

For the developing munition plants, more defensive concerns guided site selection. Twenty-nine new sites were needed. The staff of the War College, Division of the General, provided a general military principle in 1915 that the World War II committee charged with site selection followed. "No supply depot, arsenal, or manufacturing plant of any considerable size… should be established or maintained east of the Appalachian Mountains, west of the Cascade or Sierra Nevada Mountains, nor within 200 miles of our Canadian or Mexican borders."[30] Beyond that, production and transportation concerns

were the leading criteria involved with the selection of munitions plant sites. The result was an integrated network of factories in the Midwest's agricultural and manufacturing region. Problems with land acquisition rather than construction would haunt this group of sites and, due to quick action on the part of the site selection committee, the defined area for the production facilities was not influenced by political or social concerns. The President's Advisory Commission had advocated a decentralized munitions industry that would encourage industry in traditionally non-industrial areas such as the South and West. The War Department's alacrity won out.[31]

Corps area commanders rather than the staff from Construction Division of the Quartermaster Corps were chosen for the individual site surveys for the ground-services sites. As a result, when the men responsible for construction got on site, they were presented with a plethora of problems. Poor topography, swampland, lack of transportation links, and other myriad problems had to be faced prior to construction. While only one proposed site for a camp was not built out, the need to improve and remediate conditions could have been avoided through more thorough site investigations. And construction officers pointed this out. It is notable that Colonel Leslie Groves, then a Captain and a construction engineer, raised objections to the process of site selection in which he and his cohorts were embroiled. In 1940, he had no idea what was ahead for him. During the Manhattan Project, he made site selection a streamlined operation based on thorough data collection. While the secrecy of that time contributed to his methodology, it is not unlikely that his experience with site selection in 1940 helped shape how the selection process later evolved with the atomic energy facilities.[32]

While the Savannah River Valley did not suit the criteria for a munitions plant, Augusta was a large enough urban entity to bid on a chunk of the mobilization program. Lester Moody was dispatched to Washington to place a bid for an army camp. Ever diligent, he came home with a promise for an air base and a National Guard installation. Moody, probably listening to the debate over the construction of new airfields versus the reuse of municipal fields in Washington, saw further opportunity for his home city. Camp Hancock's air field, a survivor of the Great War that was acquired by the city in 1927 and renamed Daniel Field, was offered and accepted as a candidate for a short-runway training base. Late in 1940, the old field became the operating base for 2,000 men and 100 planes. Air Force General H. H. "Hap" Arnold was the inspector of the facilities when completed. It was like old home week to the general, who recalled flying over the Hill in his "motorized glider," dropping notes to his lady friends thirty years earlier.[33]

Augusta's bid for an army camp was still under advisement, as the site selection committee was also looking at a competitive bid from Spartanburg. Both communities vied for the military nod, welcoming military personnel on their evaluation tours. Each host community gave their best offer for potential services to be rendered to sharpen their competitive edge. For Augusta, this included assuming the cost of laying water and sewer mains to the camp. Both cities actually had winning proposals. Augusta was chosen as the site for an army cantonment while 20,000 acres near Spartanburg were reserved for a replacement center. In 1942, Camp Gordon, established on Tobacco Road, became home to the "Rolling Fourth" division until they were shipped overseas to France. They would be one of the last divisions to arrive at Normandy.[34] In addition to Camp Gordon, a small airfield, named after an instructor, Donald C. Bush, who died in a training crash, was also built for training army pilots.

Other World War II improvements included the following: a new hospital and an upgraded and expanded Arsenal complex. The Army requisitioned the Forrest-Ricker Hotel for use as a hospital in 1943. The new hospital was named in honor of Dr. Robert T. Oliver. The Augusta Arsenal was greatly expanded during World War II with large warehouse facilities, new shop buildings, and a guardhouse.

> It was this massive infusion of military spending that changed Augusta. The long depression was over and there was a hustle and bustle as in the best days of the Age of Enterprise or of the New South. And the face of the whole region changed. It would take some string pulling by Lester Moody and his political friends, but all these temporary installations would become permanent features of Augusta life. Oliver General would be used as a veterans hospital until the 1980s. Camp Gordon became Fort Gordon, a city unto itself. Bush Field became the city's modern airport, while Daniel Field remained in use for private aircraft. The greatly expanded Arsenal was easily transformed into Augusta College. Augusta emerged from the war a different town from the depression-bound thirties.[35]

World War II also vastly changed South Carolina. Historian Walter B. Edgar notes that the War did what the New Deal could not do, it brought full employment to the state.[36] Defense industries played a significant role in this change. While some would have less impact after the War, they provided an industrial education, a taste of what the manufacturing sector had to offer.



Annual Luncheon of the South Carolina State Chamber of Commerce held on November 21, 1957. Pictured in the photograph are Harold Butt of Charleston and President-elect of the Chamber that year, W. B. Camp of Bakersfield, California, Eleazer of the State, and Lt. Governor Ernest I. Hollings (Left to right front row). Senator Thurmond, John Linton, President of the Chamber, and Honorable Mendel Rivers, member of the U.S. House of Representatives, 1st Congressional District of South Carolina. Strom Thurmond Collection, Mss 100, Photograph 1444. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

Prior to the war, the state's industrial sector was devoted to textiles, primarily to the processing of cotton. Agriculture anchored the state's economy, and three out of four Carolinians still resided in the country as late as 1940. This began to change after the war as mechanization and federal programs decreased the need for farm labor. Families who had earned their livelihood from sharecropping moved to the cities in search of work. The war had expanded South Carolina's industrial horizons, and in the 1950s industrial expansion became a state objective. In Governor-elect Jimmy Byrnes' words,

> South Carolina's government is basically sound and it is friendly towards industry. Our government, our communities, and our people want industry and want to see that it is prosperous and happy. No state and no people can offer more.[37]

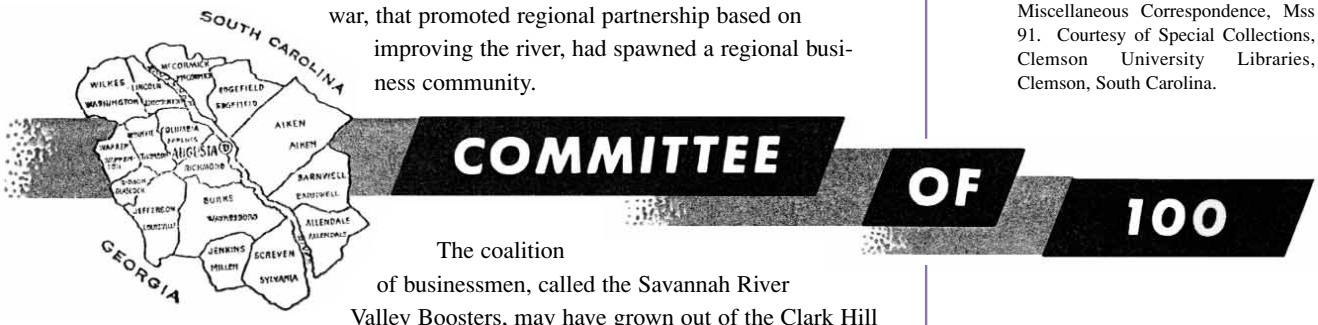
Not all South Carolinians thought well of industrialization but South Carolina communities that wanted industry after the war were dependent on their own resources to

attract it. The intensity of a community's program was dependent on available funding, the size of the community, etc. Charleston, for example, had a development board with five full-time employees. In most cases, a town's chamber of commerce would lead the search using publications and recruiting trips to attract prospective businesses. Smaller communities simply relied on brochures, advertising, and the help of the state's Research, Planning and Development Board, the predecessor agency to the State Development Board, to drum up industrial prospects.

The State Development Board was created in 1954 to better help South Carolina communities find suitable industrial matches with the resources they had to offer. The creation of the board underscores the importance of industrial expansion to South Carolina's leadership. Edgar notes that Governor Strom Thurmond was the first to open the Governor's Mansion doors to industrialists, using the first family's residence as a venue to drum up industrial prospects. Jimmy Byrnes, Thurmond's successor and the state's "New Deal man," was surprised to find that he was expected to follow in Thurmond's footsteps in this regard. Later governors would automatically follow suit.[38]

Aiken and Barnwell counties, the western South Carolina counties that bordered the Savannah River across from Augusta, were not home to any new defense industries or Army camps during or immediately after the war. On the state level, Fort Jackson in the Columbia area, Camp Croft in Spartanburg, and the coastal area benefited the most from military dollars. Due to their location, the war-related regional activity that most impacted South Carolinas within the central Savannah River basin was centered in Augusta.

Moreover the booster organizations that had grown after the war, that promoted regional partnership based on improving the river, had spawned a regional business community.



Logo on letterhead for the "Committee of 100" that shows the extent of the organizations area of influence in fostering economic development of what would become the Central Savannah River Area. Edgar Brown Collection, Miscellaneous Correspondence, Mss 91. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

The coalition of businessmen, called the Savannah River Valley Boosters, may have grown out of the Clark Hill Project and associated flood control projects. Other organizations, such as the "Committee of 100 for the Development of the Augusta Area," helped forge a new regional identity. In recognition of this identity, *The Augusta Chronicle* sponsored a contest in June 1950 for a name that would better describe the greater Augusta area. "Central Savannah River Area," the winning submission selected from 2500 entries, was penned by C. C. McCollum of Wrens.[39]

While high-level booster programs successfully enticed industry to the river basin, brochures written by small communities to describe their assets could also produce dramatic results. Word reached South Carolina in 1948 that Du Pont was searching for a new commercial site in the state to locate a plant that would produce a mystery product. It would be the company's first plant in the Palmetto State. The State Research, Planning, and Development Board was probably involved in preparing profiles of possible plant sites. The Ellenton community was one of the candidate sites, and the city of Ellenton prepared such a brochure.

THE ELLENTON COMMUNITY



(Above) View of Laurens Street in downtown Aiken, Aiken County's seat. Courtesy of J. Walter Joseph.



(Inset) Aiken's Winter Colony, "A Morning Canter through the Pines, Aiken, S.C". Postmarked February 9, 1942. Courtesy of J. Walter Joseph.

Ellenton, South Carolina, was a railroad town and rural trade center located about 25 miles southeast of Augusta, Georgia, in southwest Aiken County. Historian Jim Farmer describes Aiken County as distinctive among South Carolina counties of this period in that it contained a mixture of cultures. Farming families, both white and black, populated the eastern and southern reaches of the county. In contrast, a fifteen-mile belt of textile mills ran along the Horse Creek Valley to the Savannah River west of Aiken, the county seat. William Gregg's sermons and example had been well received in Horse Creek Valley where mill workers were called "lint heads" by non-industrial folk. The kaolin industry was the county's other industrial enterprise. The mines and operating facilities for this industry were located north and west of Aiken. The county seat also contained diverse groups:

> Here lived some 7,000 people, white and black, most descended from refugees from the Lowcountry's hot and unhealthy climate, who began arriving in the 1830s on what was briefly the world's longest railroad. Some fifty years later they were joined, for half the year at least, by a winter colony of wealthy, sports-minded families from the northeast. Joined is perhaps not the best word, however, for the winter colonists, whose local raison d'être was the horse and activities associated with it, kept largely to themselves. Still, old Aikenites were glad to have them for the regal tone they brought, the homes they built, and the money they spent on the necessities of the good life.[40]



Interior view of unidentified textile warehouse in Horse Creek Valley, Aiken County, 1955. Courtesy of SRS Archives, negative 3301-14.

Ellenton, located in the southern reaches of the county near the county line, was homogenous in comparison to Aiken. It had a 1950 population of 746, the majority of whom were white; only 27 percent of Ellenton's residents were black. Commerce contributed to the success of the community within the mile-square incorporated town. "The citizens of the community, planning for a future as stable as their past, had built a new brick school, paved some streets, cared for their old mansions and erected some new homes. These characteristics stood out against a background of modest old homes, Negro schools, and sandy, rutted side streets which made up the familiar setting for the bulk of the population."[41] A sociological study conducted in the early 1950s described Ellenton life as a weave of kinship-economic-governmental rela-

tionships that tied white Ellenton families together and in turn threaded its support through the town's African American community. Stability in one network created stability in the second.[42]

With its 56 merchants, a telephone company, and solid residential neighborhoods, Ellenton would have a lot to offer a new business interested in a South Carolina location.[43] The Charleston and Western Railroad, originally the Port Royal-Augusta Railroad, was the town's backbone, with most of the town extending to the east of the tracks. And the river was only two miles to the west. It was also close enough to larger cities such as Aiken and Augusta to allow easy access to services not available in the small town.



Aerial of Ellenton, circa 1950. Courtesy of the Savannah River Archaeological Research Program, J02768.02ai.

Despite its rural setting, Ellenton was also used to industry. The Leigh Banana Crate Company, located south of Ellenton in Barnwell County, provided industrial employment for area residents from the late 1920s onward. This firm produced veneer of cypress, gum, and pine and manufactured hampers for fruit and vegetable storage and shipping. Its holdings included a factory, a mill, a 14-mile railroad that connected the main rail line with its facility at the Savannah River (two-thirds of which was supported by trestles constructed of native cypress), two locomotives, and a narrow-gauge battery-operated industrial railroad at the factory.[44] The industrial village named Leigh, after the company's president, was home to the factory's workers and families; one oral history source estimates the Leigh population at 150 to 300 persons. Homes in the industrial community had electricity, running water, and public buildings such as a church, hotel, and general store.[45]

While the rolling sandhills of Aiken and Barnwell counties did not support great lumber operations like those in the Lowcountry, the swamps of the Savannah River and its tributaries in Barnwell County were logged. Acquisition records for the Savannah River



Aerial showing the Leigh Banana Company located south of Ellenton in Barnwell County circa 1950. This factory operation, which produced veneer of cypress, gum, and pine and manufactured hampers for fruit and vegetable storage and shipping, was extensive. The company town of Leigh (possibly the area in the upper left of the photograph) was also part of the company's holdings. Courtesy of SRS.

Plant indicate that timber companies such as International Paper and West Virginia Pulp and Paper held rights and owned land in Aiken and Barnwell counties, but the actual extent of their operations there is unknown.

The population figures noted above reflect the town proper; not the larger community of farming families that surrounded the town. Many of these families would be considered part of the Ellenton community. In 1950, average farm size in Aiken County was 124 acres while Barnwell County farms were slightly larger at 139 acres. Cotton, peanuts, corn, other vegetables, and cereal crops were grown.[46] Truck farming increased in importance in the area's economy by 1950, and peaches provided income for many area farmers.[47] The farms that surrounded Ellenton were in the throes of change. Tenancy, once the hallmark of turn-of-the-century southern agriculture, decreased in favor of fewer owner-operated farms that grew more diversified crops. Tenant farmers had composed 70

percent of Aiken and Barnwell counties' farmers in 1925. Only 49 percent of all county farmers were tenants twenty-five years later. Many left the farm in search of work at some of the new factories and commercial enterprises that World War II had spawned.

The brochures that were developed to attract the Du Pont firm would have emphasized Ellenton's size and location along the railroad and river, the availability of labor and land, and the town's well-established commerce. Despite Ellenton's assets, Du Pont chose a site in Kershaw County. Ground was broken in February 1949 for the May Plant, which was to be located in Lugoff near Camden, South Carolina.[48] Strom Thurmond officiated at the opening for the plant that would manufacture Du Pont's new product, "Orlon," which had been in development for years.

Despite their failure to garner the Orlon plant, the Ellenton-area boosters hopefully redistributed the prepared brochures to other prospective firms interested in selecting a South Carolina venue for their future plants. The Du Pont firm placed the Ellenton community brochures on file, in case of further plant expansion into South Carolina. They would be pulled out in the summer of 1950 and reviewed for an entirely different purpose. They were thought "of considerable help in the final selection of an atomic energy plant, despite the fact that the planning board had no idea they were being put to that use."[49]



Frank Smith Home and farm located in what is now New Ellenton in 1955. Courtesy of SRS Archives, negative 2713-9.

7 Site Selection

In almost military fashion, the Du Pont organization developed its approach to the new project. Robert M. Evans, William Mackey, and Lombard Squires of Du Pont's Explosives Department came to Washington on June 15, 1950, to learn about the project in front of them and to initiate their technical survey of the AEC's plans. Another Du Pont sortie of a different nature was already in the making. The search was on for possible sites for the new production facility.[1]

SITE-SELECTION PROCESS FROM OAK RIDGE TO IDAHO

The majority of the nation's weapons production complex was constructed in two waves, in 1942–1944 and 1947–1953. The criteria developed for the selection of Oak Ridge and Hanford during the Manhattan Project were inherited by the AEC for their 1947–1953 expansion, then refined as the agency's knowledge of reactor technology advanced. Individuals involved with the expansions learned from each project, honing their skills at site selection and compiling basic criteria needed for construction. Among them, they possessed a rich corporate memory.[2] Those involved with choosing the future Savannah River Site were participants in creating this corporate memory.

Three military terms were used to define the considerations involved in determining basic criteria. "Strategic" concerns were broad in nature and related to national military and economic potential, defending the facility from enemy attack, and the proposed facility's relationship to other facilities within the production system. "Operational" considerations referred to an area's terrain, population, and resources that had to fit the proposed plant's requirements. "Tactical" considerations included local housing availability and transportation links, and were often the basis for a secondary set of criteria applied in the later stages of decision making.[3]

OAK RIDGE SITE

In his first act after assuming control of the Manhattan Project, General Leslie Groves selected the Oak Ridge site in 1942. Until that time, site acquisition for Oak Ridge had not progressed under the Office of Scientific Research and Development (OSRD).

Tennessee was chosen as the general site area for its ample supply of electrical power; wartime had made electricity a strategic concern. It also was a good geographic fit with the War Department's policy, established for the defense munitions industry to site plants between the Appalachians and the Rockies and no closer than 200 miles to the Canadian and Mexican borders. The OSRD concurred with this strategy. Planners agreed only on preliminary criteria, based on best practices in engineering, and their sketchy knowledge of what would be needed by an atomic production facility. This included isolation from population centers, terrain broken by ridges that would act as natural barricades, access to water, and a strong power supply. A 200-square-mile federal reservation was needed to safely enclose the processes under development. Initially, all production units were to be at one site, for secrecy and to facilitate construction and operations. Stone and Webster, the proposed construction firm, added construction concerns to these basic criteria. The sticking point was the 200-square-mile requirement set by the OSRD for the reactor exclusion area. While this requirement delayed action on the part of Colonel James C. Marshall of OSRD, his successor, Leslie Groves, acted immediately, claiming a bad decision was better than no decision.

HANFORD SITE

Du Pont objected to the idea of locating the reactors, then called "plutonium production piles," at Oak Ridge. The proposed exclusion area was not sufficient and if a "premature criticality" of plutonium resulted in an explosion, Knoxville could be threatened. Preferring not to interrupt ongoing construction at the Tennessee facility and reluctant to slow the project by acquiring more land, Groves agreed to find a new site for the reactor complex.

Du Pont and Manhattan Project personnel developed basic criteria for reactor siting at a meeting held on December 14, 1942—the first systematic attempt to match technical reactor requirements to engineering and safety considerations.[4] The Metallurgical Laboratory in Chicago generated operational requirements, and Du Pont, in concert with Groves' staff, responded to these, to develop criteria to assure operational safety while meeting production goals.

They recommended taking enough land for six reactor areas, separated from each other by not less than a mile, and four "secondary areas" for the even more hazardous separation plants, to be spaced not less than four miles from each other and the reactors. Six reactor areas would be more than needed for the number of reactors then planned (two). This decision made good sense from the strategic standpoint, but it complicated the operational task of finding a site isolated enough where all six reactors could be operated at full power without endangering the adjoining population. The reactor engineers recommended evacuating a 10-mile wide "exclusion area" around the "manufacturing area." A 10-mile complex would require an "exclusion area" of about 700 square miles. And beyond it the engineers suggested prohibiting residential occupancy in an area of 44 by 48 miles—more than 2,100 square miles. There could be no major public roads or railroads within the 700-square-mile reservation. There could be no towns with more than 1,000 population closer than 20 miles.[5]

The primary requisites included abundant electric power and the availability of pure cold water, flowing through the area at 25,000 gallons a minute. Secondary criteria included level land for building, mild climate for construction and operation ease, and access to coal and oil. There was one final criterion; the creation of the site should displace as few individuals as possible. The Corps of Engineers was then called upon to find a site that best fit these requirements, and a 670-square-mile circular tract in Benton, Yakima, Grant, Adams, and Franklin counties in Washington State was chosen for development into the Hanford Engineer Works. Du Pont built and operated the facility until 1946. General Electric operated the Washington State facility during the second expansion.

POCATELLO SITE

In 1947, the AEC began investigating the feasibility of constructing two new reactors at a site other than Hanford for "strategic insurance." The Army encouraged the selection of a new site from a defensive perspective, as the Pacific Northwest was now vulnerable to Soviet long-range bombing. The projected high costs and implications for the labor force within the young complex were daunting, however, and the idea was put aside. By early 1948, the Cold War changed minds, and the AEC's Production Division drafted a list of ten potential sites. The Reactor Safeguard Committee created a formula for large production facilities in which the radius of the totally evacuated "exclusion zone" was to be directly proportional to the thermal power output of the reactors ($r = 0.01\sqrt{P}$, where r = exclusion radius miles and P = thermal power kilowatts).

The Commission was at this time siting its new experimental reactors, which were becoming more powerful and simultaneously more dangerous to have near population centers. A remote reactor proving ground was needed, and site selection began based upon the older criteria and the list of ten sites drawn up in 1948. The selection process was poorly handled from the start, involving confusion over the project's scope, an incorrect disclosure to a state politician, the rewriting of site criteria during the selection process, and the replacement of the lead site at the last minute.

A congressional hearing was held in April and May 1949 to investigate the many problems involved. Pocatello was selected in March 1949; the acquisition process was completed when the Arco Naval Proving Ground was transferred to the AEC late in the year. The lessons learned in siting the new facility, the Idaho Reactor Testing Station, were immediately put to use in 1950 when the new production facility site was under study.

LOOKING SOUTHWARD

When AEC Commissioner Sumner T. Pike negotiated with the Du Pont Company to undertake the construction of the new reactor project, he made it clear that the firm was to be responsible for all phases of the project, including site selection. In progress reports to the JCAE about the site-selection process, Commission chairman Gordon Dean emphasized to the congressional committee that Du Pont had the decision-making power over the location of the new site. He tempered this in more public documents, referring to recom-

mendations that would be submitted by Du Pont for review by a government site-review committee. This difference in emphasis may reflect a concern over how the site-selection process would be viewed by the press and public who, in the 1950s, had become part of the process.[6]

Strategic concerns, such as the number of reactors and separation facilities to be constructed, would determine the size of the new reservation. Du Pont and the AEC would settle these issues as the scope of work developed. However, defense issues were paramount in the site-selection process, with the Military Liaison Committee drawing up a map of defense zones for the AEC's Production Division. The preferred zone for the new complex, the First Defense Zone, stretched across the South to central Texas and north to Virginia and the lower Midwest. A 100-mile strip along the coast was excluded, along with all of Florida. Two other zones, the Second and Third Defense Zones, were shown; however, both were vulnerable to Soviet bombers from Siberia. The "Northeast Industrial Triangle" was to be avoided by specific request of the Department of Defense; it would make the new complex even more enticing as a target for Soviet bombing should the complex be located there.

A major departure from earlier site-selection procedures was the exclusion of a "government town" from the scope. Previously, worker's towns, known as atomic cities, were incorporated into the atomic energy reservations for secrecy and for public safety. The three atomic cities of Oak Ridge, Richland, and Los Alamos, were owned in their entirety and administered by the Commission.

> Everything from cemeteries and sidewalks to homes and grocery stores was Government property. In 1947 Oak Ridge and Los Alamos were still closed communities surrounded by patrolled security barriers. Even relatives of residents could not enter without a pass. Behind the fences the scientists, engineers, technicians, and laborers who manned the production plants and laboratories lived with their families in an isolated world of their own. The Army and then the Commission, through local management contractors, operated the bus systems, collected rents, delivered coal, repaired homes, manned the fire departments, operated the movie theaters, leased stores, and ran the schools.[7]

The communities were an unwelcome legacy for the AEC, which began to seek ways to divest themselves of the problems inherent in managing community life. The Commission looked to the National Housing Agency for help in charting a future course for these communities, and began planning ways for the towns to incorporate, and for the residents to own their homes and commercial enterprises and to begin to manage their community life. Hewlett and Anderson point out that beyond these practical matters there also important policy considerations before the Commissioners in January 1950. While self-government and free enterprise appeared to be the way to go, the Commission could not let these aims interfere with the primary purpose of these communities. The towns existed because they supported the Commission activities. However, the Commission could not guarantee the operation of any production facility over time. Changing missions and plant obsolescence could lead to financial doom for a one-industry town.[8]

A solution was reached for the new production facility that would avoid these issues. The construction of a government town was simply eliminated from the project scope. Instead, the Commission asked Du Pont to look aggressively for areas that could absorb the new operations staff within established communities. Driving the point home, AEC Commissioner Sumner T. Pike warned that should Du Pont site the new complex in an area that could not support the operations staff, then Du Pont would assume responsibility for the construction and administration of such a community.[9]

The defense considerations and the housing requirement made the South a leading candidate for the complex. Federal dollars and large industrial complexes were welcome, and word that the South was under consideration spurred trips to Washington in search of favor. Truman's office received enough visits that he advised AEC's Gordon Dean not to brook any political pressure in the decision making process.[10] While Truman's words underscored that a location should be chosen on its own merits, the new parameters—that an existing community infrastructure be in place within the preferred defense zone—would not fully erase such pressures for the site survey team.

PROGRESSIVE ELIMINATION

On June 19, after discussion with Du Pont, the Commission's Production Division sent preliminary criteria to the Office of the Chief of the Corps of Engineers. These criteria would be later expanded, as process development was concurrent with the site-selection process. The Corps was first asked to identify any government-owned reserves that were between 100 and 150 thousand acres (approximately 350 square miles) within the preferred zone of defense that could be considered isolated, but also was within 15 miles of a neighboring community with a population of 25,000 to 50,000 individuals. Sufficient water and transportation links were also initial considerations.

The site survey team, composed of two Du Pont men and an AEC representative, then further consulted with the Corps of Engineers on all potential areas within the Corps' Ohio River, South Atlantic, and Southwestern Divisions, an area that roughly corresponded to the preferred defense zone. The Commission had clearly stated that all sites with potential should be investigated to avoid problems that had cropped up on earlier site selections, notably with the Pocatello site. The Corps of Engineers recommended nearly 100 areas that had potential, at least on paper.

The AEC Production Division then requested that the Corps provide detailed information on all of them, keeping tight scrutiny over the selection process. Changing plant requirements suggested that sites outside the preferred region should be considered based on the need for cold water and lower wet-bulb temperatures. The territory for the search was thus expanded and, by mid-August, profiles of 105 potential sites had reached Washington. These were duly sent to Du Pont for review.

Over time, the chemical firm had developed a meticulous procedure for selecting its commercial plant sites. This method, expanded to fit the search for the new AEC production site, allowed Du Pont to hit the ground running once the basic criteria had been defined. At its heart, the Du Pont site-selection procedure involved the "systematic investigation of significant factors and the correct evaluation of their importance." Through a logical progression of six steps, undesirable sites were eliminated, acceptable sites were

further evaluated, and the most appropriate site that filled the selection criteria was chosen.[11]

1 - Basic data
2 - Preferred region
3 - Office study
4 - Preliminary field inspection
5 - Preliminary selection and optioning
6 - Evaluation for final selection.

The documentary record shows that Du Pont assiduously followed each step in the site-selection process for the new production facility, which was identified as Plant 124 in Du Pont reports and memorandums that date to the summer of 1950. Charles H. Topping, a scholarly looking man with a neat mustache who would become Du Pont's principal architect and civil engineer in 1954, was responsible for the search for Plant 124's location.

Topping was a New York native who received his degree in civil engineering from Massachusetts Institute of Technology in 1928. After school, he worked overseas first in Venezuela's oil fields, then in Persia as a superintendent of construction for the South Persia State Railways, the rail system that later carried American war supplies to Russia. While in Persia, he also worked as surveyor for a University of Pennsylvania archaeological expedition. When he returned to the states in the mid-1930s, he worked first in New York, then in Texas, where he designed oil refinery structures and Houston's municipal water facilities. He accepted a job as a civil engineer with Du Pont's Design Division in 1942. Like others on the staff, he became part of Du Pont's Hanford team, working on that facility and other wartime industrial plants.[12] In 1955, at the Nuclear Engineering and Science Congress held in Cleveland, he gave a professional presentation on the expanded use of the Du Pont method of selecting chemical-plant sites for the reactor production site. His paper gives an insider's look at the way the massive search was conducted.

The basic data developed by the AEC and Du Pont were organized into six categories: water, wastes, labor, isolation, acreage, and power. Data were assembled from the Corps of Engineers, branches of the Department of the Interior, and Du Pont. In some categories, the survey team devised calculations or formulae that would allow for comparison between sites. For example, a formula was created that would simultaneously fulfill the isolation requirement while identifying a supporting population and civic infrastructure. The preferred region within which to locate the site, about 25 percent of the continental United States, had already been selected by the AEC under guidance from the Department of Defense.

With this data in hand, the "office study" step commenced. The team plotted "basic data" on the Strategic Map of the Corps of Engineers, locating all potentially acceptable sites within the preferred region and eliminating unsuitable sites. Military requirements specified the automatic elimination of certain areas surrounding specific cities and installations.[13]

> Water supply was again the first factor used to find all possible acceptable areas and eliminate unusable areas. The economic limit for pumping the required large quantity of water was judged



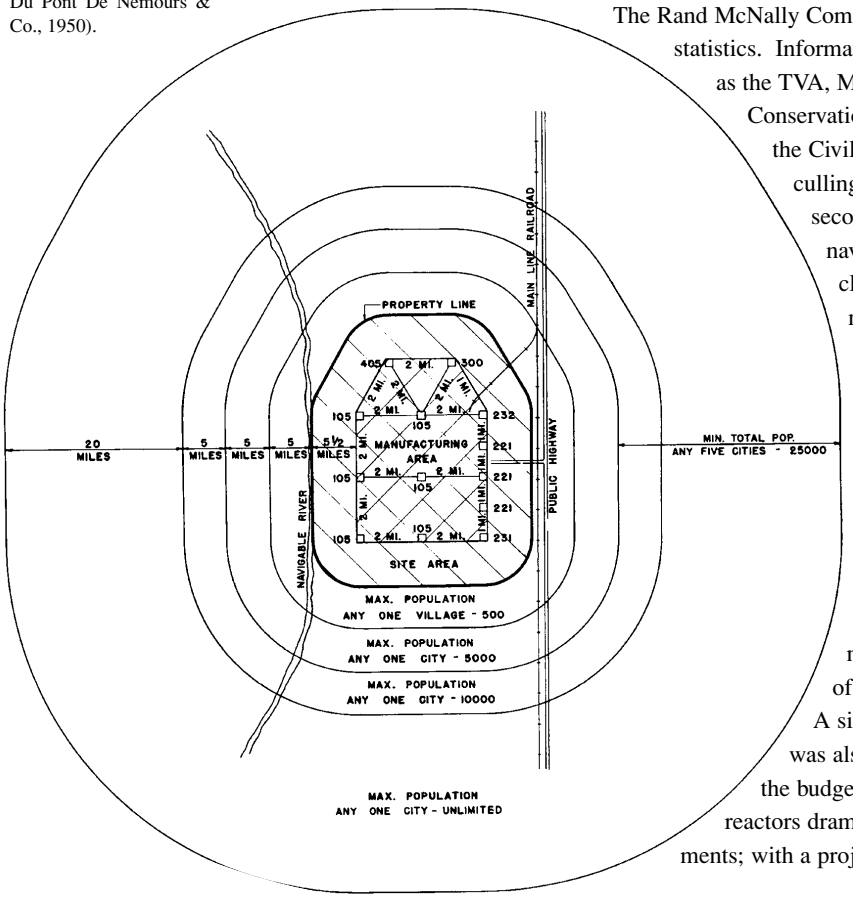
Charles H. Topping, Du Pont's principal architect and civil engineer, was responsible for the "plant survey." Topping gave a professional presentation in 1955 at the Nuclear Engineering and Science Congress in Chicago on the application of Du Pont's chemical plant selection process to the selection of the new production facility for the AEC. Source: *SRP News and Views*, October 22, 1954.

to be less than 20 miles. Consequently, we were able to limit the area searched to a 20-mile-wide band on either side of rivers or bodies of water from which the required amount could be safely obtained. These strips were plotted on the Strategic Map of the Corps of Engineers. The population of all communities in the neighborhood of these strips was also entered on the map.

[A diagram] was drawn to scale on transparent plastic. It was laid on a map with the plant area falling within the previously mentioned 20-mile-wide strips on either side of the rivers or lakes. Where the population spacing and acreage requirements shown on the diagram could be fitted into the data on the map, that area was marked for further study. This rapid method positively located every potentially acceptable area and eliminated relatively large unusable areas from further consideration.[14]

The First Defense Zone yielded 114 general areas within 20 miles of a firm source of 200-cubic-feet-per-second (20 cfs) of surface water, with the required supporting population and required isolation from cities, installations, and population centers of more that 5,000 people. This number was reduced to 84 specific sites by the application of isolation criteria for all communities shown on the U.S. Corps of Engineers Strategic Map. The Rand McNally Commercial Atlas of 1950 was used for population statistics. Information on maps from the Army and agencies such as the TVA, Mississippi River Commission, State Conservation Departments, Department of Agriculture, and the Civil Aeronautics Authority was also reviewed. The culling process continued when Du Pont applied the secondary criteria of terrain, freedom from floods, navigable streams through the site, accessibility, climate, pumping lift, and pumping distance. The number of potential sites was reduced to 17. Three local sites made it to this shortlist—two in South Carolina and one in Georgia.

In order to apply the basic criteria at each candidate site consistently, Du Pont's engineers formulated a template for use that highlighted each concern from transportation to safely dispersing manufacturing units. In the "Diagrammatic Outline of Certain Basic Criteria: Used for Determination of Manufacturing Area, Purchased Property, Population Support and Isolation," No. 105 represents a reactor, Nos. 221, 231, and 232 refer to separations facilities, No. 300 refers to a metal fabrication facility, and No. 405 was used to refer to a technical testing facility. When Topping was conducting the survey, six reactors were under consideration as well as three separations units. The sixth reactor and third separation unit were later dropped from Du Pont's scope of work. Source: Charles Topping, *Plant 124–Site Survey*. (Wilmington: E. I. Du Pont De Nemours & Co., 1950).



CHANGING THE BASIC CRITERIA

In June 1950, the North Korean Army drove across the 38th parallel into the Republic of Korea. In response, the AEC added three more heavy-water reactors to the Du Pont scope of work, bringing the total to five for the new site. A sixth, a power-producing heavy-water reactor, was also initially planned, but was later dropped from the budget in November 1952.[15] The addition of these reactors dramatically changed the previous water require-

ments increased from 200 cfs to 600 cfs. Du Pont's engineers eliminated ten sites on that basis and then two more on late-arriving secondary criteria information. Five sites within the First Defense Zone made it through the "office study" step; two in South Carolina, two in Texas, and a fifth in Oklahoma.[16] However, the leading candidate among this group was "South Carolina No. 5, 22 miles southeast of Augusta, Georgia" on the Savannah River.[17]

Basic Site Requirements

Manufacturing Area - Potential sites were first screened on the basis of a one-mile-square manufacturing area with topography suitable for building. Final consideration was on the basis of at least twelve separate plant locations, each with topography suitable for the construction of the main manufacturing buildings and their attendant service buildings. Six reactor locations and one test-reactor location must be spaced approximately two miles apart. Five separation plant locations must be spaced approximately one mile apart. There must be approximately a two-mile spacing between a reactor and any other plant.

Site Area - The site area will include not only the manufacturing area proper, but also a 5.5-mile-wide zone outside the critical manufacturing area as defined above. (Since this criterion was set, power levels of reactors greater by some 25 percent appear feasible so that a 6-mile zone is more desirable.) All inhabitants or personnel not connected with the plant must be evacuated from the total site area.

Supporting Population - There should be a minimum distance of 20.5 and a maximum of 40 air miles from the edge of the manufacturing area to the center of a population of 25,000 individuals. Smaller communities of 5,000 individuals up to a total of 25,000 individuals were an acceptable equivalent.

Isolation - The size of communities and distances from the edge of the manufacturing area shall be limited as follows:

Circular area 5.5–10.5 miles:	maximum 500 persons
Circular area 10.5–15.5 miles:	maximum 5,000 persons
Circular area 15.5–20.5 miles:	maximum 10,000 persons

Water - The source of water should be ample to furnish the following quantities without damage to other presently established users.

Water Requirements in Cubic Feet per Second (cfs) for Six Reactors

Method of Cooling	Once-Through	Cooling Tower
Withdrawal for Plant	600	150
" Electric Power Generation	0	30
Total	600	180
Consumptive Use – Plant	50	50
" Electric Power Generation	0	15
Total	50	65

Electric Power - 125,000 kilowatts was considered desirable for use in six reactors. Uninterrupted power supply is of utmost importance to operation in all manufacturing areas.

Railroad - The site must be accessible by railroad.

Highways - The site must be accessible by highway.

Meteorology - The possibility must be recognized that radioactive gases may be discharged to the atmosphere, and situations can be visualized whereby a large cloud of active materials could be discharged. Consequently, a favorable site would be one where the prevailing wind velocity is above 3 miles per hour and the prevailing wind direction, if any, is away from centers of population closer than 20 miles. Sites with high frequency of fog and severe sleet conditions, extended seasons of snow cover if close to a center of population, or low frequency of sunshine would be undesirable. Climate in general should be as favorable as possible for plant construction and operation, and wet-bulb temperatures should not exceed 75 degrees F during more that 2.5% of the summer hours if cooling towers are to be used.

Geology - The geological substructure and overburden should be stable. The area should have a low earthquake record and probability. Allowable bearing for foundation loads of 12,000 psf or lb/ft2 may be required. It is desirable but not essential that the top strata be relatively impermeable to prevent contamination of groundwater or public water supply in the event of accidental discharge of radioactive wastes. About 1.5 million cubic yards of concrete and road aggregate will be required. This material should be obtainable nearby.

Construction and Operating Costs - The site should have characteristics, which will assure economy consistent with other requirements for satisfactory operation.

Source: Charles Topping, *Plant 124–Site Survey*. (Wilmington: E. I. Du Pont De Nemours & Co.,1950), 1–3.

In October, the "preferred region" changed based on the possibility that savings could accrue from using colder water to cool the reactors. Du Pont recommended that a search be made within the Second Defense Zone and in neighboring areas. Topping notes that the extended search used the same methodology, but was limited to likely sources of cold surface water or ground water from aquifers replenished by large streams. Thus the shores of lakes Superior, Michigan, Huron, and St. Clair were considered, as well as areas along the Missouri, Mississippi, St. Croix, and Wabash rivers. The North Platte and Arkansas rivers were also evaluated. Six "cold-water sites" survived the office study step.

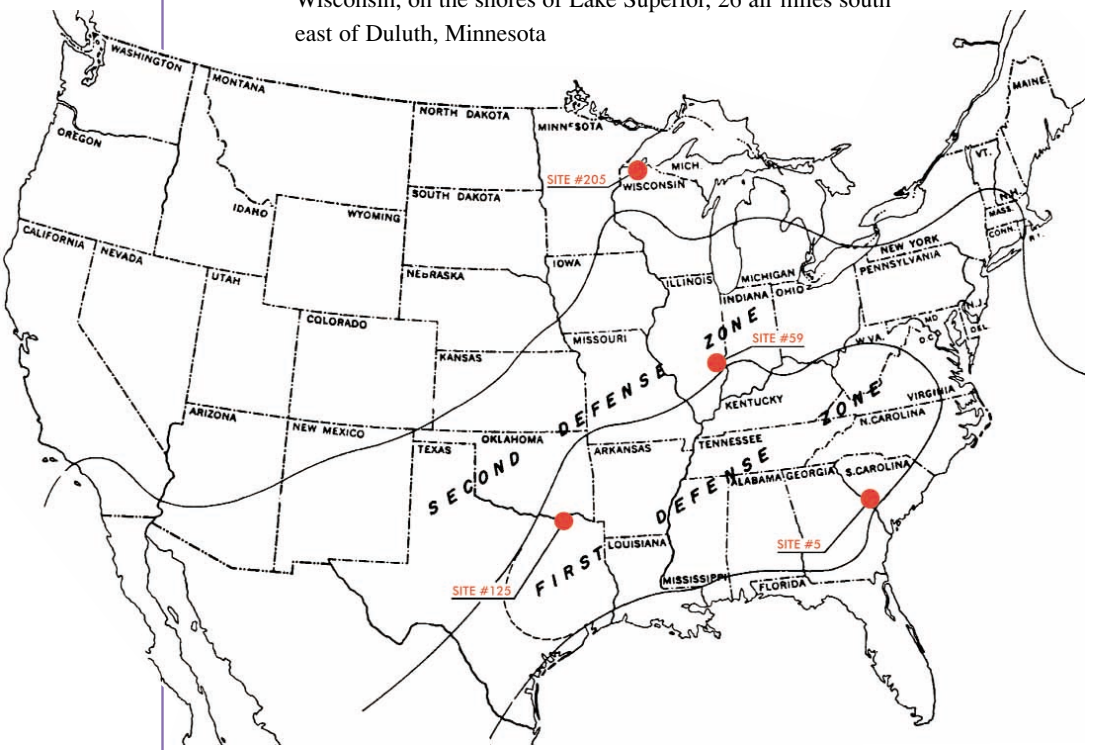
Personnel from the AEC, the Corps of Engineers, and Du Pont conducted preliminary field inspections of eleven sites and eliminated nine. The final candidates were reduced to four, two within the First Defense Zone, one with moderately cold water temperature in the Second Defense Zone, and a fourth adjacent to the Second Defense Zone.

Site Number 5 – Located in Aiken and Barnwell counties in South Carolina on the Savannah River, 20 air miles southeast of Augusta, Georgia, and 15 air miles south of Aiken, South Carolina

Site Number 125 – Located in Fannin and Lamar counties in Texas and Bryan and Choctaw counties in Oklahoma on the Red River, 15 air miles east of Bonham, Texas, and 76 air miles northeast of Dallas, Texas

Site Number 59 – Located in Crawford and Clark counties in Illinois and Sullivan County in Indiana on the Wabash River, 20 air miles southeast of Terre Haute, Indiana

Site Number 205 – Located in Bayfield and Douglas counties in Wisconsin, on the shores of Lake Superior, 26 air miles south east of Duluth, Minnesota



This illustration was used in *Plant 124–Site Survey Report* to show the location of the final four candidate sites and their relationship to the preferred military defense zones. Strategically, the preferred zone for the new complex was the First Defense Zone that was least vulnerable to Soviet bombers. Site No. 5 in South Carolina became the Savannah River Plant. Source: Charles Topping, *Plant 124–Site Survey*. (Wilmington: E. I. Du Pont De Nemours & Co., 1950).

At this juncture, an overview committee was brought in to review the work to date. The Commission had created a Site Review Board for this purpose in August. The board was headed by General L. J. Sverdrup, an Army Engineer in the Pacific Theater in World War II and later head of the engineering consulting firm of Sverdrup and Parcel, Inc. of St. Louis, Missouri. Other members included: A.T. Waidelich, vice-president of The Austin Company of Cleveland, Ohio; H. L. Bunce Jr., vice-president of Stone and Webster Engineering Corporation of Boston, Massachusetts; James F. Towers of Ford, Bacon, and Davis, Inc. of New York City; and, finally, W. S. Finlay, executive vice president of J.G. White Engineering Corporation of New York City.[18] Considered national experts in site selection, the committee reviewed the selection procedures to date and gave their go-ahead for the final selection process.

FINAL SELECTION

G. P. Church, J. A. Burns, W. C. Kay, and J. B. Tinker of Du Pont visited the First Defense Zone sites between August 29 and September 1. In almost checklist fashion they ran through the many considerations involved, citing when each site had the "edge" over the other. South Carolina's No. 5 had a construction advantage, while the Texas site was considered to have better population support. The availability of skilled labor was scarce at both venues and the report notes that the South Carolina population, both white and African-American, was rural and lacking in industrial experience. The Texas site was composed of more productive and fertile land than its South Carolina counterpart, whose land was described as marginal. The bottom line stressed by the survey was that both sites met the general criteria upon which the site survey was based.[19]



Du Pont's survey technical advisors conducted a field inspection of Site No. 5 by land, air, and boat in October 1950. A lifejacketed and capped Robert Mason, future Field Project Manager for the Savannah River Plant, is in the center standing on a Savannah River dock. The other men in the photograph may be Andrew McCullin and George Dutcher who were also part of the Du Pont team. Courtesy of the Mason Family.

A second round of study and evaluation began in which the four sites were vigorously reevaluated. In addition to the physical comparisons drawn from the field surveys, economic comparisons were made based on an arbitrary plant design. The team worked diligently, almost like devil's advocates, to show what advantages or disadvantages each site possessed in comparison to the others. The study of cost differentials, with the assumption of a fixed reactor design and an average productivity, did not elicit any clear-cut winners.

For waste disposal and contamination, the Savannah River location appeared to be the most desirable for "normal operation or catastrophe." The high percolation rate of the area's soils could facilitate locating and correcting an unintentional spill. Also, the only public water intakes were 160 miles downstream, a distance thought sufficient to dissipate any possible contamination.

The four candidate sites were considered comparable in terms of population support, with operating labor and housing conditions judged inadequate at all four sites. However it was perceived that the Savannah River communities could better absorb the impact of the project. Community data was collected and presented in tabular form noting populations, housing and transportation services available, and numbers of hotels, banks, schools, and hospitals. Savannah River was estimated to have the lowest construction labor rate, best met the isolation criteria, and was composed of lands that were not extensively cultivated in food crops.

What's Coming?

In the fall of 1950, an air of excitement pervaded the sleepy little town of Ellenton nestled contentedly in South Carolina's historical lowlands near the Savannah River. For several months its easygoing folk had noticed unusual events happening in and around their community; and they knew they were significant: Why were boring crews circulating the town? Why were soil samples needed? Why were strangers continually coming and going? Since no one seemed to understand these mysterious missions, speculations flew over the community like migrant birds. The most likely conclusions were: either oil had been discovered or useful materials found in the soil.

But regardless of what might come, the people would welcome it to spur their lagging economy and increase the population. Since this agricultural community had few natural resources to attract newcomers, it suffered from a stunted growth. And even though industry was slowly moving in, it wasn't sufficient to give the impetus needed for the progress the people longed for. Now after all these years Ellenton was fast becoming a nonagenarian; the population had barely reached a thousand. So, like excited and impatient children waiting for Santa on Christmas Eve, the people waited for developments.

Quoted from Louise Cassels, T*he Unexpected Exodus*, (Aiken, SC: Sand Hill Press, 1971), 1.

Other favorable attributes included good topography with easily accessible rail and highway links, no bridges needed to be constructed, little clearing was needed, and the land needed for the manufacturing core was well above the maximum flood level. The Savannah River had a seven-foot-deep navigable channel, making delivery of materials by barge or boat possible. Some subsoil testing was undertaken, and exploratory drilling conducted in September showed that some corrective measures needed to be taken. However, the costs involved would be offset by the better excavation and drainage conditions the site offered. Climate and the frequency of natural disasters such as earthquakes, hurricanes, and tornadoes were considered.

A second field inspection of the South Carolina site occurred on October 17. The South Atlantic Division, under orders of Colonel A. G. Kirchoff, provided military aircraft for an aerial inspection. H. A. Robinson of the Corps and George Dutcher, Andrew McCullin, and Robert Mason from Du Pont were invited as technical advisors. Mason summarized the three-day "close field investigation of Site 5 by land, air, and by boat in a report titled *Plant Investigation—Project 8980, Site #5*.[20] Oral interviews with descendants of the survey crew note that the work was done in secrecy with participants using assumed names for work done prior to the site selection.[21]

The technical advisors, who were in Du Pont's Construction and Design Division, tentatively identified twelve sites as building areas. A heavy-water production area (400 Area), five chemical separations and fabrication facilities (200 areas), and six reactor areas (100 areas) were marked on a map and photographed. This number and types of proposed building areas clearly shows that Du Pont was working with preliminary data at this juncture.

Area A - 400 Area (Building 405)
Area B - 200 Area (Building 221)
Area C - 200 Area (Building 221)
Area D - 200 Area (Building 231)
Area E - 200 Area (Building 221)
Area F - 200 Area (Building 232)
Area G - 100 Area (Building 105)
Area H - 100 Area (Building 105)
Area J - 100 Area (Building 105)
Area K - 100 Area (Building 105)
Area L - 100 Area (Building 105)
Area M - 100 Area (Building 105)

No identification was made for a 300 area because Mason felt there was sufficient area that it could be located with ease. A temporary construction area and camp could be set up two miles west of Dunbarton on the north side of then State Road 64. A plant siding was also tentatively located. In general, the proposed manufacturing area looked very acceptable from a construction standpoint.

The survey team flew from Bush Field to Clarks Hill Dam, then to the proposed site area. The detour to Clarks Hill was to inspect progress on the project, which had eight months of work left until completion, according to Robinson. The presence of a completed Clarks Hill Project was initially considered a major factor in the selection process, and

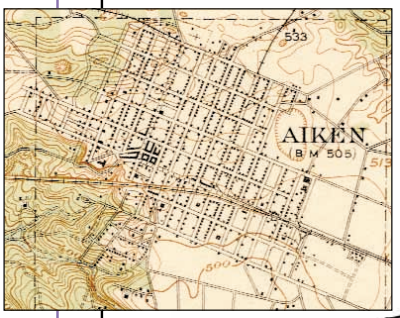
there is no doubt that Lester Moody, Augusta's Chamber of Commerce secretary, and Barnwell's Edgar Brown were consulted. The possibility of the atomic energy plant would help fuel the completion of the dam, much to their liking. The survey team also toured the area by boat, looking at soil types, and exploring the extent of the swamp along the river, to investigate the need for cofferdams for the pumphouses and to assess the principal drainages.

From the tone of Robert Mason's conclusions, it appears that Site 5 was the leading candidate. After pointing out the site's many physical advantages from a construction man's perspective, he noted that the low pay scales (the average in Atlanta was then $1.95 per hour) would make it difficult to attract the number of experienced mechanics needed for the job. In pragmatic terms he also advised that racial discrimination could be a problem at the South Carolina site. Du Pont had already faced the segregation issue by constructing and operating its private Orlon plant near Camden, South Carolina, in 1950. The documentary record suggests that Du Pont was already considering how to uphold the nation's law while working within a milieu that did not. Unlike their Camden plant, the new plant was a federal project. Mason astutely noted how the other large federal property in the site area was handling segregation. "A check of Camp Gordon reveals that within the reservation the Military practice is no segregation; however, on bus lines leaving the reservation, there prevails the practice of segregation. On a project such as we expect to construct, it appears that the no-segregation law would be impractical to administer."[22] Later studies show that Du Pont explored this issue at the state's other federal reservations, seeking information not only on the "official" policy but also on how that policy was actually implemented. Notably, race would not surface in subsequent reports as an issue.

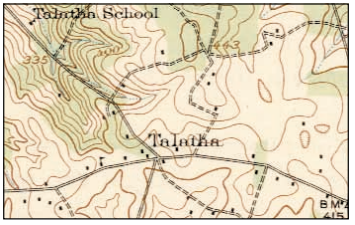
SOUTH CAROLINA SITE NO. 5

The recommended site was located in South Carolina's western Aiken and Barnwell counties, situated within two subdivisions of the Atlantic Coastal plain: the Aiken Plateau and the Alluvial terraces that lie along the river. Eighty percent of the site was situated within the Aiken Plateau, where elevations ranged between 300 and 385 feet. The terraces were composed of three tiers of varying widths banding the river. From north to south, six streams dissected the tract: Upper Three Runs Creek, Four Mile Creek, Pen Branch Creek, Steel Creek, Hattie Creek, and Lower Three Runs Creek. Five streams emptied into the river in a southwesterly direction; the sixth, Lower Three Runs, flowed to the southeast and drained the eastern portion of the proposed site.

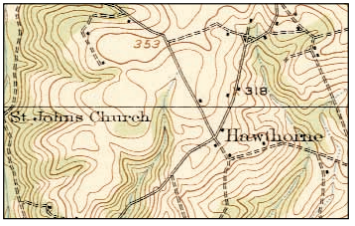
Reconnaissance of the proposed site by the Site Survey Committee revealed its agricultural economy, and community data gathered during the site-selection process underscored that fact. Sixty-seven percent of the proposed site's acreage was wooded, while thirty-three percent was either cultivated or used for pasture. Corn, grains, cotton, and peanuts were grown along with watermelon, soybeans, seed lupine, and grain sorghum. The farm operations encountered ranged from one-mule tracts to machine-operated multi-tractor farms. Small farms predominated, with larger farms operating on a sharecrop or tenant basis. Appraisers would later verify what Du Pont saw from its field inspections, that most of the farms were tenant-operated and the majority of the agricultural work force was African-American.



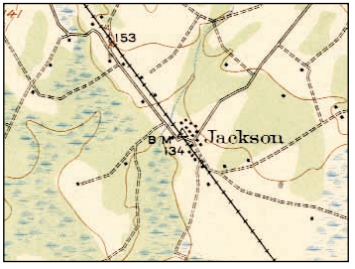
AIKEN, 1919
USGS Quadrangle Aiken, S.C., 1921.



TALATHA, 1921
USGS Quadrangle Talatha, S.C., 1921.

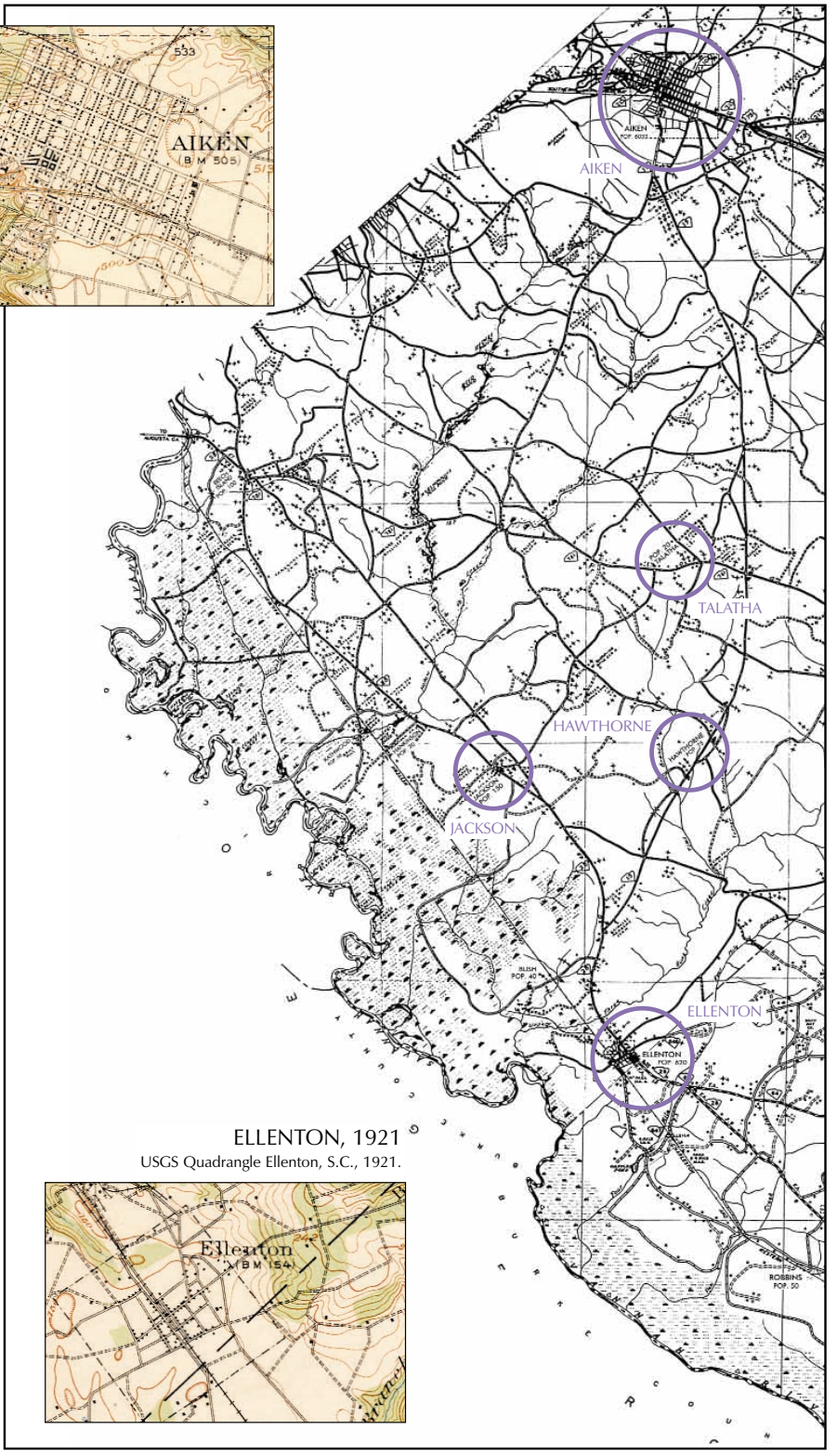


HAWTHORNE, 1921
USGS Quadrangle Talatha, S.C., 1921.

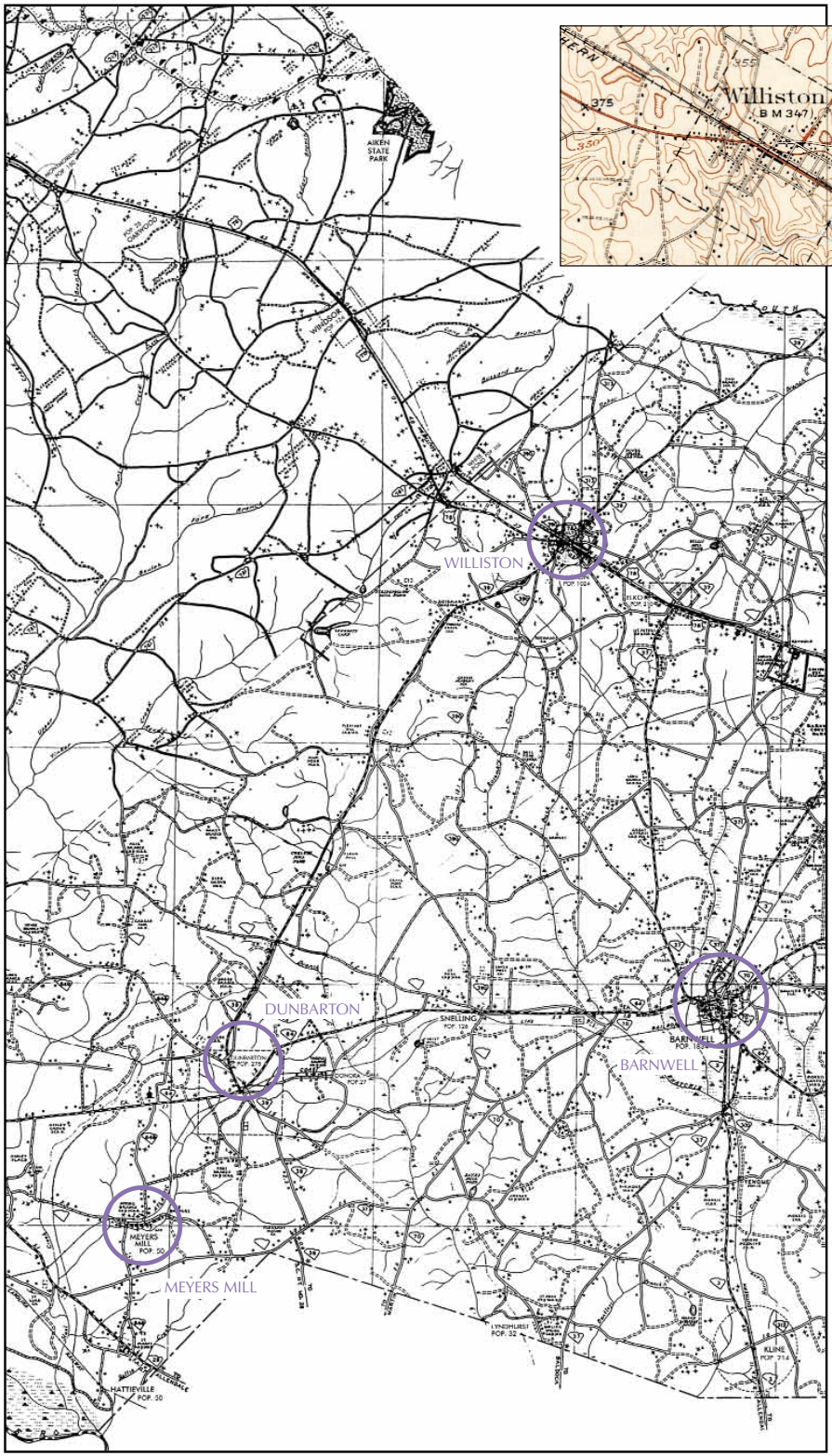


JACKSON, 1921
USGS Quadrangle Augusta, S.C.-GA., 1921.

Savannah River Site Area and Environs. Compiled Map of Site Area Showing Communities, 1939. Base Source: Barnwell County Highway Map and Aiken County Highway Map, 1939. Courtesy of University of South Carolina, Cooper Library, Columbia, SC.



ELLENTON, 1921
USGS Quadrangle Ellenton, S.C., 1921.



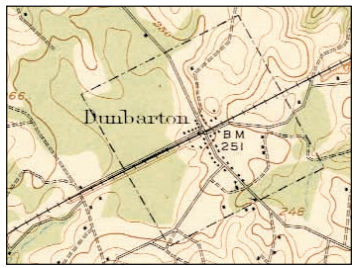


WILLISTON, 1927
USGS Quadrangle Williston, S.C., 1927.

Source: USGS Topographic maps from 1919, 1921, and 1927 are courtesy of New South Associates, Stone Mountain, GA.



BARNWELL, 1919
USGS Quadrangle Allendale, S.C., 1919.



DUNBARTON, 1921
USGS Quadrangle Ellenton, S.C., 1921.



MEYERS MILL, 1921
USGS Quadrangle Ellenton, S.C., 1921.

Community statistics were gathered for each candidate site that contained necessary data on the availability of housing, schools, medical facilities, infrastructure, as well as the presence of cultural and religious advantages. The assessment of available housing if Site 5 was to be selected was of primary importance. When this data was gathered only Barnwell, Aiken, Allendale and Augusta had available housing.

The proposed site was rural but not isolated. The nearest large urban centers were Augusta (20 miles northwest), Atlanta (155 miles west and north), and Savannah, Georgia (85 miles to the southeast) and Columbia, South Carolina (65 miles northeast). Community data was gathered on 21 towns with populations of over 1,000 individuals within a 50-mile radius of the site. The area under investigation contained a number of communities: Ellenton, Jackson, and Hawthorne in Aiken County; and Dunbarton, Meyers Mill, Robbins, Leigh, Snelling, and Hattieville in Barnwell County. Ellenton, a post-Civil War railroad community and local trading center, was the largest with a population of 600. Dunbarton, also a railroad town, had a population of 231 individuals. The remaining communities were smaller. Meyers Mill possessed some stores and a cotton gin, while Leigh

Community Data Collected by During Site Selection Process, Extracted.

Town	App. Miles from Center of town to edge of MFG Area	Population	Transportation	Hotels	Banks	Schools	Hospitals
Williston, SC	14 mi	1,107	State hwy, RR, Bus	1	0	consolidated high and grammar	0
Barnwell, SC	18 mi	1,922	State hwy, RR(2), Bus(2)	1(45 Rms)	1	high, grammar, African American school	emerg. ctr
Aiken, SC	19 mi.	7,067	U.S., State hwy, RR(1), bus(3)	5	2	high(2), elementary(2), private	3
Langley, SC	21 mi.	2,500	U.S., State hwy, RR(1), bus(1)	0	0	high, grade	0
Bath, SC	21 mi.	1,000	U.S., State hwy, RR(1), bus(3)	0	0	grade	0
Graniteville, SC	22 mi.	2,000	U.S., State hwy, RR(1), bus(1)	1	1	high, grade(2)	0
Blackville, SC	28 mi.	1,456	U.S., State hwy, RR(1), bus(2)	1	1	high, grade	0
Augusta, GA	24 mi.	71,000	U.S., State hwy, RR(6), bus(6)	6	6	high(5), jr. high (2), African American school	4
Allendale, SC	34 mi.	2,217	U.S., State hwy, RR(2), bus(2)	6	1	high, grade	0
Denmark, SC	33 mi.	2,810	U.S., State hwy, RR(2), bus(2)	1	1	high, grade	0
Fairfax, SC	39 mi.	1,500	U.S., State hwy, RR(1), bus(2)	2	1	high, grade	1
Edgefield, SC	41 mi	2,502	U.S., State hwy, RR(2), bus(1)	1	1	high(2), grade(2)	1
Johnston, SC	51 mi.	1,385	U.S., State hwy, RR(1), bus(3)	2	1	high, grade(4)	health ctr.
Batesburg, SC	35 mi.	3,188	U.S., State hwy, RR(1), bus(2)	2	2	high (2), grade(2)	1
Hampton, SC	48 mi.	2,000	U.S., State hwy, RR(1), bus(1)	1	1	high, grade	1
Estill, SC	50 mi.	1,661	U.S., State hwy, RR(1), bus(1)	1	1	high, grade(2)	0
Orangeburg, SC	50 mi.	10,275	U.S., State hwy, RR(2), bus(2)	3	3	high, jr. high, grade(10)	2
Varnville, SC	50 mi.	1,200	State hwy, RR(1), bus(1)	0	1	high, grade(2)	1
Branchville, SC	50 mi.	1,650	U.S.,State hwy, RR(1), bus(1)	1	1	high, grade	1
Bamberg, SC	40 mi.	3,000	U.S.,State hwy, RR(1), bus(3)	1	1	high, grade	0
Saluda, SC	51 mi.	1,590	U.S.,State hwy, RR(0), bus(2)	1	1	high, grade	health ctr.

was synonymous with a box and crate manufactory, the Leigh Banana Case Company, that operated at that site between 1904 and 1954, employing about 300 people in 1950.

Camp Gordon, Oliver General Hospital, Daniel Field, and the Augusta Arsenal were military installations less than 26 miles from the proposed site. Six airports—five municipal fields on which there was a recapture clause in case of war, and one USAF inactive airfield—were within 40 miles.[23] The existing road system was composed of state highways that intersected with U.S. highways and, in addition, there was a well-defined network of unpaved farm-to-market dirt roads. Rail service was already in place. The Charleston and Western Carolina (CWC) Railroad paralleled the river, providing service from Savannah to Augusta, and the Atlantic Coast Line Railroad ran from Barnwell to

Source: Charles Topping, *Plant 124–Site Survey*. (Wilmington: E. I. Du Pont De Nemours & Co., 1950).

Town	Recreation	Available Housing	Housing Under Construction	Electricity	Gas	Churches
Williston, SC	Movie, pool	limited	limited	yes	0	3
Barnwell, SC	movies(2), golf, state park, pool	0 houses, 40 apts plenty of capital	0	yes	0	4
Aiken, SC	movies(2), polo, golf(2) horseriding	100 (mostly apts) plenty of capital	mostly homes	yes	yes	15
Langley, SC	0	0	0	yes	0	5
Bath, SC	Park	0	0	yes	0	3
Graniteville, SC	park,pool, baseball	0	0	yes	0	6
Blackville, SC	movie, baseball, pool	0	0	yes	0	5
Augusta, GA	movies (10), parks, golf, baseball	many apts avail just built, plenty of capital		yes	yes	130
Allendale, SC	movie, park	12 houses	0	Yes	0	5
Denmark, SC	movies(2). parks(2)	0	0	yes	0	4
Fairfax, SC	movie, pool	0	0	yes	0	5
Edgefield, SC	movie. pools(2)	10	0	Yes	0	10
Johnston, SC	movie, park	0	0	Yes	0	5
Batesburg, SC	golf, movie, pool	16	24	Yes	0	6
Hampton, SC	movie, pool	4	8	Yes	0	4
Estill, SC	movie, pool	0	0	Yes	0	6
Orangeburg, SC	movies (6), stadium, parks(8), rec ctr	70	100	yes	0	7
Varnville, SC	movie, pool	3	0	yes	0	4
Branchville, SC	movie, pool	0	0	yes	0	3
Bamberg, SC	movies(2), pool, baseball	capital available		not given	not given	not given
Saluda, SC	movie, baseball	0	0	yes	0	4

Robbins where it joined the CWC line. The CWC ran through Ellenton and Dunbarton, and the smaller communities were railroad stops on the line.

Three companies provided power to area residents and businesses: South Carolina Electric and Gas Company, Aiken Electric Cooperative, and Salkahatchie Electric Cooperative. Two phone companies, Southern Bell and Cassels Telephone Company, were communications providers, and there were telegraph offices in Ellenton and Dunbarton. U.S. post offices were located in Meyers Mill, Ellenton, and Dunbarton.[24]

DU PONT'S RECOMMENDATION

On November 10, 1950, Du Pont advised Walter J. Williams, the Commission's Director of Production Division, that the plant be located on the Savannah River. Five reasons were given for the choice:

1 - It met the basic criteria for isolation from centers of population. There was sufficient room to locate six reactors no less than two miles apart with minimum air-line distance from reactors to Aiken, South Carolina, and Augusta, Georgia, of nearly 20 and 25 miles, respectively.
2 - Savannah River water was considered chemically excellent.
3 - The land to be acquired was considered marginal for agricultural use, producing mainly non-food crops such as cotton.
4 - The soil was characterized as sandy and well drained. The climate was favorable to construction.
5 - Based on generic estimates, lower construction costs were expected in South Carolina.[25]

The Texas site was eliminated due to its poor water quality, while the Midwest site was not sufficiently isolated and the plant would be placed in a farming environment devoted to subsistence (food) farming. The Wisconsin site did not possess sufficient advantages that would make the survey team consider choosing a site out of the preferred region. Evans pointed out that the evaluation of sites was predicated on minimum requirements. With the site selection complete, Du Pont moved forward to a more detailed study to recommend specific property boundaries. "This recommendation will give consideration to efficient plant layout, natural boundaries, principal traffic arteries, topography, efforts to restrict growth of nearby population centers, provision for adequate safety distances required for reactors of potentially higher power level, and possible future expansion."[26]

The search had lasted from mid-June through early November. Using the Du Pont method, the site-selection team had scoured about one-third of the United States. Twenty-nine copies of Topping's compiled *Plant 124–Site Survey*, replete with maps and supporting data, were prepared for submission to the AEC. The Site Review Committee met on November 20 to discuss Du Pont's findings. The committee had been advised by the Commission to look hard at the survey criteria, which would be the basis for the final Du Pont recommendation. This suggests that the Commission felt that Du Pont's recommendation would naturally reflect a "technical point of view."[27] The commission would be

responsible for explaining to the American public all of the variables involved in the site selection; an explanation that could be difficult to muster if non-engineering considerations in the public's interest had received short shrift. Despite this caution, the Site Review Committee unanimously concurred with the Du Pont recommendation.[28] A meeting was set for November 22 between Commission officials and Du Pont to give the site-selection team a forum in which to fully disclose their findings.

BOUNDARY DEFINITION AND REACTOR SAFETY

Seven Du Pont engineers were present at the morning meeting on November 22, 1950, in Washington to present the results of the site selection and their recommendation on site boundaries. The engineering manpower was needed as the AEC learned that Du Pont was recommending the acquisition of 240,000 acres rather than the 160,000 first projected. This increase was based on developing design issues, specifically that the proposed reactors' operating power could be increased by 25 percent several months of the year. The size of the exclusion area around each reactor was calculated on the basis of thermal power, and the power increase expanded the exclusion zone from 5.5 miles wide to 6 miles. Du Pont also felt it prudent to create a wider buffer zone between the reactors, preferring a 2.5-mile area between any two, to ensure more security against collateral damage from "strategically placed missiles." Traditionally, the distance was 1 to 2 miles. In addition to expanding the site perimeter to accommodate the larger exclusion area, Du Pont wanted possession of the area along the river to shorten the distance needed to pump water to the reactor areas. Finally, they requested acquiring more property on the northwest side of the proposed site that adjoined the highway and railroad. The motivation for this increase was to regulate anticipated private development there.[29]

The increased acreage requirements and the concomitant increase in the number of individuals who would be displaced were grave concerns to the Commission. The closing of the through highway seemed untoward, and the proposed evacuation of existing communities such as Jackson and Ellenton was not well received. It was pointed out to Du Pont that problems of unrestricted growth adjacent to the plant boundaries could, and would, occur regardless of where the boundaries were set.

Granville M. Read, Monte Evans, and Charles Topping rebutted. First, the additional acreage required was composed of two small triangles of land on the riverfront plus the town of Ellenton. This additional river frontage and the town site were needed to provide security for the vital water supply lines, to allow engineers flexibility in locating river pumphouses, and as a natural boundary. Dunbarton was too close to the manufacturing area, so it needed to be evacuated, and the remainder of the newly requested land was the result of the new exclusion area that was specified by formulae produced by the Reactor Safeguard Committee of the AEC. The commissioners offered some comment, noting that the existing community of Jackson might be better left out of the site boundary as workers could find housing there, and that it might be easier to control development in an existing community than in an unzoned undeveloped area.

No formal decision was made to approve the site, but November 28 was decided as the date for the public announcement, and the official name for the site, the "Savannah River Plant," was designated. On November 26, Commissioners Henry D. Smyth and T.

Keith Glennan visited the proposed site, touring it by air and by car. They met the next day at Brookhaven National Laboratory with their fellow commissioners to approve the selection of Site No. 5 with the expanded boundaries. Within a week, the Site Review Committee, the Joint Chiefs of Staff, and the AEC's Reactor Safeguard Committee had reviewed the proposal and all agreed with the choice. The commissioners then passed a resolution that allowed the acquisition of 240,000 acres, more or less, in Aiken and Barnwell counties in South Carolina and requested that the Corps of Engineers handle the acquisition of land. The public announcement remained on schedule for the next day.[30]

FIRST HURDLE - THE EVALUATION OF HAZARDS

While the resolution passed, the records of the November 27th meeting show uneasiness on the part of the Commission at the new boundaries. The inclusion of towns such as Jackson, Snelling, and Ellenton was troublesome, and Commissioners Glennan and Smyth's field inspection indicated that each, along with good farm land, was located at the periphery of the recommended site boundary. In their opinion, a slight adjustment in the proposed boundaries would dramatically decrease the number of individuals who would be affected by the plant. Seeking a less intrusive solution, they would argue that the perimeter towns, including Ellenton, be left alone.

The Du Pont position was clearly based on technical concerns. On one hand, the commissioners were impressed by the importance of the evaluation of hazards associated with the operation of production facilities for fissionable materials that had been conducted by Du Pont. The firm had rigorously followed the Reactor Safeguard Committee's formulae in proposing locations for the reactors and the dimension of the exclusion area around the manufacturing area. The commissioners further recognized that the evaluation of hazards would shape the final boundaries of the site and also would influence the type of control that would have to be exercised over lands within that area to assure the security and safety of operations. However, had the Commission's objective of minimizing the dislocation of people been upheld in the site-selection process? [31]

The Commission requested that Du Pont formally review its suggested layout and site boundaries. Commissioners Smyth and Dean went further, stating that the reevaluation should be conducted independent of the guidelines given by the Reactor Safeguard Committee. The Commission apparently considered the guidelines too conservative.

Monte Evans, Du Pont's General Manager, in a letter to Walter Williams restated his position this time with vehemence:

> …. unwarranted importance is given to protecting the several small towns in the area, some of which must be absorbed to insure safe and efficient development of the site and to allow for possible future growth. Further study has already indicated the desirability

Reactor Safeguards Committee and the Rule of Thumb

This group, established in 1947, was founded to evaluate the safety of nuclear reactors and to advise the AEC on reactor safety matters. Experts in appropriate fields typically from academic backgrounds were asked to participate on the committee that reported directly to the AEC's general manager. In 1950 they prepared a report that contained the first guidance on reactor siting, providing formulae to calculate an exclusion radius for a reactor site. Residential land use would be prohibited in that area. The size of the exclusion area was directly proportional to the proposed reactor's wattage.

Figuring exclusion radius calculations:
1 MW = 1000 KW
$\sqrt{3}$ = 1.73205

For 30-MW reactor
$R = 0.01 \sqrt{30{,}000}$
R = 0.01 x 173.2
R = 1.732 mi.

For 3000-MW reactor
$R = 0.01 \sqrt{3{,}000{,}000}$
R = 0.01 x 17329
R = 17.320 mi.

Unhappy with the conservatism of their guidance, the commission established an Industrial Committee on Reactor Location Problems in 1951. It is likely that the problems that occurred with the boundary definition of the Savannah River Plant played a role in its establishment. The new group was given the responsibility of advising on the location of nuclear reactors. Their advice, arrived independently of their predecessors, was the same, so the two were combined into the Advisory Committee on Reactor Safeguards (ACRS) in 1953.

Source: David Okrent, *Nuclear Reactor Safety On the History of the Regulatory Process*. (Wisconsin: The University of Wisconsin, 1981), 4.

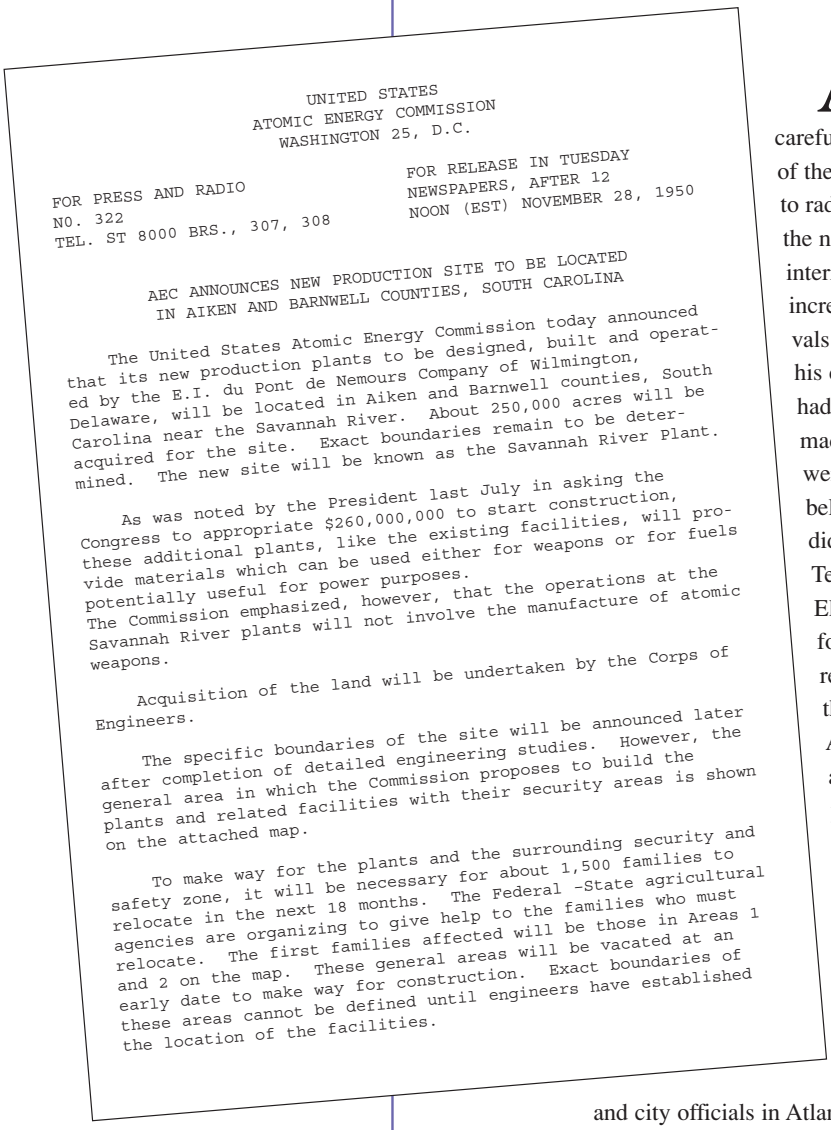
> of shifting the manufacturing area slightly to the South. A shift toward the river would have obvious advantages. Of the small communities, Ellenton, which lies in a likely path for water supply lines, and to a lesser extent Dunbarton, present the most serious problems. To permit them to remain as uncontrolled communities would, in our judgement, create an almost intolerable situation. As islands of uncontrolled population they would present serious safety and security problems. It is inconceivable that they could retain their present character in the changing environment and, deprived of their surrounding agricultural areas, it is unlikely that they would retain their present means of livelihood. Not only would the towns represent a continuing problem to the Commission and the Company, but also we would expect them to become increasingly unattractive places of residence to many of the present inhabitants. We feel that this problem should be attacked positively when public-mindedness can be expected to be highest. Temporizing with the problem can be expected to aggravate it.[32]

The boundary dispute continued through December. Beside contract negotiations, it was the first project-related hurdle between the Commission and its contractor and it was not officially solved until one month after the public announcement. Essentially, there was a compromise rather than a solution. By moving the manufacturing area slightly, Du Pont was able to shift perimeter boundaries to exclude the towns of Jackson and Snelling. Ellenton and Dunbarton, because of their geography within the proposed layout, remained inside the proposed boundary. This change would placate the "dissenting commissioners" but retain the majority of the layout that Du Pont had proposed earlier without sacrificing any security or safety issues. South Carolina State Highways Nos. 28, 64, 19, and possibly 781 were to be closed to the public at the site boundary.

The proposed layout allowed for five reactors, with two potential areas left for expansion. A safety distance of 2.5 miles between any two major manufacturing areas remained. While this remained in accordance with the guidance provided by the Reactor Safeguard Committee, Du Pont shifted the emphasis of their argument, pointing out that the layout satisfied strategic military concerns. Professor Harry L. Bowman, a consultant on structural design, and the U.S. Air Force confirmed the need for this separation interval to reduce the chances of multiple damage to critical facilities as a result of enemy action or sabotage.[33] It was also considered necessary to confine the effects of a possible accident without interrupting production at the other reactors. While the commissioners were correct in characterizing Du Pont's approach to the site-selection process as technically driven, they had underestimated the chemical firm's almost religious adherence to safety. In a final rejoinder, Monte Evans stated, "We are confident the factors of safety are not extravagant under the circumstances."[34] The AEC agreed.

With these changes, the new site finally came into being. On December 28, the Corps of Engineers received the final go-ahead to acquire the needed land.[35] The legal basis for the acquisition had already been established on September 27 with the passage of Public Law No. 843, giving the AEC the authority to acquire land for a plant to produce radioactive products.[36]

8 Changing Identity



UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D.C.

FOR PRESS AND RADIO
NO. 322
TEL. ST 8000 BRS., 307, 308

FOR RELEASE IN TUESDAY
NEWSPAPERS, AFTER 12
NOON (EST) NOVEMBER 28, 1950

AEC ANNOUNCES NEW PRODUCTION SITE TO BE LOCATED
IN AIKEN AND BARNWELL COUNTIES, SOUTH CAROLINA

The United States Atomic Energy Commission today announced that its new production plants to be designed, built and operated by the E.I. du Pont de Nemours Company of Wilmington, Delaware, will be located in Aiken and Barnwell counties, South Carolina near the Savannah River. About 250,000 acres will be acquired for the site. Exact boundaries remain to be determined. The new site will be known as the Savannah River Plant.

As was noted by the President last July in asking the Congress to appropriate $260,000,000 to start construction, these additional plants, like the existing facilities, will provide materials which can be used either for weapons or for fuels potentially useful for power purposes.
The Commission emphasized, however, that the operations at the Savannah River plants will not involve the manufacture of atomic weapons.

Acquisition of the land will be undertaken by the Corps of Engineers.

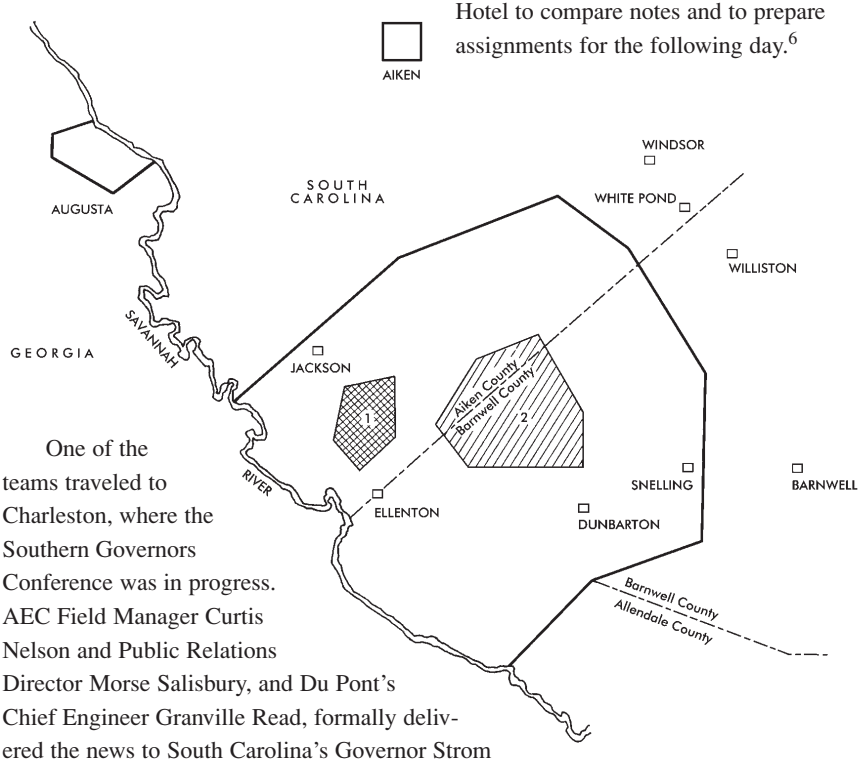
The specific boundaries of the site will be announced later after completion of detailed engineering studies. However, the general area in which the Commission proposes to build the plants and related facilities with their security areas is shown on the attached map.

To make way for the plants and the surrounding security and safety zone, it will be necessary for about 1,500 families to relocate in the next 18 months. The Federal -State agricultural agencies are organizing to give help to the families who must relocate. The first families affected will be those in Areas 1 and 2 on the map. These general areas will be vacated at an early date to make way for construction. Exact boundaries of these areas cannot be defined until engineers have established the location of the facilities.

At 12 noon on Tuesday, November 28, 1950, a carefully worded announcement accompanied by a map of the proposed plant area was released to the press and to radio stations. Flash radio announcements brought the news into homes and businesses in the CSRA, interrupting regularly scheduled programming. The incredible announcement was repeated at regular intervals throughout the day. Billy Tisdale of Ellenton and his co-workers at the Leigh Banana Crate Company had heard that an important announcement was to be made for people in their community. "At noon we went out to listen to our car radios. It was hard to believe; in fact we didn't exactly believe it. But we didn't get much work done the rest of that day."[1] Teacher Louise Cassels heard it second-hand in her Ellenton classroom from a student who went home for lunch.[2] The announcement was one of the region's top news stories, making headlines across the South. Newspaper extras were run in Atlanta, Augusta, Savannah, Columbia, and Charleston, and the *Barnwell People-Sentinel*, a small weekly paper, ran its first special edition in its 74 years of news reporting.[3] Major American papers also carried the story, mostly providing little more information than was given in the press release, but some accounts correctly likened the new operations plant to Hanford.[4]

Word had leaked out that morning as AEC and Du Pont officials, working in twelve teams, began with military precision to inform state and city officials in Atlanta and Augusta in Georgia and in Aiken, Columbia, and Barnwell, in South Carolina through simultaneous interviews scheduled for 11:00 a.m. The week's frigid weather would no longer be a topic of conversation as South

Carolinians and Georgians learned about the new plant. The contents of the announcement had been carefully crafted over a three-week period, as well as the plan for its delivery.[5] A parallel program was unfolding in Washington, DC, so that members of Congress were equally informed. The teams, probably both exhilarated and tired, gathered that evening in the office of the Du Pont Field Project Manager Bob Mason at the Richmond Hotel to compare notes and to prepare assignments for the following day.[6]



One of the teams traveled to Charleston, where the Southern Governors Conference was in progress. AEC Field Manager Curtis Nelson and Public Relations Director Morse Salisbury, and Du Pont's Chief Engineer Granville Read, formally delivered the news to South Carolina's Governor Strom Thurmond and Governor-elect James F. Byrnes. Read had made an appointment with the state executives the preceding day for 11:00 a.m. Upon hearing the good news, Governor Thurmond invited Georgia's Governor Herman Talmadge to join in a regularly scheduled press conference for the annual meeting where the announcement was made at noon.[7] The timing of the announcement for what could only be forecasted as a regional economic success story was excellent for all concerned. All three men were major figures in national and regional politics and it is unlikely they watched the "secret" site-selection process unfold without knowledge or interest.

The announcement team would spend the following day in local communities, particularly those to be acquired: Jackson, Snelling, Ellenton, and Dunbarton. The teams consulted the mayor or commissioner of each town and reviewed the press release and map, along with the acquisition procedure and the "acquisition time element." Jackson and Snelling were still included in the plant area at this point in time. Teams visited elected officials of neighboring communities such as Williston, White Pond, Windsor, and Blackville with the press release and map in hand to discuss the scope of the project and housing needs and to request the community's cooperation and assistance.

(Opposite Page) The announcement of the location of the new production facility on November 28, 1950, made headlines in all the area's newspapers. The carefully worded announcement, that outlined the project and the more immediate concerns for those who would be displaced, was delivered to the press and radio for distribution. Source: United States Atomic Energy Commission, Washington, DC, Press Release No. 322, November 28, 1950. Courtesy of SRS Archives.

(Left) The first map of the proposed project area was released by the AEC with the November 28 announcement. The stylized map showed a roughly irregular area within Aiken and Barnwell counties bounded by the Savannah River on the west. Four towns were within the original boundaries: Jackson, Ellenton, Dunbarton and Snelling. The hatched areas within the project boundary were priority areas needed to begin construction. They would be targeted for immediate acquisition. Source: *Aiken Standard and Review*, November 29, 1950.

(Below) Front page of *The Augusta Chronicle,* November 29, 1950, reported on the announcement from several angles reflecting the many meanings the new plant would have for the country, the CSRA, and for those to be displaced by the proposed land acquisition.


The Augusta Chronicle

$260,000,000 H-bomb material facilities will be constructed in S. C. near Augusta

Allies facing 'new war'

Grim note is voiced by Gen. MacArthur

Aiken-Barnwell site is selected for plant

Shocked officials seek urgent steps

Plant means big boom for Augusta

Ellenton's residents stunned, but accept news patriotically

While teams were dispatched to the above locations, H. Magoon of Du Pont and Edwards of the AEC were sent to Augusta to locate office and warehouse space on a rental basis for a four- to six-month period. City officials made space available initially at Augusta's Bell Municipal Auditorium. Thursday and Friday were reserved for meetings with the director of the F.H.A., U.S.E.S., transportation officials, state and county highway officials, city police and local sheriffs, boards of education, local selective service boards, S.C. Power and Light Company, Bell Telephone, Western Union, Atlantic Coast Line and West Charleston railroad companies, retail merchants associations, heads of realtors associations, local contractor's associations, and hotel managers concerning housing.[8] The weeklong schedule was rigorous and the coverage thorough as the announcement team and an unknown number of secretaries and support personnel removed the cloak of secrecy, taking Georgia and South Carolina by storm.

Inside Story

Horace A. Andrews, a member of the Safety Division in 1955 well remembered the day in 1950 when he was summoned hurriedly to Wilmington from his home in Walla Walla, Washington and told of a new atomic energy plant to be built by Du Pont.

About ten sites were still being considered for the plant at that time, and Mr. Andrews, who had done housing work for Du Pont Construction at Hanford during World War II, spent the next few weeks collecting housing data on various sites.

It was Nov. 26 when Mr. Andrews boarded a train for Augusta, a good tip-off to him that the South Carolina site had been selected. This was confirmed in a secret briefing with other Du Ponters and AEC representatives the next day in a hotel room in Augusta. The group had registered with different home addresses to avoid suspicion and had avoided congregating in the hotel.

Then the visitors paired off, and Mr. Andrews and an AEC representative flew to Atlanta. At 11 a.m. the next day (Nov. 28) they met with newsmen and handed them an announcement.

Source: Plant Announcement Five Years Ago Set Stage for 'Biggest Project,' *Savannah River Plant News*, Vol. III, No. 21, November 25, 1955.



Augusta's Bell Municipal Auditorium, circa 1950. This Art Deco style Augusta landmark served as the AEC and Du Pont's first "office" during the winter of 1950-1951 until the first administrative buildings were constructed in the project area. Courtesy of SRS Archives.

"SENATOR BROWN'S WELL KEPT SECRET"

Reaction to the public announcement of the site selection was jubilant in Georgia and South Carolina. Barnwell's Senator Edgar Brown and Augusta's Chamber of Commerce secretary, Lester Moody, had been working for months to secure the new plant for the CSRA. The two "economic statesmen" for the Clarks Hill Project had turned their attention to the AEC project when approached, and then linked the completion of the federal dam project to the new Savannah River Plant.

> State Senator Edgar A. Brown has a smile on his face and relief in his voice, now that the best kept secret of the year has been shared with the public. Senator Brown was the only public official in South Carolina who knew what was going on behind exploratory investigations which had residents of Barnwell and Aiken counties in a mild state of suspense for six months or more.[9]

State Senator Edgar Brown and Representative Solomon Blatt, known recruiters for economic development in their home county of Barnwell, received a personal visit on the day of the announcement.[10] Brown had been part of the site-selection process, acting as South Carolina's sole point of contact. After the meeting, Senator Brown gave an *Aiken Standard and Review* reporter his story: "There were no politics involved in this at all."[11] The reporter indicated that readers would find this hard to believe as most people associate the senator's every move with politics, yet Brown's statement seemed to be borne out by the facts.

Brown pointed out that Du Pont had already accumulated information on the Ellenton area during the site-selection process for their Orlon factory. The state's Research, Planning, and Development Board had prepared brochures and summary data describing the Ellenton vicinity as a candidate site for an industrial plant, and Du Pont had received the promotional materials. Government officials and Du Pont used this informational packet in their decision-making for the 1950 project.

Clarks Hill Dam, Hartwell Dam, and the new H-bomb plant were evolutionary steps in the shaping of the CSRA's industrial future. In November 1950, the Clarks Hill Dam was 80 percent complete. Its first generator capable of producing 280,000 kilowatts was projected to go into operation in October 1952; all seven generators would be scheduled for completion to provide power for the new plant. The engineer at Clarks Hill admitted that the remaining ten Savannah hydroelectric projects that had been proposed were needed to handle the upsurge of industrial development. Hartwell was next on the list of Savannah River projects. It would be sorely needed now that the AEC plant would share power with the new cotton mills and other industrial growth projected for the future of Horse Creek Valley.[12] The AEC announcement rewarded all involved with the state and region's efforts to bring industry and growth to the area. The Clarks Hill Dam was a significant factor in the site-selection process. The presence of the smaller fish had enticed a larger fish into the pond. A good portion of the $260,000,000 first appropriated for the construction of the AEC plant would find its way to the CSRA.

Newspaper headlines clamored that Augusta would become a metropolis, Aiken a "fast growing city," and Barnwell and environs would quickly follow suit. Lester Moody, the Augusta contact for the site-selection team, helped put the future in perspective in a *New York Times* interview, noting that the plant's economic impact would equal "the simultaneous installation of fifty small factories in Augusta" where he envisioned an additional 25,000 individuals would settle. Aiken's Mayor H. Odell Weeks estimated an increase of 4,000 for his city, voicing the concern that Aiken needed to handle the population explosion without losing its character. Aiken, the county seat and small resort town, supported 7,500 "year-round residents." State Representative John A. May, interviewed in Aiken's Chamber of Commerce, then housed in a remodeled log cabin, offered that



Undated photograph of State Senator Edgar Brown and Representative Solomon Blatt, both from Barnwell County. Edgar A. Brown Collection, Mss 91. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

Just Can't Escape, Mourns Ellentonian

Ellenton, SC (UP) Waitress Mary Derry was aghast yesterday at the news a plant to make hydrogen bomb materials will be built there. She came here from Oak Ridge, Tenn., several years ago to get away from the atom bomb. "It looks like you can't go anywhere any more," she said.

-*The Augusta Chronicle,* November 29, 1950.

Aiken's development could be controlled by zoning "to prevent a 'shantytown' like that at Oak Ridge. We don't want any hoodlums or honkytonks or labor racketeers."[13] Some Aiken businessmen worried about the town's fortunes such as W. I. Smith, an Aiken barber, who commented, "we haven't waked up yet." Aiken druggist H. E. Blake dourly predicted that Aiken's days as a popular resort could be ending and reported that he might sell out if he could find a "sucker." However, other Aiken businessmen, like their Augusta counterparts, were expecting to reap economic profit from the huge payrolls that would energize local commerce.



One *New York Times* correspondent commented that Aiken's tax rolls read like an abbreviated version of New York's social register. The winter colony estates within the Whiskey Road area were nestled around a set of tracks and polo fields. Trails within Hitchcock Woods were also well used by the equestrian set.

About 2,500 Northern "wealthy and socially prominent sportsmen" wintered at the beautiful resort town of Aiken. *New York Times* correspondent Ira Henry Freeman commented that the South Carolina city's tax rolls read like an abbreviated version of New York's Social Register. The Whiskey Road area contained scores of estates anchored around three tracks and six polo fields, where hundreds of racehorses were trained and polo was played for high stakes. The plant's executives, technicians, scientists, and "better paid employees" were expected to chose home sites in the Aiken area according to one report "by preference." The Nelsons, for example, would find a home in Aiken's Highland Park; the Blairs also resided in Aiken. However, Du Pont Field Manager Bob Mason and his family resided in Augusta during the construction of the plant.

While the economic promise of the plant was eagerly discussed, the social changes it would bring in an era of national social change received less mention. It is not surprising that Georgia's Lester Moody would tackle the topic:



Postcard, "Taking the Hurdles in the Hitchcock Woods, Aiken, S.C." Courtesy of J. Walter Joseph

Postcard, "Rosebank, Residence of E. G. Grace, Aiken, S.C." Courtesy of J. Walter Joseph.

> This development will revolutionize the Savannah River basin. It will make Augusta a minor metropolis. . . The new plant will bring in many educated people, technicians, professional men, highly skilled workers, Yankees and Middle Westerners with other viewpoints on race relations, labor relations, and world affairs. We may not enjoy all the changes, but it is impossible to be conservative about our future.[14]

Others saw change occurring that reversed the traditional order of Southern agricultural life. Amos Ward, an agricultural economist responsible for relocating farmers for the Department of Agriculture, commented on a group of farm hands and wood cutters shielded by felt hats and clothed in overalls who were already gathering outside AEC offices in Augusta looking for work. Ward observed that uprooted agricultural workers would never return to the soil. A sharecropper who worked even in an unskilled labor position at the project would receive cash for his work and would have money in the bank perhaps for the first time. His family would leave the farm, buy a jalopy, and "live like townfolks."[15]

In the weeks after the announcement, reporters came from all over to get an inside line on the project. Others just wanted a final glimpse of the towns that would disappear to make way for the bomb plant. Newspapers were filled with news reports, commentaries, and editorials about the new plant, its importance to the Cold War, and its meaning for the CSRA. While many debated that meaning, it was clear that the direct impact of the Cold War on this community would be dramatic, forming in historian Jim Farmer's words, "the dividing line between what was and what is."[16]

THE VARIOUS MEANINGS OF THE NEW PLANT

SRP's management team—Curtis Nelson, Robert Blair, Bob Mason, and Don Miller—appeared to be everywhere in the days following the announcement. Speaking on radio and at farmer's meetings, in public meetings, and at Rotary Clubs, they shucked their previous anonymity. Their photographs and credentials were presented on the front pages of the local papers and their words were closely followed in the press. Each showed polish, presenting a well-crafted, shared narrative. Curtis Nelson had instituted a plan for a public information and community relations program as early as August 1, and the success of the announcement was likely an outcome of this early planning between AEC and Du Pont officials.[17] The public announcement of the project and the care with which it was executed signaled that the AEC recognized that the project would be under public scrutiny. It also indicated that the AEC was aware that the transformation between what was and what is would be watched by an increasingly aggressive media.



Savannah River Plant's original management team, 1950. From left to right, Curtis A. Nelson, Manager of the new AEC operations office; Robert C. Blair, Deputy Manager; Robert K. Mason, Du Pont Field Project Manager responsible for the plant's construction; and Donald A. Miller, Du Pont's Manager of the Plant's Operations. Source: *Aiken Standard*, December 6, 1950.

On November 29, radio station WGAC of Augusta aired a half-hour roundtable discussion on the plant's meaning to Augusta and its environs, featuring prominent local leaders and SRP officials. *The Augusta Chronicle's* Managing Editor Louis C. Harris moderated the discussion. Aiken's secretary of the Chamber of Commerce, Sara Bush; Camp Gordon's Brigadier General H. G. Maddox; Henry Darling, Jr., director of plans and training for Augusta's civilian defense program; the AEC's Curtis Nelson and G. O. Robinson; Du Pont's Howard Miller; and the Corps of Engineers Assistant Real Estate Officer, Harold Robinson took part.[18]

"As far as I could see, cars almost bumper to bumper were milling around like ants. My heartbeat slowed down after I realized curiosity seekers had come to scrutinize the little town destined to die. "What better entertainment could they want on a cold, gray Sunday afternoon?" I asked in sarcasm, forgetting I was my only audience. Ellenton had never before had a traffic jam."

Source: Louise Cassels, *The Unexpected Exodus*, (Aiken, SC: Sand Hill Press, 1971), 24.

Several concerns emerged from the forum. Each shows that the new plant had multiple meanings depending on one's home place and livelihood. Would the new plant make the CSRA a primary target for the enemy? How would the land to be acquired be appraised? Would highways need to be relocated? Would local labor be hired? In answer, tenant farmers were encouraged to contact their county agents for instructions. General Maddox assured listeners that if defensive measures were needed the Third Army would respond in accordance with orders. Mrs. Bush stated that the City of Aiken had already passed resolutions to control rents and to lend aid to employees of federal agencies and the Du Pont staff. The Corps of Engineers would conduct the acquisition program. Curtis Nelson closed the program reiterating patiently that the new plant would make not only materials to be used in the manufacture of the H-bomb, but also materials for peacetime use. This last statement was very important for all concerned. A diversified plant that had multiple products translated into longevity.

While Curtis Nelson and Howard Miller answered questions on the radio, Robert C. Blair and Bob Mason attended an equally important meeting in Augusta. The Georgia Power Company auditorium was filled with over 100 representatives of agricultural agencies from ten counties who came to learn about the project and its impact on local farmers.[19] Representatives of the Production Marketing Association, Farmers Home Association, National Farm Loan Associations, Production Credit Associations, Rural Electrification Administration, Soil Conservation Service, vocational agricultural programs, the veterans' agricultural training program, and county agents of the Agricultural Service were in attendance. Arthur Miner, assistant to the Secretary of Agriculture and Amos Ward, a housing specialist with the Farmer's Home Association, had called the meeting. Their intent was to inform these groups and enlist their aid in helping farming families, owners, tenants, and sharecroppers within the plant area find new homes and assist in their relocation.

The most difficult meeting was yet to come. The map with the press release had shown very approximate project boundaries with two irregularly-shaped priority areas that needed to be vacated "at an early date." Residents within the proposed plant area listened carefully to news releases in which the South Atlantic Corps officials began to outline the acquisition procedure. Gordon Britton, the Corps of Engineers real estate officer responsible for the land acquisition, conducted a public meeting in Ellenton's school auditorium on December 6 at 8:00 p.m. A representative of each family was asked to attend the question and answer session, and the hall was filled with more than 500 individuals.[20]

> When eight o'clock finally crept in, people crowded the school auditorium, even standing against the walls, in the aisles, and barely within the doors. Naturally the first question asked was what concerned everyone most: What was the Government's acquisition policy for land and property?[21]

Who are the AEC and Du Pont officials in charge?

For the Atomic Energy Commission:

Curtis A. Nelson, Manager
Arthur L. Tackman, Personnel
Clarence A. Bergan, Labor Relations
W. C. McKelvey, Housing
James Hopkins, Property and Procurement
George O. Robinson, Public Information

For the Du Pont Company:

Robert K. Mason, Field Project Manager
Howard M. Miller,
Administrative Assistant to Mr. Mason
H. A. Andrews, Housing
J.W. Mercke, Employment
Harry Magoon, Engineering
J. W. McAuliffe, Control Department
E.B. Riggin, General Accounting

The need to inform the public about the project was paramount and the AEC and Du Pont officials in charge continually instructed the public on the proper contact points for the Savannah River Operations Office and Du Pont. Source; Savannah River Operations Office, Atomic Energy Commission, Augusta, Georgia, Information Sheet No. 1, December 7, 1950. Courtesy of SRS Archives.

Louise Cassels, who attended, described the discussion as long but peaceful. For some in the audience the plant's coming was an opportunity. For others who had generations invested in the land and their homes, a deep well of patriotism was needed to go forward. Cassels began to realize how hard the months ahead were to be that night. She correctly pinpointed that the definition of "hard" would rest on the agreement of the people and the government on "just compensation."

COE ACQUISITION PROCEDURE

The South Atlantic Real Estate Division of the U.S. Army Corps of Engineers (COE) was given the responsibility for the acquisition program. Authority was formally conveyed in a letter from the Chief of Engineers to the Division Engineer that was dated December 1, 1950. A letter from the U.S. Atomic Energy Commission to the Office of the Chief of Engineers, dated November 28, 1950, authorized the Corps to handle the work. The program that included cemetery relocations was legally authorized by the 81st Congress as Public Law 843, approved on September 27, 1950, and as Public Law 911, approved on January 6, 1951.[22]



Meeting at Ellenton Auditorium, December 6, 1950. The U.S. Corps of Engineers real estate officers responsible for the land acquisition called a public meeting in Ellenton. A representative from each family was asked to attend the question and answer session. Reportedly, over 500 individuals attended what appears to have been a segregated meeting with attendees, both black and white, spilling out of the main hall into the building entries and lobby. Courtesy of SRS Archives, negative 1221-1.

During the Manhattan Project and until the formation of the civilian AEC, atomic energy development and the siting of the early production complex were under the aegis of the Corps of Engineers. For new sites selected by the civilian agency, the AEC was accorded the authority to receive help from fellow government agencies. Under the Atomic Energy Act of 1947, the AEC was authorized to acquire land and employ the services of any other government agency in order do so. Executive Order 9816 transferred all funds and properties of the Manhattan Engineering District to the AEC; the order also stipulated that all government agencies that had rendered service to the MED should make that same service available to the AEC. David Lilienthal's letter dated January 16, 1947, to Robert P. Patterson, Secretary of War, which requested the Chief of Engineers, or his authorized representative, to conduct all real estate activities for the AEC, was the final authority.



Dunbarton's train depot is the focal point of this downtown view circa 1952. A small commercial district with frame and brick commercial buildings lined the railroad corridor. Courtesy of SRS Archives, negative M-642.

The COE had been brought into the site-selection process in June. The AEC had requested the assistance of the Chief of Engineers in site selection and in acquisition of the plant property when the site was selected. In November, AEC General Manager M.W. Boyer sent Major General Lewis A. Pick, the Chief of Engineers, the AEC press release and a map showing the area under consideration. The COE immediately developed a planning report, outlining their approach to the acquisition of land for the Savannah River Plant. The Division Engineer submitted this report to the Chief of Engineers on December 9. [23]



Meyers Mill's town square including (from left to right) the depot, Bob Peeple's store, Olan Meyer's cotton gin and the post office circa 1950. Courtesy of SRS Archives, negative 6683-1.

The planning report generally described the project area from the perspective of a buyer, noting both the area's advantages and the challenges the Corps would face over the coming months. After a brief physical description, the report moves to population data and descriptions of improvements in the areas. The initial estimate suggested that about 2,300 farms were in the proposed area. The larger farms appeared to be non-owner-operated and many were sharecropped or rented to tenant farmers. It was reported that the acquisition would affect up to 8,000 farmers of whom the majority were African American.

The project area was home to crossroad communities such as Hawthorne and Hattieville as well as four larger communities, two of which were incorporated. It is sig-

nificant that only four communities are mentioned in the report: Ellenton in Aiken County, and Dunbarton, Meyers Mill, and Leigh in Barnwell County. Snelling and Jackson were not discussed. This suggests that the COE was working with better-defined boundaries than those announced to the public. Ellenton was the largest with a population of 760 and Dunbarton was home to 300 individuals. Ellenton was briefly described as a typical southern trading center in the extreme southwestern part of the county through which the Charleston and Western Railroad ran. Municipal improvements included a city hall and jail; the city had no bonded indebtedness. Dunbarton was similarly described but with no municipal improvements nor a high school. Its incorporated land area was larger than Ellenton. Meyers Mill was described as a cluster of a few stores and a cotton gin, and Leigh's focal point was a box factory around which a small village had grown. A list of the improvements in each of the four communities was given:

	Ellenton	**Dunbarton**	**Meyers Mill**	**Leigh**
Commercial	31	15	3	2
Residences	190	35	10	52
Gin	1	2	1	
School	2	1		
Church	5	1	2	
Railroad Station	1	1		
Saw Mill	1	1		
Fraternal Halls	3			
City Hall	1			
Box Factory				1

State and county roads served the project area, rural mail delivery service was available throughout, telephone service was available in Ellenton and its surrounds, and limited telephone service was available beyond that.

COE staff had reviewed recent land sales in this area in December to identify comparable properties to establish "value trends" that would help inform the appraisers. This review was not successful, as many sales were conveyances between family members or sales by unknowledgeable absentee property owners. For example, in 27 conveyances in Aiken County the price per acre ranged from $2.00 to $162.50. Thirteen transactions required a consideration of $25 per acre or less, twelve at $75 or less, and two required $100 and over an acre. Given this fluctuation in price, the COE concluded that the recent sales data was too erratic a source for comparable sales information.

The proposed project area was considered to have minor outstanding interests. The report noted the presence of a rich kaolin deposit immediately to the north and peat bogs along the river. As no one had yet developed these interests, they did not present a problem. Only timber deeds or leases and hunting leases might pose problems. Hunting licenses, the majority of which were given for five years, covered ten percent of the project area. Large timber holdings owned by the International Paper Company and the Leigh Banana Crate Company would prove problematic as each had centered their operations in specific localities, and the interruption of their work would entail severance damage. In the case of the Leigh Banana Crate Company that assessment would be prophetic.

African-American Displacement



Barbecue for Buist Eaves farmhands at the "Owens Place," Dunbarton vicinity, Barnwell County, 1951. Courtesy of Lois "Yarby" Eaves and the Savannah River Archaeological Research Program.

The story of African American displacement caused by the making of the site is little known. While population figures from 1950 suggest that African Americans were in the majority within the future project area, the exact number of those affected has not been tallied. The U.S. Army Corps of Engineers originally estimated that the proposed land acquisition program within the rural agricultural area could affect up to 8,000 farmers, the majority of whom were black landowners, tenant farmers, and sharecroppers. The AEC later refined the total estimate to a projected displacement of 6,000 individuals, white and black, or 1,500 families based on the presence of 19 persons per square mile within the 315-square-mile tract (see compiled 1939 Barnwell and Aiken County Highway Map). This refined figure did not project how many or what percentage of that population were African American, how many lived in small towns or farms, and occupational data. A University of North Carolina study conducted in 1951 surveyed 78 white families and 81 African American families. Accurate population statistics are difficult to extract from the existing data that is weighted toward describing mainstream history or is focused upon the site's Cold War history. The absence of primary documentary sources that relate to the black communities also plays a role in this bias.



St. Luke's Church, Meyer Mill vicinity, Barnwell County, circa 1945. St. Luke Baptist Church was constructed in 1880. The founders were Simon Lafette, Lewis Sanders, Andrew Jackson, Nero Jackson, Ishmel Schaver, Offie Williams, Henry Burke, Stephen Robinson, Robert Ingram, Bob Dunbar, Joe Dunbar, Daniel Allen, Jeff Ashley, Payton Brown, Charlotte Burke, Janet Robinson, Sophie Allen, Amenda Ingram, Mollie Dunbar, and Katherine Dunbar. Reverend Commodore Dunbar was the congregation's first pastor. Courtesy of Alean Meyer Hay and the Savannah River Archaeological Research Program.



Eli and Lena Meyer Anderson, Meyers Mill vicinity, circa 1945. Courtesy of Laura Meyer and the Savannah River Archaeological Research Program.



(Right) Willie Floyd Farmhouse, 1951. Courtesy of the Savannah River Archaeological Research Program.

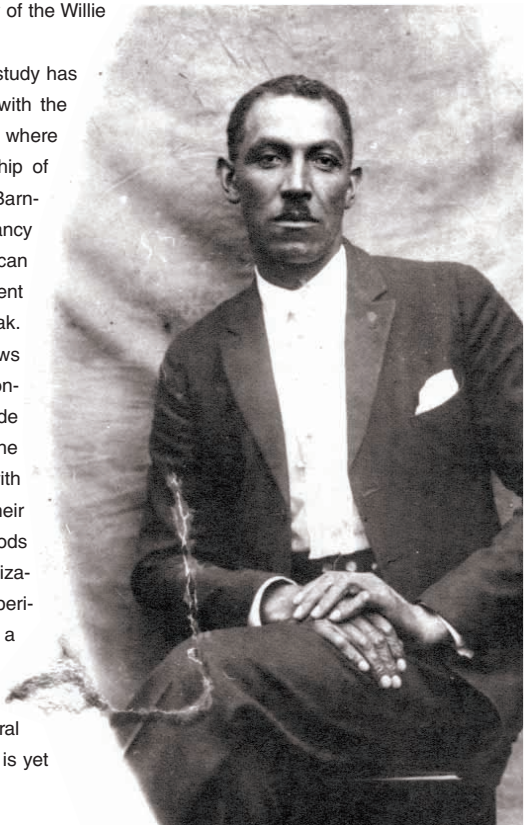
The Savannah River Archaeological Research Program's (SRARP) community studies have looked intensively at the pre-federal communities, telling through oral history and documentary data the story of the small towns and their citizens, white and black. In particular, their work on Barnwell County's Four-Mile High School and the Dunbarton and Meyers Mill communities is significant, weaving



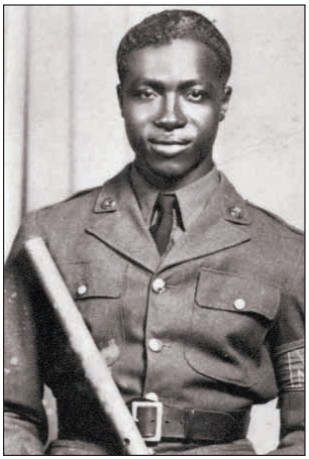
Meyer Family Reunion, Warren Meyer Homeplace, Meyers Mill vicinity, Summer 1952. This photograph captures the "1952 Meyer Family reunion when we had to sign the papers." The reunion allowed family members a last visit at their family homeplace and an occasion to gather the signatures needed to sell their property to the AEC. Courtesy of Laura Meyer and the Savannah River Archaeological Research Program.

African American history into broader cultural themes. SRARP archaeologists have also excavated archaeological sites historically associated with African Americans to help illuminate the African American experience at SRS, such as the study of the Willie Floyd Farm in Barnwell County.

Despite these efforts, no systematic study has addressed how African Americans dealt with the changes required of them in 1950 and where these changes led them. Black ownership of farms was on the increase, particularly in Barnwell County, but sharecropping and tenancy was still a fact of life. For the new African American property owner, the announcement of the plant could only have been heartbreak. For the tenant and sharecropper, the news would have been equally grim and, as non-landowners, little help was available to guide them through the relocation process. The specific parameters that were involved with the relocation of African Americans and their communities, the reshaping of neighborhoods and the reestablishment of church organizations, is all a part of this unexplored experience. Savannah River was responsible for a new landscape in and outside of the plant area. The role that African Americans took in the creation of the post-1950 cultural landscape in Aiken and Barnwell counties is yet to be told.



(Left) Council Meyer, circa 1925. Courtesy of Laura Meyer and the Savannah River Archaeological Research Program.



Albert Foreman in World War II uniform, note baton and Military Police armband. Courtesy of Laura Meyer and the Savannah River Archaeological Research Program.



Lena Anderson, Ruth Meyer Corbett and Caroline Meyer Moody, Meyers Mill, Barnwell County, circa 1950. Courtesy of Laura Meyer and the Savannah River Archaeological Research Program.



Leigh Banana Crate Factory circa 1950. This concern, located south of Ellenton in Barnwell County, was the largest industrial venture within the future Savannah River Site. Courtesy of SRS Archives, negative 6690.

A gross appraisal of land and improvements was attempted based on the reported information.

Item	Amount	Value
Farm Properties		
Timberland	20,000 acres	$1,000,000
Cut-over Woodland	40,000 acres	800,000
Cropland and Pasture	140,000 acres	5,600,000
Farm Buildings	2,000 acres	3,000,000
Community Properties		
Residences	300 units	1,000,000
Commercial	60 units	200,000
Industrial	6 units	1,200,000
Schools	21	300,000
Churches	50	150,000
Subtotal		**13,250,000**
Severance	2%	265,000
Subtotal		**13,515,000**
Contingencies 10%		1,351,500
Total		**$14,866,500**

The authors of the planning report noted that the acquisition of large areas by the government typically inflates surrounding land values and that the dispossessed owners are affected as a result. Therefore, the gross appraisal price was slightly higher than under normal conditions. The need to relocate telephone systems, railroads, roads, and cemeteries was also estimated. Ellenton's Cassels Telephone Company, a private franchise, had to be dissolved and at least 4,500 graves relocated. Relocation costs were estimated at $300,000.

Disposal of existing improvements was defined in the report. If neither the owner nor the AEC were interested in retaining a building or improvement then it would be sold at a public sale on a sealed-bid basis. The COE hoped to accrue $50,000 from such sales. The

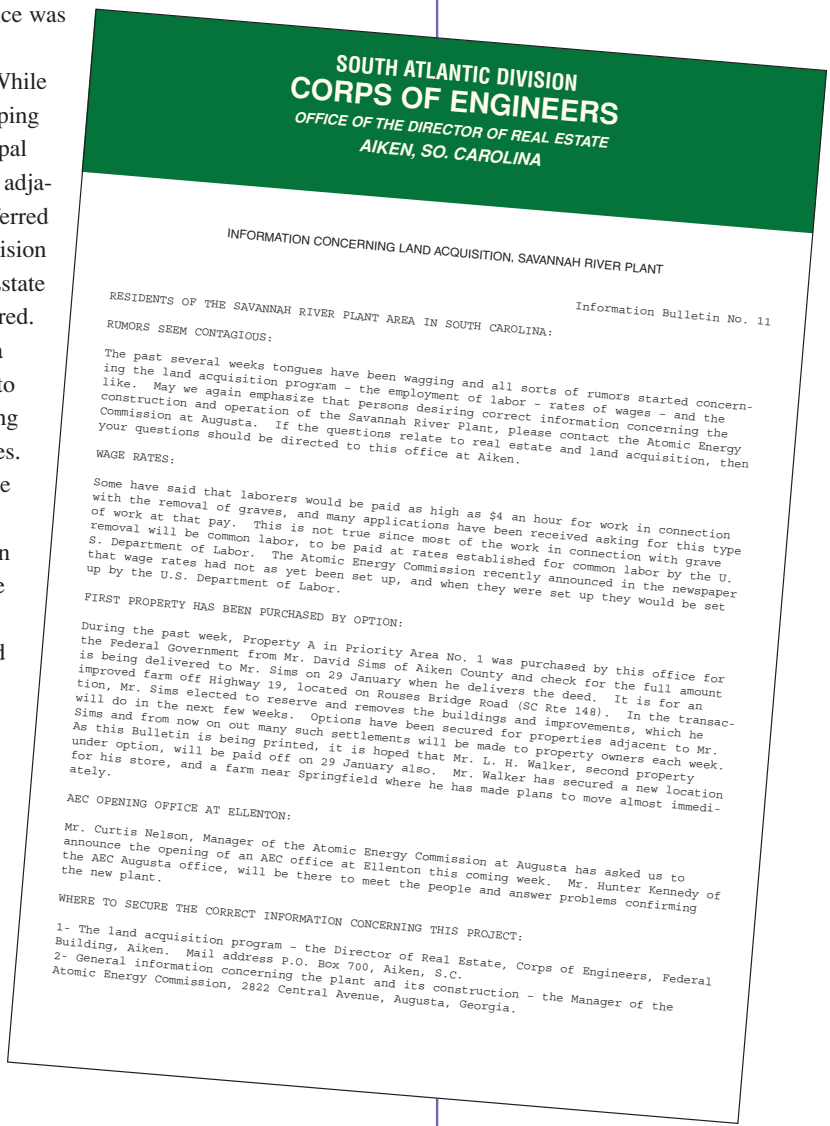
report also noted the need for help from other federal agencies in relocating farmers. The COE stated that they would follow the AEC's lead in hiring local personnel where possible on the acquisition program. They would also write a weekly bulletin to be mailed to all "boxholders" in the area that would offer information and advice about the land acquisition program and related issues.

The acquisition program formally began the day after the announcement so that the government would have the necessary lands either by declaration of taking or through actual purchase by June 30, 1952. Gordon Britton and his assistant, George L. Fryer, established the Real Estate Office in the United States Courthouse in Aiken. Burton J. Bell was the COE's public relations director and probably was the author of the information bulletins mailed to area homes.

Sixty-four graded employees were initially assigned to the program and at least three additional local appraisers were to be hired according to the planning report. Until the U.S. Courthouse office was fully staffed, appraisers were borrowed from the Columbia, SC, Office of the Federal Land Bank. While the U.S. Courthouse was the main office, the Mapping and Survey Branch was located in Aiken's Municipal Building and the Appraisal Branch in an unnamed adjacent building. Key COE personnel had been transferred from other positions within the South Atlantic Division and several persons who had worked in the Real Estate Office of the COE during World War II were re-hired. On December 29, a contract was let to a Columbia firm styled as James D. Walters, Title Examiners, to provide the legal legwork involved with establishing accurate title information on the acquired properties. Like the COE, the title firm opened an Aiken office for the project's duration.[24]

COE personnel had actually begun to arrive on November 29, and by December 12 they were able to open the Aiken office. The COE office lived up to its promise. Of the nineteen staff members hired locally, twelve were Aiken County residents and five were from Ellenton.[25] Over 120 persons had been interviewed for clerical and survey work. By January 26, four (more than the initial announcement of three) local men had been added to the field appraisal staff.

The first project area map published in the newspaper had shown the approximate boundaries and two priority areas for acquisition. From the beginning it was clear that the acquisition would occur in stages set by construction requirements. Landowners outside the first priority areas were advised "to go about their reg-



SOUTH ATLANTIC DIVISION
CORPS OF ENGINEERS
OFFICE OF THE DIRECTOR OF REAL ESTATE
AIKEN, SO. CAROLINA

INFORMATION CONCERNING LAND ACQUISITION, SAVANNAH RIVER PLANT

Information Bulletin No. 11

RESIDENTS OF THE SAVANNAH RIVER PLANT AREA IN SOUTH CAROLINA:

RUMORS SEEM CONTAGIOUS:

The past several weeks tongues have been wagging and all sorts of rumors started concerning the land acquisition program - the employment of labor - rates of wages - and the like. May we again emphasize that persons desiring correct information concerning the construction and operation of the Savannah River Plant, please contact the Atomic Energy Commission at Augusta. If the questions relate to real estate and land acquisition, then your questions should be directed to this office at Aiken.

WAGE RATES:

Some have said that laborers would be paid as high as $4 an hour for work in connection with the removal of graves, and many applications have been received asking for this type of work at that pay. This is not true since most of the work in connection with grave removal will be common labor, to be paid at rates established for common labor by the U. S. Department of Labor. The Atomic Energy Commission recently announced in the newspaper that wage rates had not as yet been set up, and when they were set up they would be set up by the U.S. Department of Labor.

FIRST PROPERTY HAS BEEN PURCHASED BY OPTION:

During the past week, Property A in Priority Area No. 1 was purchased by this office for the Federal Government from Mr. David Sims of Aiken County and check for the full amount is being delivered to Mr. Sims on 29 January when he delivers the deed. It is for an improved farm off Highway 19, located on Rouses Bridge Road (SC Rte 148). In the transaction, Mr. Sims elected to reserve and removes the buildings and improvements, which he will do in the next few weeks. Options have been secured for properties adjacent to Mr. Sims and from now on out many such settlements will be made to property owners each week. As this Bulletin is being printed, it is hoped that Mr. L. H. Walker, second property under option, will be paid off on 29 January also. Mr. Walker has secured a new location for his store, and a farm near Springfield where he has made plans to move almost immediately.

AEC OPENING OFFICE AT ELLENTON:

Mr. Curtis Nelson, Manager of the Atomic Energy Commission at Augusta has asked us to announce the opening of an AEC office at Ellenton this coming week. Mr. Hunter Kennedy of the AEC Augusta office, will be there to meet the people and answer problems confirming the new plant.

WHERE TO SECURE THE CORRECT INFORMATION CONCERNING THIS PROJECT:

1- The land acquisition program - the Director of Real Estate, Corps of Engineers, Federal Building, Aiken. Mail address P.O. Box 700, Aiken, S.C.
2- General information concerning the plant and its construction - the Manager of the Atomic Energy Commission, 2822 Central Avenue, Augusta, Georgia.

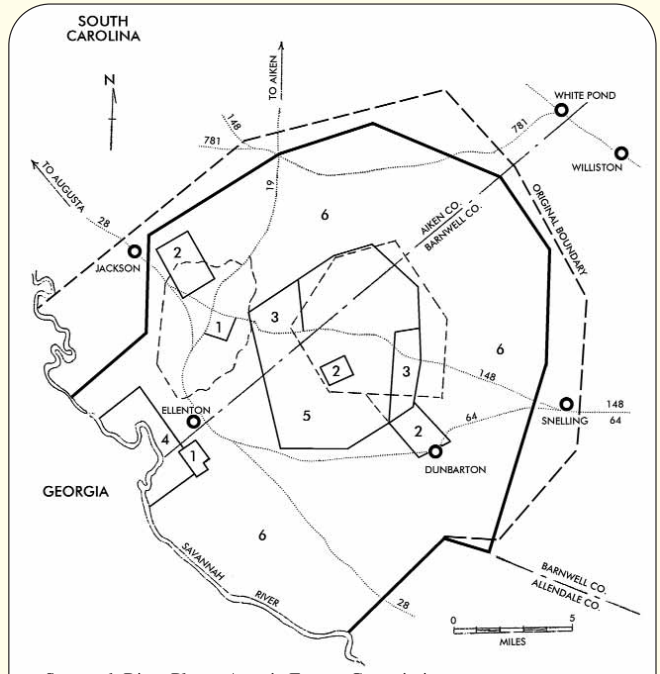
Circulars were sent out by the U.S. Corps of Engineers Office in Aiken to keep landowners informed about the land acquisition and their progress. Source: Prepared by the office of the Director of Real Estate, South Atlantic Division, Corps of Engineers, Aiken, S.C. Savannah River History Project.

ular business." Their properties would not be affected until the end of the year, and farmers were further advised that the proposed action should not affect the production of their 1951 crop.[26]

Appraisal of the tracts in Area No.1 began on December 18. All residents within Area No, 1 had to leave before March 15; residents of Area No. 2 had until June 1 to relocate. Chief Appraiser Spencer R. Cooley was in charge of the appraisals of Area No. 1. His team included Y. H. Daniell, Clark B. Honold, and Andres L Mauney.[27] Rights of entry to 54 properties and 3 cemeteries were acquired by December 21. The first property transfers occurred on January 29 for 582 acres of land and 20 buildings.

Boundary Definition

Between January 29, 1951, and June 30, 1952, the U.S. Army Corps of Engineers completed the land-acquisition program, acquiring by declaration of taking or by actual purchase 1,706 tracts of land. Ultimately 123,100 acres in Barnwell County, 73,462 acres in Aiken County, and 4,084 acres in Allendale County were acquired. Boundary alignments occurred as the acquisition program progressed. The first major change occurred on January 11, 1951, when the AEC and Du Pont reached a compromise on the acreage needed for an exclusion area and for safe reactor spacing. This change spared the towns of Jackson and Snelling from the plant boundaries. A second change occurred on September 5, 1951, when approximately 1,800 acres in Barnwell County were eliminated from the planned site and 1,650 acres in Allendale County were added. This change affected the plant area's southern boundary. A third major change in the project boundaries occurred in May 1952 when a 4,453-acre corridor of land on both sides of Lower Three Runs Creek in Barnwell and Allendale counties was added to the plant area. The addition of the creek and its banks allowed for a more efficient drainage system for the proposed facilities.



Savannah River Plant - Atomic Energy Commission

Note: Areas are designated by numbers (1 to 6) in the priority in which they will be acquired for the U.S. Government by the Corps of Engineers. Exact location of railroad right-of-way undetermined until engineering studies are completed.

- - - Project Boundary and Priority Areas as Originally Announced

——— Revised Project Boundary

——— Revised Priority Areas

This map with revised boundaries for the plant area was released by the AEC showing the elimination of Jackson and Snelling from the project area. Source: US AEC Press Releases.

The names and experience level of the appraisal team were released in an information bulletin so that all involved would be aware of their professional experience, particularly their work in South Carolina. It also served to identify the men to the larger community. *The Augusta Chronicle* reported that individuals posing as federal agents or Du Pont employees were canvassing property owners in the vicinity. A bogus agent posing as a Du Pont employee told one North Augusta property owner that she was personally representing Mr. Du Pont.[28] Luckily, the owner declined the offer.

One of the challenges that the COE recognized at the outset was the inflationary effect the program would have on land prices. Reports in both South Carolina and Georgia surfaced early of the "greed and chop-licking" of Aikenites who had raised the price of housing and land in the weeks after the announcement. One Ellenton man commented in disgust, "We're just clay pigeons and these people are shooting at us."[29] While some community members acted out of self-interest, others offered a helping hand. Sol Blatt of Barnwell welcomed those who were displaced into his home county. "We would like to have them come to Barnwell. If they do every effort will be made to assist. We want them in our churches, our lodges, our clubs."


FREE LOTS!

THE NEW ELLENTON
Chamber Of Commerce

has secured a number of choice homesites which they will give to anyone willing to build a home.

FOR ADDITIONAL DETAILS CONTACT
ARTHUR TATE

TATE REALTY COMPANY

MAIN STREET NEW ELLENTON

FREE LOTS!

The invitation to Barnwell County was somewhat compromised by the actions of State Senator Edgar Brown and an "option" committee. *The Barnwell People-Sentinel* reported that a group of local landowning citizens, including Brown, had optioned their contiguous properties along with adjacent smaller tracts to reserve the acreage for use as a housing project. Brown cleared the air, explaining that prior to the announcement he had committed to the COE Barnwell County's help in housing those displaced as well as the incoming operation and construction forces.[30] The local paper commented that the timing of the options might have looked like bad judgement but noted that civic good was the aim of all involved.[31] A more serious incident occurred earlier when an AEC official tipped off a Salt Lake City grocer about the new plant location. The grocer made a quick profit on two parcels that he sold to a lawyer and developer, J. C. Long of Charleston. The AEC official resigned and a FBI investigation was undertaken.[32]


BOMBED OUT?

Aiken-Barnwell County's D.P's will find in Edgefield opportunities for dairy and beef cattle production, peach growing, poultry farms, pulp-wood and timber products, and excellent jobs in industry. Edgefield has good schools, low taxes, strategic location for industrial and agricultural GROWTH—and the same kind of good people you have known.

This bank will gladly discuss in confidence your future plans. Loans are available to people of ability and good character for home building, farm purchase, and business expansion.

Maybe we can help you.

THE SECURITY BANK

R. H. Morris, Executive Vice President
Telephone 3311
Member F.D.I.C. Edgefield, South Carolina

Other communities, near and far, extended a welcome to those affected by the project. The newspapers contain scores of invitations, letters of condolence, and even editorials that called for "just compensation" for the properties to be taken:

> Even if a man owns a little ramshackle barn, and a tumble-down house, this property means far more to him than the market value which some appraiser might place upon it. It is his home; his roots are there.

Area newspapers were filled with invitations to those who were displaced by the plant.

Free Lots! Source: *Aiken Standard and Review*, January 22, 1953.
Bombed Out? Source: *The Augusta Chronicle*, December 4, 1950.

OUR WARMEST WELCOME

Our deepest Sympathy and warmest welcome are extended to our friends in hydrogen plant reservation area – our friends, who will vacate their homes and leave their friends, churches and schools.

We the undersigned firms and individuals offer you a hand of understanding. We invite you to the City of Aiken where you will find neighborly folks, excellent schools, and friendly churches:

W. Herbert Stiefel, Contractor
Owen & Thomas
American Oil Company
Buchanan Home and Auto Supply
Thomas Laundry and Dry Cleaning, Inc
B. C. Moore and Sons
Bank of Greenwood
Swingle Chevrolet Co., Inc
Commercial Pharmacy
Holley Tractor and Implement Co.
D. M. George Funeral Home
Nelson Implement Co.
Redd-Mc Lain Furniture Co.
Holley Motor Co.
Hutson-Etherredge Insurance Agency
Wise Hardware Co.
Auto Supply and Appliance Co.
Eulalie Salley and Co.
Lyon-Croft Mutual Insurance Agency
Belks Department Store
Farmers & Merchants Bank
Ram's Theatres

Source: *Aiken Standard and Review*, December 6, 1950.

> In our opinion, the only fair thing for the government to do is to pay every one of these displaced South Carolina residents the replacement value on their property. What with the skyrocketing prices, and the fact that these people are going to have to start life all over again, they should be paid enough for their property so that it can be replaced somewhere else without any monetary loss to them.[33]

The appraisers sent out to inspect the properties were intrepid. Their orders were to appraise and evaluate the affected properties according to federal regulations that made no mention of sentimental value in the evaluative process nor "replacement value." To do their jobs, these "government men," armed only with the credentials that identified them as official appraisers, entered into the lives of rural and urban families and placed a value on what they possessed, regardless of its meaning.

The acquisition program moved forward. For those who had the financial wherewithal to move regardless of the financial outcome on their land in the project area, it was fairly straightforward. These individuals or families were able to move quickly before inflation set in and had a better selection of available house sites or farms. For those who sharecropped or rented, choices were to move elsewhere and continue farming or to apply to the project's employment office. From the first, displaced persons were given first consideration in the plant work force that was developing. The COE information bulletins always included information on where and who to contact for a job. Many residents found jobs that changed their lives and the future of their families, as second and third generations of these families would later work at the site. For those residents who needed the purchase money to acquire a new home, the appraisal process and the speed with which it happened was crucial to their chances to establish satisfactory new lives elsewhere.

The task of creating an accurate site map was considerable. Joseph E. Hovas, Chief of the US COE Mapping Section, and his multiple survey crews were responsible for completion of the field survey. Hovas had signed on with the Corps of Engineers in 1948 working as a cartographic engineer on the Clarks Hill Project. He was transferred to the Savannah River Project in 1951, later joining the AEC as a civil engineer. The original survey's accuracy is still commented on by later surveyors and Joseph Hovas' signature is present on all original maps. Source: Savannah River Operations Office, Atomic Energy Commission, News Release No. 956, December 16, 1974.

(Below) Unidentified surveyor in peach orchard, August 13, 1951. Courtesy of SRS Archives, negative M-241.



SURVEY AND APPRAISAL

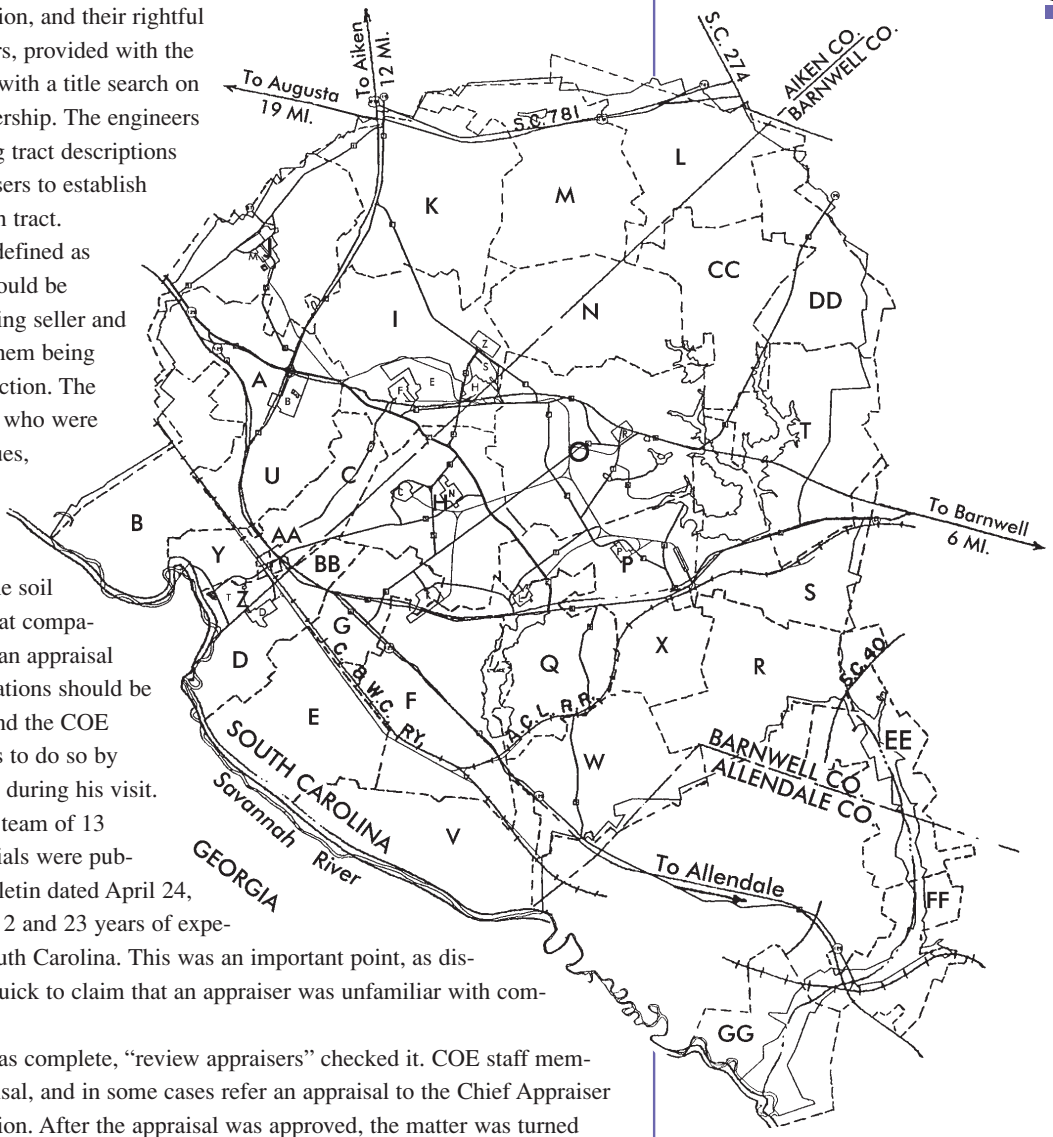
Based on the premise of "negotiated purchase," the land acquisition involved several steps.[34] First, the engineers were given specific boundaries for the area to be acquired. In the case of the Savannah River Site, these boundaries were not fixed until January 11; approximate boundaries were used initially. The acquisition map showed six areas that were prioritized according to the construction schedule.

The first task was to create an accurate map of the project area, based upon field survey and aerial photography. Joseph Hovas, the Chief of the Mapping Section, led six to eight survey crews in the field to accomplish this task. The surveyors, using aerial photography supplied by Aero Service of Philadelphia, located recognizable property lines on larger tracts, typically those along the river. From these known points, the surveyor could better ascertain the boundaries of the smaller tracts.

The COE organized the plant area into 33 sections, listed alphabetically. The COE staff would then identify individual tracts and their

boundaries within each section, and their rightful owners. Government lawyers, provided with the field information, followed with a title search on the property, verifying ownership. The engineers could then begin assembling tract descriptions that would allow the appraisers to establish the fair market value of each tract.

Fair market value was defined as the amount of money that could be agreed upon between a willing seller and a willing buyer, neither of them being obligated to enter the transaction. The COE hired local appraisers, who were familiar with local land values, to prepare the first appraisals. These men were asked to look at the buildings, the timber, and the soil on each tract and then look at comparable properties to arrive at an appraisal value. Any special considerations should be brought to their attention, and the COE encouraged property owners to do so by accompanying the appraiser during his visit. The identities of the COE's team of 13 appraisers and their credentials were published in an information bulletin dated April 24, 1951.[35] Each had between 2 and 23 years of experience as an appraiser in South Carolina. This was an important point, as disgruntled landowners were quick to claim that an appraiser was unfamiliar with comparative farm prices.



Acquisition map for Savannah River Site used by US COE for acquisition tract register dividing the site area into 33 sections. Courtesy of Savannah River Site Archives.

When each appraisal was complete, "review appraisers" checked it. COE staff members would check the appraisal, and in some cases refer an appraisal to the Chief Appraiser for the South Atlantic Division. After the appraisal was approved, the matter was turned over to the U.S. Department of Justice, which was responsible for approaching the rightful owner with the appraisal and legal documents in preparation for acquisition. Due to federal regulations, the owner was not provided a breakdown of the appraisal, and the appraiser was not permitted to quote a price higher or lower than what was considered the full fair market value as disclosed in the appraisal. The latter regulation was invoked for the property owner's protection against being a paid a price less than the Government believed the property was worth.

If both parties were in agreement, an option contract was signed. If there were improvements on the property—i.e., a house, barn, shed, office—the value of these improvements was reflected in the appraisal. If the owner elected to keep any or all of the buildings on their property, he or she could reserve them at their salvage value in the option contract. When the option contract was finalized, a timetable for the removal of the

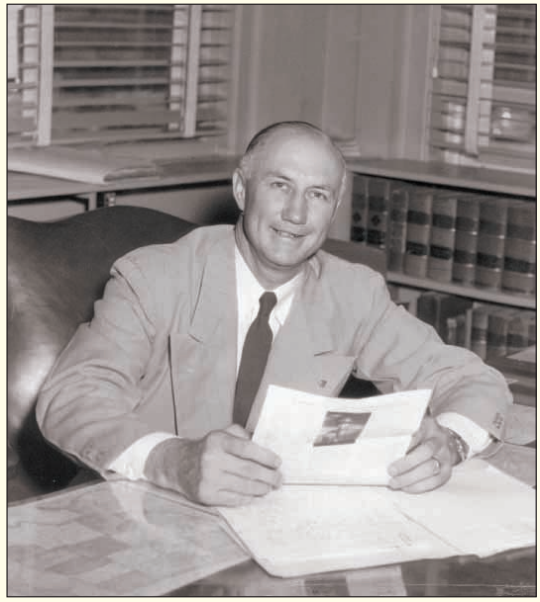
Strom Thurmond in downtown Aiken law office, 1951. Strom Thurmond Collection, Mss 100. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

"reserved improvements" was provided. If an owner chose not to reserve homes or any other types of improvements, the government had the right to dispose of them to the highest bidder.

If the owner disagreed with the appraisal, then the Real Estate Office would request that the Federal Court decide what the property was worth in a condemnation proceeding. At the outset of such a proceeding, the appraised value of a tract was deposited with the Court so that the owner could petition the Court for 80 to 90 percent of the amount deposited as a credit against the final award. All sellers had the right of a jury trial to ascertain whether an appraisal was fair. A ruling later passed in August "replaced a jury

Strom Thurmond

Born in 1902 in Edgefield, South Carolina, Strom Thurmond began his career as a farmer and an educator. He was a product of the Edgefield County public school system and had obtained his degree from Clemson College (now Clemson University) in 1923 in horticulture. His political career began when he became Edgefield County's superintendent of education in 1929, a position he held through 1933. Thurmond read law with his father, John William Thurmond, and was admitted to the South Carolina Bar in 1930, after which he served as the Edgefield Town and County attorney from 1930-1938. During the 1930s he held positions in the state legislature and the U.S. Court of Appeals, followed by service in the army during World War II. A member of the Civil Affairs section of the First Army headquarters, Thurmond was a part of the Normandy invasion while on assignment with the 82nd Airborne Division. After a stint in the Pacific, he returned to his home state where he was successful in his bid for state governor in 1946.



In response to the nomination of Harry Truman for President in 1948, he sought the presidential nomination of the States Rights' Democratic Party, a race in which he won 39 electoral votes. His later race against Olin D. Johnston for U.S. Senator in 1950 was unsuccessful. After his tenure as governor he retired to private life in Aiken where he practiced law. He was instrumental in helping many landowners secure better prices for their property during the land acquisition program for Savannah River. In 1954, he was the first person in U.S. history to be elected as a write-in candidate for the state senate seat, defeating Edgar Brown. He has served as a member of the United States Senate from South Carolina since 1954. He switched to the Republican Party in 1964, helping Barry Goldwater in his campaign for president and played a significant role in the Nixon presidential campaign strategy, marshalling the Southern vote.

Thurmond's senatorial career includes a number of committee appointments to the Armed Services, Judiciary, and Veteran's Affairs committees. He was the President Pro Tempore between 1981-1987 and 1995 of the U.S. Senate, and has served as chair of the aforementioned committees. In these contexts, Senator Thurmond has been a strong supporter of Savannah River and atomic energy, looking for ways early on to deepen his home state's edge in atomic energy, supporting projects such as the Parr Shoals Nuclear Reactor and other private power projects. Later he and other influential South Carolinians would go to bat for Savannah River in 1963 when the closure of R reactor loomed large, protecting the State and region's interests.

Source: "Strom Thurmond Biography," The Strom Thurmond Institute. http://www.strom.clemson.edu/strom/bio.html.

trial with three judges who would go direct to a Claimant's lot in order to make the final decision."[36] Land that was needed immediately was obtained through declaration of taking, which uses the government's power of eminent domain. Where this happened, the government took land by court proclamation after paying for it.

As Louise Cassels had pointed out, the appraisal value of land would be the sticking point. On March 27, at a public meeting in Aiken, about 200 persons met with Representative John J. Riley and Colonel Gordon Britton to express their dissatisfaction with the AEC appraisals.[37] Two resolutions were formed. In the first, those affected by the AEC plant asked to be exempt from capital gains tax on property sold to the government for the plant. The second resolution requested that the COE condemn land to be used in 1951, serve notice, and place the money with the clerk of court so that those who were forced into an early removal would have the financial wherewithal to relocate. The second resolution also asked that the COE provide a complete breakdown of a property's appraisal to anyone appealing his or her land transfer to the court. J. Strom Thurmond, former governor, was in the audience. Thurmond advised that the people should receive fair and just compensation for their properties and that they have recourse through the courts to obtain what they thought was fair.

Two days later a second meeting was held in Ellenton. State Senator Dorsey K. Lybrand joined Congressman Riley at this meeting along with 200 attendees. William E. Bush, an Augustan and landowner in the project area, spoke forcefully asking state officials—governor, senators, and representatives—to work in their behalf by passing an act that stated clearly that a property owner must be paid the full replacement value for property. Also, each property owner should have a breakdown of his/her property's appraised worth. The latter should be signed by two appraisers and approved by the head of the COE's acquisition program.[38] No resolutions were generated at the Ellenton meeting. Despite the dissatisfaction with their efforts, the COE forged ahead. On April 20, condemnation proceedings began on 22 tracts. As promised, funds equaling appraised values were deposited with the clerk of court, and landowners with clear title to those tracts could draw down the full amount accorded their property. An answer also came on the first resolution formed at the Aiken meeting. The House Ways and Means Committee approved a bill to eliminate the capital gains tax clause from the proceeds from seized property that was condemned by government agencies.[39]

Some of those who were unhappy with the COE appraisals followed the course of action suggested by Strom Thurmond. The former governor had become an Aiken resident in 1950, practicing law with Charles Simons and Dorsey Lybrand from their downtown Aiken office. Styled Thurmond, Lybrand, and Simons, the local firm handled a number of suits against the government brought by area landowners.[40] *The Aiken Standard and Review* reported on several cases in 1952 where the Aiken firm successfully represented the landowners, sometimes doubling the original appraisal offer.[41] Other local attorneys such as Fabian Keirce of Bamberg and Henry Busbee also provided legal advice to project-area landowners.[42]

In May a special three-member commission appointed by Federal Judge George Bell Timmerman heard the Leigh Banana Crate Company's suit against the government. The appointees were Dean Samuel L. Prince of the University of South Carolina Law School, Louis O. Rast of Swansea, and C. D. Barr of Leesville. Carl G. Leigh sought $3 million dollars for his production plant, which was sited on land owned by the Cassels Company,

which in turn lodged a suit against the government, contesting the appraisal amount.[43] As the COE mentioned in their planning report, the relocation costs of this business would cause problems. The Corps would end up paying $1,280,965 for the Leigh Banana Crate Factory, almost $500,000 more than its appraised value.[44]

In July 1953, the District Engineer, Savannah, took over responsibility for completing all remaining real estate transactions. The COE Aiken office closed in May 1954; personnel would be sent up to Aiken when needed from this point onward.[45] At the close of the land acquisition program, 46 percent of the property acquired resulted from condemnation proceedings. The largest single condemnation action was filed in the Federal District Court by the government in September 22, 1952, and it embraced 19,302.35 acres in all three counties. Faulty title was attributed to one-third of the 698 tracts that were condemned.[46] When completed, the COE would purchase all the land and necessary improvements for $15,582,026. The State of South Carolina was to be reimbursed $471,621 for its costs in relocating highways affected by the project. The cost of relocating the major utilities, not including the railroads, was $270,673. The utilities were Aiken Electric Cooperative, Salkehatchie Electric Cooperative, S.C. Gas and Electric, Cassels Telephone Company and Williston Telephone Company. Finally, the cemetery relocations totaled $168,749. The entire program was estimated in 1959, prior to the final audit, to cost $19,000,000.[47]

"EVEN THE DEAD"

The Corps was also asked to handle cemetery removals. An inventory of the site area identified 161 cemeteries, some of which dated to the late 1700s. One hundred twenty six cemeteries were removed, and 5,984 graves were relocated outside the project area with the approval of the next of kin. The reports written by the COE show the care taken with this aspect of the land acquisition program. Relatives were involved in the decision-making and the AEC bore all costs involved. Notably, area historical societies were contacted for discussions about removing graves that had historical significance. Cemeteries that were located within the site's outer boundary were left in place, and visitation privileges were established.[48]

Between 1951 and 1954, the Corps contracted with private firms to handle the removal and reinterment. E. H. Moody of Bryson City, North Carolina, handled the first group, which were located in the northwest section of the plant area. Colburn and Shumaker of Wagoner, Oklahoma, handled the second group located in the center of the plant area, and Scherwin and Jessen of Charleston handled the remaining three groups. Final removals were completed in February 1954.[49]



Dunbarton Grammar School with schoolbuses and children lined up for school photograph in 1926. Courtesy of Margaret Anderson and the Savannah River Archaeological Research Program.

FROM "WHAT WAS" TO "WHAT IS"

Agriculture was the area's economic backbone. Farmers reportedly occupied 73 percent of the 1,706 tracts acquired.[50] This fact, reported in 1960, was probably based upon the field observation of the



Dunbarton Grammar School converted for use as a weather station furnishing needed weather information for construction crews, 1951. Courtesy of Savannah River Archives, negative M-144.

appraisers. However, a recent study has shown that even individuals involved in commerce operated or rented farm property. This study, conducted by the SRARP, identifies 99 percent of all SRS land as agricultural lands, containing home places, cultivated fields, idle fields, pastures, and woodland. The average size of a rural property on the site in 1951 was 197 acres.[51] This was larger than average farms in Aiken and Barnwell counties in 1950. Aiken County farms averaged 123.9 acres in size and Barnwell 138.8 acres. For both counties sharecropping was on the decline, and an early report noted many vacant buildings on the area farms as a result.[52] Also for many of the younger generation, the job market was slim. As a result, there was a steady out-migration of younger men and women who made their homes in regional cities where work could be found.[53]

While some large tracts owned by lumber companies would traditionally be considered commercial properties, they were not extensively timbered, but used dually for agricultural pursuits. The SRARP land-use study considered them as agricultural properties as well.[54] The lumber company landholdings included the following: International Paper Company (15,204.3 acres), Aiken Lumber Company (72 acres), Savannah River Lumber Corporation (256 acres), United States Plywood Corporation (101 acres), West Virginia Pulp and Paper Company (245 acres), and the Woodward Lumber Company (362 acres).



Agriculture was the economic mainstay of the project area with farmers occupying the majority of the land acquired for the new plant. Modest vernacular residential and farm buildings like this frame tenant home were commonly found shaded by a single tree, surrounded by fields. Courtesy of SRS Archives, negative M-199.

The appraisal records detail through photography and written descriptions the assemblage of buildings that were typical of the many rural properties on these tracts. Rural vernacular house types characteristic of the eighteenth, nineteenth, and early twentieth centuries were all present. I-houses, shotgun houses, hall and parlor houses, cottages of all types, and bungalows were architectural styles that suited the area's residents. Tenant homes tended to be simple in plan and construction. For both the main house and the ancillary dwelling, unpainted frame buildings with porches were in evidence, shaded by a stand of trees. Surrounding fields of corn, cotton, peanuts, orchards, and vegetables provided the livelihoods of the occupants. Small southern barns, sheds, smokehouses, corn cribs, chicken coops, and privies were familiar companions to the main house. While the COE appraisers recorded 32 different types of outbuildings, chicken houses, barns, and privies







This sequence of photographs shows the appraisal record captured on film for one tract of land. Each building was assigned a number. Seven buildings are shown including a main house denoted as a six-room unpainted dwelling on brick piers with twelve windows and five doors with a kitchen ell on its back elevation, a privy, stable, corn crib, barn and shed. In addition a five-room tenant house with a barn and shed was also recorded. Courtesy of Department of Energy, Site Acquisition Appraisal Records.

Appraisal Report for Land and Improvements for the J. B. Large Tract (F-546–296 acres)

VALUATION OF LAND

Present Use	Soil type	Topography	Area	Unit Value	Total Value
Cultivated & Idle	DSL	Level-Undulating	73	45.00	3,285.00
Cultivated	OSL	Undulating	6	40.00	240.00
Cultivated & Idle	OLS	Undulating	25	30.00	750.00
Idle	OLS	Level	23	25.00	575.00
Reverting	DLS	Level	57	15.00	855.00
Woodland (Upland)	OLS	Undulating	24	10.00	240.00
Woodland (Swamp)	PLS	Level	88	6.00	704.00
			TOTAL	**171.00**	**$6,649.00**

Source: Cabak, Melanie A. and Mary M. Inkrot. *Old Farm, New Farm An Archaeology of Rural Modernization in the Aiken Plateau, 1875–1950*. Savannah River Archaeological Research Papers 9, Occasional Papers of the Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

were the most prevalent. If a property had a tenant or sharecropper's home on their farm, this secondary dwelling probably had its own "area."[55]

Churches, cemeteries, and schools anchored the scattered rural communities. While an occasional poker game, cockfight or "snort" of moonshine was tolerated, area residents placed a high value on church attendance and membership.[56] Baptist, Methodist, and Methodist Episcopal churches predominated among the 44 church congregations and religious societies that owned land in the project area.[57] Rural and urban, frame and brick, these buildings provided structure to the landscape and the people they served. A University of North Carolina study of urbanization in the area in 1954 describes the









VALUATION OF IMPROVEMENTS

Kind	Size	Construction	Roof	Foundation	Condition	Present Value	Salvage Val.
6-rm dwelling (3379)	14x42						
Ell	22x24	Frame	Metal	Brick Piers	Fair	2,000.00	350.00
Privy (3380)	4x4	Frame	Wood Shingle	Wood	Poor	5.00	XXX
Stable (3381)	8x14	Frame	Board	Wood	Poor	15.00	XXX
Corn Crib (3382)	14x18	Frame	Metal	Wood Block	Good	125.00	20.00
Barn (3383)	10x40	Frame	Metal	Brick Piers	Poor	135.00	25.00
Shed	10x12						
5-rm Ten. House (3384)	20x25	Frame	Metal	Wood	Poor	300.00	40.00
Barn (3385)	10x12	Pole	Metal	Wood	Poor	50.00	10.00
Shed	10x12						
Main house – 1 story unpainted – 12 windows – 5 doors – no electricity – 2 chimneys I flue Sills 6 x 6 Floor Joists – 2- 10”x 30” cts							
190’ deep well – 2” casing hand pump						175.00	10.00
Approximately 410’1” pipe galvanized A.15						61.50	20.00
					TOTAL*	**$2,866.50**	**$475.00**

* Estimated contribution improvements to appraised market value of the property as a whole.

mechanics of the many small close-knit communities in the project area at the point of change:

> Communities have been small and unchanging. Families of whites and Negroes have worked together for decade on decade, the one guaranteeing a minimum of physical security, the other providing hands to till the soil, and the labor for the stores, the yards, the homes. Neighbors and relatives have valued highly the personal, close ties of life on settlements where everyone knew everybody else’s joys, sorrows, scandals, and hopes.[58]

Excerpt from C. S. Anderson Diary



C. S. Anderson and son Randolph, circa 1920. Photograph courtesy of Margaret Anderson and the Savannah River Archaeological Research Program.

Another day of comotion all day don't Suppose there will ever be another day of Happiness here Since the Government has come in and hit a death blow on this part of the world see nothing and hear nothing else - December 4, 1950

don't think there was ever a Saturday night Since Dunbarton was in existence that there was so few people here all stores closed before the regular time no money and no one knows what to do or where to go - December 30, 1950

Things have changed up a little in the place with the government they come in today and informed Henry Moody Bo Corley and Lane they would have to be out by April the 1st has got things all up in the air we don't know what to expect next. - January 12, 1951

Ham Dicks had a sale today at his farm they say there was quite a crowd there Margaret had to go up with Ham to keep records - January 31, 1951

I cleaned up the backyard this AM and opened up the flower pit and taken out what was left in it. think I will fill it up. don't suppose they will ever need it again here. there has been a good deal stirring around here today. guess things will soon be different - February 12, 1951

They had a regular election to see what should do with the church funds and parsonage a lot of confusion too - February 18, 1951

Today has been a busily day around here they had a bake sale on Clarence Dicks all daylong there was quite a crowd attended the Sale they sold Clarence Albert Ellis & Geddings Farm implement I went over for a few minutes this AM don't think they finished up. I could hear them at Sun Set. - February 28, 1951

We all went to ride taken Jule up to see the Bumed Area up by Rouse Bridge and on up to New Ellenton and back by Ellenton. - March 18, 1951

The Government Man was here this PM and settled up for the old Homeplace after being in the family for 80 years or more it don't seem fair that Such a thing could happen. - July 5, 1951

They started up with the House (old Home Place) today got the Kitchen & dining Room as far as the Bay just below Hams Fertilizer House the dwelling got as far as Clarence Dicks Corn Field. - August 1, 1951

They moved Thomas Grove Church today takeing it out about Elko. September 13, 1951

Done nothing all day. Dupont work in full blast from the way the machines are passing through here during the day. the House movers are busiy too. Wallace Harley house got this far in PM that makes 3 I have seen pass through today. Beatty Gin House caught on fire this PM. Dupont fire Truck put it out. - October 12, 1951

One year ago today the Government anounced they was going to take over everything in this part of the country there has been quite a change Since Tuesday November 1950. old Homes that had been in the family for generations has been vacated and they have moved to new Homes. Some locaitys there is nothing left to mark the old Home Site. never in the History has people been so demoralized as they have been during the past year. They have not taken Dunbarton yet but we are expecting it to happen any day. One year ago today the Government taken Over. - November 28, 1951

Clarence Dicks moved his clubHouse from his fish pond to Barnwell today. - December 6, 1951

No doubt today was the quietest Christmas Day that was ever seen here. and as we stop to think this will be the last Christmas that will ever be spent in Dunbarton. enough to make all feel Sad for Soon it will a thing of the past like the song, I use to hear that my old Daddy did love to hear Jerry Snelling Sing the words of it was (Far Away). - December 25, 1951

Today winds up the old year 1951 and none of us can realize the many changes that has been made this year. and Soon (there) will be more as it (is) just a question of time (until) Dunbarton will be like other places. a thing of the past. Meyers Mill passed out today. the PO and mail Route was closed today. we can all see now what the Government has done for us. Dupont will Soon blot Dunbarton (off) the map. it is hard for the people to understand why we have to give up our Home and locality Somewhere else. (we) do not know where we will live to see it closed out if I am living. hope God will give me the courage and strength to leave the old familiar places with a Smile instead of sheding tears. - C.S. Anderson Diary, December 31, 1951

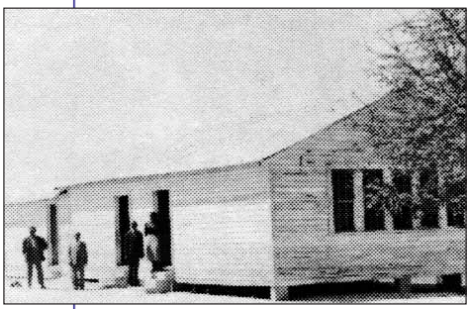
Source: Richard Johnson, Jr, Tonya Algerine Browder, Richard David Brooks, and David Colin Crass. *Memories of Home: Dunbarton and Meyers Mill Remembered*. Savannah River Archaeological Research Heritage Series I. Occasional Papers of the Savannah River Archaeological Research Program, Community History project, South Carolina Institute of Archaeology and Anthropology and University of South Carolina, 1993: 56.

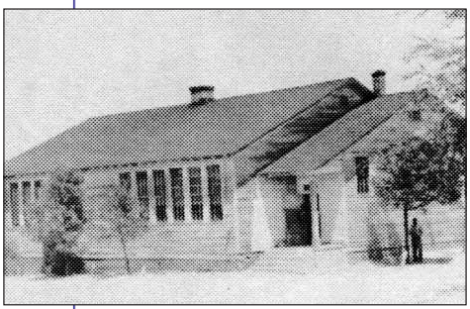
Attesting to this sense of community, many of these churches would be moved to new locations where a majority of their congregation was relocating.

Community schools were listed in the acquisition records. There were 23 schools of various sizes in the project area that served the area's children. Their names, enrollment for the beginning of the 1950/51 school year and number of teachers are shown below.

Name	County	Pupils	Teachers
Ellenton	Aiken	290	12
Ellenton	Aiken	123	4
Brinkley	Aiken	73	3
Bloomingdale	Aiken	47	2
Fairfield	Aiken	27	2
Oakview	Aiken	12	1
Greendale	Aiken	43	2
Willow Pitt	Aiken	25	1
Mill Branch	Aiken	11	1
Mossy	Aiken	17	1
Dunbarton	Barnwell	44	3
Thomas Grove	Barnwell	330	12
Union Branch	Barnwell	29	1
Fair Branch	Barnwell	34	1
Union Branch (Four-Mile District)	Barnwell	40	2
Haley Branch	Barnwell	28	1
Craig Pond	Barnwell	22	1
Ashley Grove	Barnwell	45	2
St. Luke	Barnwell	31	1
Gum Pond	Barnwell	60	3
Ned Branch	Barnwell	68	2
Four Mile Park	Barnwell	119	4
Spring Branch	Barnwell	50	2
Total Pupils		**1,568**	**64**

Only two of the above schools were attended by white students; the remainder served African American students. The Ellenton schools closed in February; their closure was delayed until a new school in Jackson was completed. Unlike the Ellenton students, students at the Dunbarton School completed their school year in June 1952.[59] Places for all children had to be found at either new schools or at already established outer community schools. Local school boards began to work with AEC officials almost immediately in planning closures and in realigning school districts to accommodate the substantial changes in their school populations.





"The school was constructed in the early 1920s and was built by a Mr. Rosenwall as a gift to the people. The school was known as the Academy. Then a group of black churches, called the Association, took over operation of the school and changed the name to Thomas Grove. Later the state took over and that was when the name was changed to Four Mile, because of the Four Mile Association. Four Mile also had a boarding house, because it was the only black school in the area. Children came from all over the county came to the school. They would come to school on Sunday and go back home on Friday." Source: Richard Johnson, Jr, Tonya Algerine Browder, Richard David Brooks, and David Colin Crass. *Memories of Home: Dunbarton and Meyers Mill Remembered*. Savannah River Archaeological Research Heritage Series I.

"The first of the house movers, a man by the name of Ralph South, set out for these parts from Ordway, Colorado, on November 28th, the day the government announced the project."

Daniel Lang, "Camellias and Bombs, " *The New Yorker*, July 7, 1951.



TOWN CLOSURES



On April 23, 1951, the AEC asked the COE to move forward with appraisals of Ellenton and Dunbarton. The need to expedite the process stemmed from changing construction requirements and from a request from town officials to get the process underway so residents could begin planning their futures. Mapping the town was their first priority, and this was forecasted to be a two-month proposition. The maps and appraisal records prepared by the COE along with the comments of the residents quoted in newspapers or captured in oral history accounts offer an incomparable image of these towns and their environs before they disappeared.

The End of a Hometown



Mike Cassels, the proprietor of the Long Store turned UPI correspondent, wrote a story about the end of his hometown:

"It wasn't a very beautiful place except to the people who lived there. The railroad ran through the middle of town, and the folks who had nothing better to do met the 4:30 passenger train, which we called 'Fido'. Lord knows why.

The depot was right across the street from my father's general store….That was the center of town because the fire bell was there too. In the winter, the farmers would stand around the pot-bellied iron stove in the long store and wonder whether it would ever quit raining. In the summer, the fields turned white with cotton and the sun that baked down so intensely that it was hard to find energy enough to do anything except go swimming in the creek, or eat a cool watermelon or plan a possum hunt for the cool of the evening.

That was the way it was when my grandfather was a boy, and that's the way it still was when I took my son there for the first time a few years ago.

I am afraid my son won't remember it that way, though. What little Mike will remember, I suspect, is all the noise and confusion and feverish activity which has descended on Ellenton when he made his last visit to grandmother's house last Thanksgiving. Armies of bulldozers were snorting through the cotton fields, turning them overnight into flat expanses of land."

Source: *The Augusta Chronicle*, November 29, 1950.
Photograph Source: Louise Cassels, *The Unexpected Exodus,* (Aiken, SC., Sand Hill Press,1971).

Ellenton, incorporated in 1880, was a railroad town 25 miles southeast of Augusta founded by a number of wealthy land-owning families including the Bush, Dunbar, Ashley, and Buckingham families.[60] These same surnames occur in the 1950 acquisition records, joined by the Cassels, Brinkley, Risher, and Smith families. All appear to have deep roots in the community in which they and their extended families lived. Ellenton's half- and one-acre rectangular lots within a one-mile-square incorporated area, reached back away from the tracks of the Charleston and Western Railroad. River, Jackson, and Dunbar streets paralleled the railroad; Evergreen, Center, Fair, and Church streets paralleled Main Street. South Carolina State Highway 28 also sliced through the eastern edge of town. Some roads, such as Main Street, were paved while side streets were typically unimproved. The town's 1950 population was 746 prior to the announcement.[61]



(Opposite Page) February 29, 1952, the last day for postal service for Ellenton Post Office, is reported on live by Augusta's radio station WGAC crew. Courtesy of SRS Archive, negative M-581.

(Inset) Cassels' Long Store, was an Ellenton landmark on Main Street. The 210' general store built circa 1900 heated by a pot-bellied stove was an important gathering place for the townspeople. "From early morning until late afternoon, male customers coming into the store would take time to 'set a spell' in these chairs. They debated how to correct the evils of the world, the nation and the state. Somehow I doubt there was much wisdom imparted around that hot stove, but judging from the laughter, there must have been a lot of wit…" Source: Louise Cassels, *The Unexpected Exodus*, (Aiken, SC., Sand Hill Press, 1971), 54. Courtesy of SRS Archives, negative 6675.

(Below) Oswalt House Moving Company of Batesburg, S.C. jacks up a house to prepare it for moving offsite. Courtesy of SRS Archives, negative 9273-1.



Housing ran the gamut from large mansions to smaller frame vernacular buildings such as central-hall homes or hall and parlor types. The presence of bungalows and cottages attest to Ellenton's twentieth-century growth. County tax records show that Ellenton had 56 merchants whose respective businesses were housed in 33 buildings in 1950. Main Street was the place where businesses clustered. The Cassels Family, a major force in modernizing Ellenton and wielding considerable influence in town affairs, operated the "Long Store" on Main Street. The frame commercial building, 210 feet long and 41 feet wide, was a town fixture; most residents and farmers from outlying areas remembered the store that had everything from "toothpicks to coffins."[62] In addition, this family built and operated a power plant and owned a Standard Oil and Gas franchise, two funeral homes, a dairy farm, a sawmill, several large farms, the telephone company, and the bank. Other Ellenton businesses included barbershops, a dry cleaner, auto garages, a movie theater, a drugstore, two icehouses, auto parts store, a Chevrolet dealership, a post office, several restaurants, and a hotel.

Churches, such as Ellenton Baptist Church, Ellenton Christian Church, Ellenton Methodist Church, Four Mile Baptist Church, House of Prayer, Mount Mariah Baptist Church, and Runs Missionary Baptist Church, served the town's white and black congregations. Children were educated at two schools. African American children attended a grammar school in town that ended at the seventh-grade level. For their high school education, these children attended Four Mile High School in Dunbarton or Schofield School in Aiken. Attending either

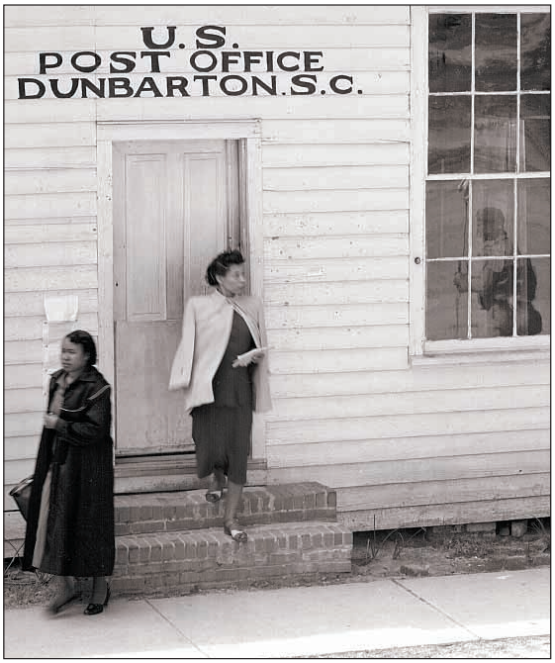
required traveling long distances. White children attended both grammar and high school in a new complex that featured a gymnasium and other new improvements, indicating that Ellenton was building for its future.

After the appraisals began, change rapidly occurred in Ellenton. The business people were the first to evacuate, followed by their employees. Louise Cassels described Ellenton in the spring of 1951 as a "well groomed corpse." Residents spruced up their homes, gardens were well tended, and interiors kept immaculate as residents waited for the appraiser's knock on the door.[63] Over the next year, the town and its environs would take on a "snaggletooth" appearance as houses and other improvements were moved away. Du Pont assigned an engineer–coordinator, D. M. Murphy, to aid those who wished to move their homes to other sites and to coordinate those moves with their construction schedule. Murphy was responsible for removing overhead wiring in Ellenton and on certain highways to assure that the houses were safely moved through the plant area, and for scheduling and coordinating the expected 200 to 300 house moves from Ellenton and Dunbarton. By January 1952, one source reported that owners had removed only 75 buildings of all types from Ellenton.[64] This was almost half of the town's total building stock. A subsequent report noted that five other buildings had been removed and several more still were to be moved.[65] The new owner left municipal buildings in place for use. Curtis Nelson reassured all that any building that remained on the AEC plant area would be used not indiscriminately razed.[66] He also noted that buildings with historical significance would be protected.[67]



Dunbarton Baptist Church, circa 1950. Courtesy of the Zobel Family.

Ellenton was to be evacuated by March 1 and Dunbarton by April 1. Dunbarton, a nineteenth-century railroad community named after the Dunbar family, was incorporated in 1910; its town limits extended one mile in all directions from the Atlantic Coast Line railroad depot in its center. The majority of the town was situated south of the tracks of the Atlantic Coast Line along Main or Hickory Street and off the three blocks that were south

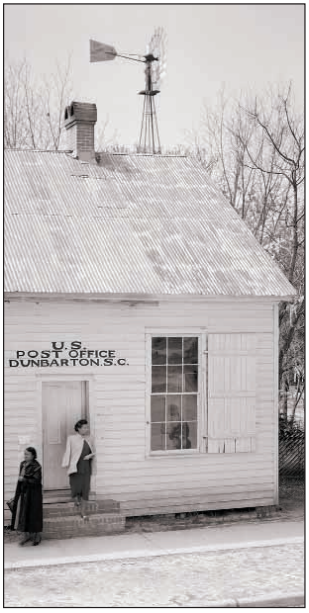


Detail of Post Office entry where postal customers pause to look at COE surveyor at work. Profile of surveyor is reflected in window glass.

of Bay Street. The town's commercial area and public buildings were contained on about 17 lots that were sandwiched north of the railroad but south of SC Highway 64.

Dunbarton was home to about 300 people in 1951; the majority of the population were old time residents. Sixty-six landowners were contacted about Dunbarton property. The Anderson, Brailsford, Dicks, Doe, Eaves, Greene, Hiers, Moody, Rountree, Schumpert, Tisdale, Wall, Whaley, and Williams families are well represented in the acquisition register. While the COE acquisition planning report counted 15 commercial buildings, 35 homes, 2 gins, a church, a sawmill, a school, and a railroad station, the actual acquisition records show there were additional buildings in the small agrarian community. The two-story brick grammar school and the high school were open from 1920 through 1950 for white children. Four-Mile High School, which taught eleven grades for the black community, was also in the general community. This single-story frame school had dormitories so that students who had to travel to get to school could be accommodated during the week.[68] Churches, particularly Baptist churches, were plentiful in and around the community. Cypress Chapel–Dunbarton Baptist Church, St. Luke Baptist, Bethlehem Baptist, Joyce Branch Church, Pleasant Mountain Baptist Church, Ned Branch Baptist, and Steele Creek/Meyers Mill Baptist Church were all described in a community history.[69]

Dunbarton Post Office was a local landmark and community gathering spot. Courtesy of SRS Archives, negative 6684.



Dunbarton's house types reflected the community's rural origins and primarily consisted of I-houses and vernacular farmhouses such as hall and parlor types. Photographs shown in a community history show up-to-date remodeling, as older house types are discernible behind more fashionable bungalow details. A small brick jail comprised the sole municipal improvement. The town was electrified but had only two telephones. Its post office was perhaps its most well known building. The Rountree, Hiers, Anderson, and Dicks families operated several general stores, and in 1950 Barnwell County's first department store, the Western Carolina Trading Company, opened in Dunbarton.[70]

Meyers Mill stretched along the Atlantic Coast Line. The Ellis, Halford, Hankinson, Meyer, Peeples, Phenix, Simon, and Swett families owned small lots in the mill area, all one acre or less in size. Olan Meyer's cotton gin was the major business in the community. Leigh, an industrial village that produced crates and boxes, was also taken. The only large industrial operation in the plant area, the banana case factory, was in operation from 1926 to 1952. Mill housing was available for workers, and the mill village also had a church, store, and hotel. Up to 350 people would work at the plant during their springtime peak



Mrs. Ida Jones, at age 87, was one of Ellenton's oldest residents. Courtesy of SRS Archives negative M-455.

season in preparation for the peach harvest.[71] Other smaller crossroad communities or "whistle stops" were also in existence such as Hawthorne, a community of dispersed farmsteads, and Talatha, Robbins, Greenland, Skinface, Hattieville, and Bush.

Although they constituted only one percent of the land area, the removal of these communities—Ellenton, Dunbarton, and to some extent Meyers Mill and Leigh—captured the nation's attention. Some residents held onto the hope that the two larger towns could be saved, some even inquired about whether their land could be bought back when the government was done with it.[72] Reporters chronicled the process, writing objective stories about their plight and more emotional pieces that went right to the heart. Historian James O. Farmer's study of the impact of the plant on Aiken shows that as the meaning of the plant finally sunk in, reactions varied among the displaced from anticipation, patriotic resignation, resentment, to self-pity.

The young, who saw excitement in the many changes, and those who profited from the plant's coming, were the happiest. H. M. "Mike" Cassels, one of the latter, would tell a *New York Times* reporter that "I haven't got a gripe in the world." The government purchased his store and his gas station. He then liquidated his stock, bought the gas station back at the salvage price of 12 percent and moved it to New Ellenton, a community forming at the plant's northern rim. The AEC was buying 9,000 gallons of gas from his new operation per day.[73]

The elderly, both black and white, were the least happy. Their emotional investment in their homes and communities was too great to measure in dollars.

> Eighty-seven-year old "Miss Ida" Jones had lived in the same house for sixty-seven years. She met her fate with the quiet resignation of the powerless. Dr. Fred Brinkley took the news harder. Also a lifelong resident, he had been present at the births and deaths of many of his neighbors, and had treated them as long as many could remember. *The Times* reporter who interviewed him wrote that "he cannot reconcile himself to the evacuation."…. Another local doctor, Paul Culbreath, predicted that most of the evacuees would not long survive the trauma of their forced uprooting. Many, including himself, would bear out his prophecy.[74]

By the end of June all former inhabitants, about 1500 families, were evacuated. Louise Cassels stated with irony that the railroad was the impetus for Ellenton and it also

brought its death as she watched the huge shipments of construction materials offloaded at the Ellenton station. By the time she left her home in March, neighbors' homes had become "pipe shops" or storage buildings for other construction materials. Familiar places and placenames were fast disappearing. Even the composition of her classroom, now in Jackson, had changed. "Trailer children" attended classes along with the local children. The construction force had arrived.



"It is hard to understand why our town must be destroyed to make a bomb that will destroy someone else's town that they love as much as we love ours. But we feel that they picked not just the best spot in the U.S., but in the world. We love these dear hearts and gentle people who live in our home town."

Bonner Lee Smith's words of protest written in December 1950 and mounted on an Ellenton town sign have become an icon at SRS. "In December 1950, I was working for Leigh Banana Case Company. When I went home to lunch that day, I went by Cubie Hill's Home & Auto Supply and bought a bottle of Griffin shoe polish or dye for 15 cents. When I got to the mill, I went over to the Cleat Mill and got five 13/16 black gum boards. I went back to the box factory, laid the boards on the floor and started writing. I had no script or plan as to what to say…. That afternoon, when I went home, I nailed the boards on the sign." Source: Maureen B. Chavis, *Aiken Standard,* November 27, 2000.

9 One Mighty Force

Caricature of Du Pont's Field Project Manager, Robert K. Mason, in charge of the construction of the Savannah River Plant. The caricature shows Mr. Mason with the Savannah River Project buildings, for which he was responsible, in his hands. Numerous images showing highlights from the construction era form the background. Site artist and cartoonist J. Cauthen was responsible for this finely drawn caricature. Courtesy of SRS Archives, negative M-3962-6.



In Augusta, Ga this week, an invading army of engineers, builders and technicians jammed the city's hotels and spare rooms to the rafters. Across the Savannah River in South Carolina, the aluminum glint of hundreds of trailers winked among the pecan groves. Giant bulldozers ripped through slash pine and red clay, pushing a four-lane, 20-mile express highway from North Augusta to Ellenton (pop. 700), a town soon destined to disappear before the bulldozers' onrush.

The target of this invading army is just beyond Ellenton; a 200,000-acre site spotted with hundreds of hustling trucks, steam shovels and cement mixers. There the steel skeleton of a headquarters building is already rising- the focus for sightseers who come from miles around to see what the DuPonts are doing. What E. I. du Pont de Nemours is doing is worth considerable attention. It is building the Government's $600 million plant to make the components for the hydrogen bomb.[1]

Du Pont's invading army of engineers, managers, and construction workers was responsible for the "development, design, construction, installation, and operation of facilities for the production of heavy water, fissionable and fusionable materials, and related products" as the prime contractor with the AEC.[2] Center stage for this chapter belongs to Du Pont and its workforce, headed by the able and inventive Bob Mason, Du Pont's Field Project Manager. The magnitude of the Savannah River Project was monumental, calling for the construction of nine integrated industrial plants at the South Carolina site as well as the Dana Plant, in Dana, Indiana. The schedule was urgent and the design processes involved were constantly evolving. All involved applied their knowledge to the tasks at hand, bringing the processes on line. Du Pont's Chief Engineer Granville Read would later commend those involved from the bottom to the top. "The part construction men played in it [the project] will never be glamorized or make the headlines, but for my part, I want to thank management, designers, construction engineers, consultants, craft supervisors, technicians, and all other persons who combined their talents and skills into one mighty force to build the Savannah River Plant."[3]

PROJECT SCOPE OF WORK

The scope of work for Project 8980, Du Pont's internal project number for Savannah River Plant, was continually refined through the first three years to meet production requirements set by the AEC who, in turn, formulated their production projections based on national policy and defense, budgetary concerns, and design imperatives. The expansion program under which the Savannah River Plant was first envisioned was and could be further expanded. Du Pont played a primary role in defining the scope as their engineers began to tackle the project needs. As they responded to modifications to the scope, other changes resulted. All design was conducted within this fluid environment, changing as new variables, new research, and new policy developed.

As discussed earlier, two reactors were contemplated for Savannah River in July 1950. This number was increased to five by August 1 in response to North Korea's drive into the Republic of Korea, Soviet espionage, and the Soviet bomb.[4] The AEC provided Du Pont with a general scope of work, requesting the construction of five full-scale heavy-water-moderated production reactors on normal (natural) uranium, a facility for Purex (solvent extraction) separation, a fabrication facility for plutonium shapes, a tritium separation plant, and facilities where bismuth could be irradiated if needed. This scope was changed in December 1950 to include a second separation area and plans to expand into a third. The increase in reactors compelled the AEC to authorize the construction of a second heavy-water production plant so that an adequate supply of heavy water was available when the reactors were constructed. This generated another major change in the project's scope.



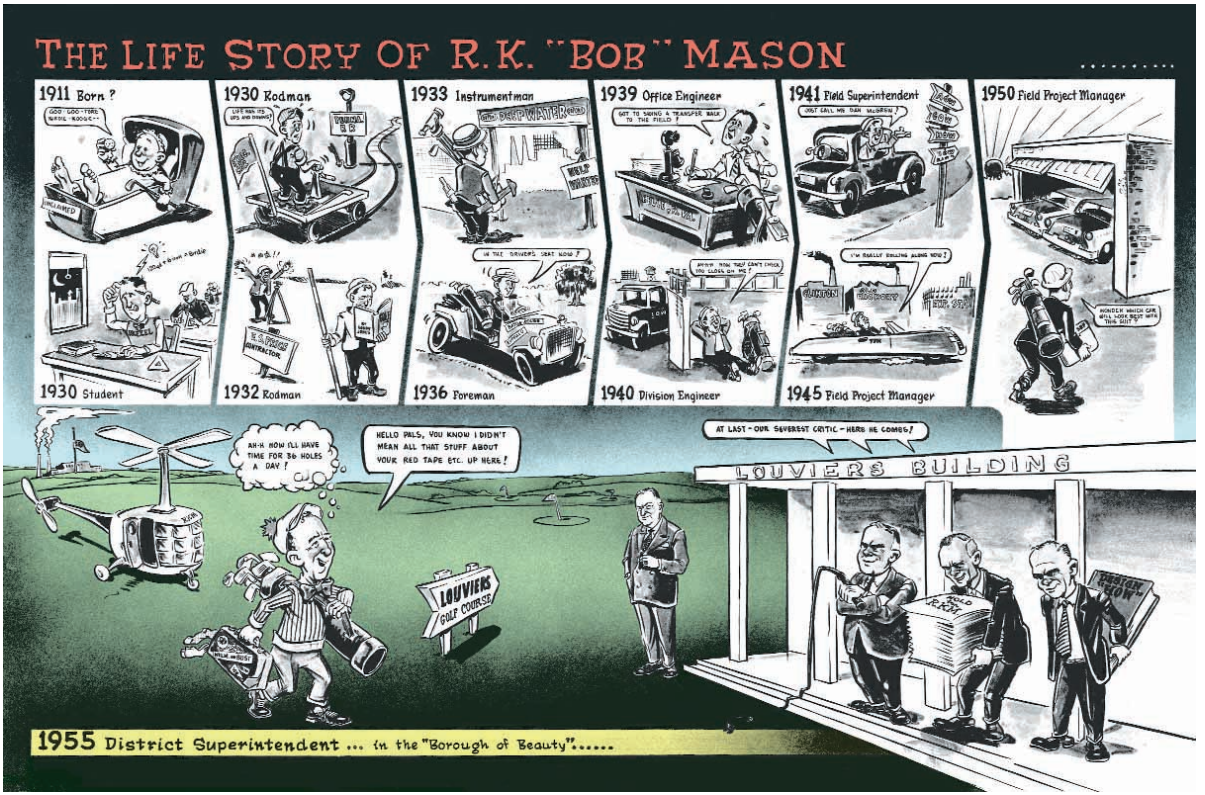
Packed dinner meeting of AEC and Du Pont's "invading army of engineers" possibly in December 1950. Field Manager Robert Mason (second from left) and AEC Manager Curtis Nelson (third from left) are standing in back of room that is decorated for the holidays. Courtesy of SRS History Project.

Robert K. Mason, Field Project Manager, Savannah River Project (1950–1955)

As Field Project Manager for the Savannah River Project, Robert (Bob) K. Mason was responsible for building the Savannah River Plant, the AEC's largest undertaking up to that time. Like AEC SROO Manager Curtis Nelson, he was posted to the project in mid 1950 while the AEC and Du Pont entered into the decision-making process involved in the plant's formation. Mason led a survey to the proposed site in November 1950 and participated in the site-selection process. After site selection, he had the monumental task of translating these decisions into reality.

Mason, a Wilmington, Delaware native, took on the position of Du Pont Field Project Manager for SRP at the age of 39. Son of a pipe fitter, he grew up with his father's extended family in Wilmington as his mother had passed away when he was a child. At age 19, he began working for the Pennsylvania Railroad, studying engineering at Drexel Institute Evening School in Philadelphia at night. This experience led to his employment three years later as a rodman at Du Pont's Deepwater, New Jersey, plant. From there, Mason worked up through Du Pont's ranks, serving as foreman at company plants in Baton Rouge, LA, and Buffalo, NY. He also served as office engineer for the expansion program at Belle, West Virginia; division engineer and assistant field engineer at Indiana Ordnance; and field superintendent at the Alabama Ordnance plant; and later at the St. Paul, Minnesota, Ordnance Works. His construction career continued with a stint at Hanford as supervisor of the company town of Richland; work at Rocket Powder Plant in Charlestown, Indiana, and as field project manager overseeing an addition to Du Pont's Old Hickory, Tennessee, cellophane plant. Prior to Savannah River, Mr. Mason was responsible for the construction of Du Pont's Experimental Station in Wilmington. All of this experience would be needed at Savannah River.

Source: Oral history interview, Mrs. Letitia Mason, July 1999.



After study, Du Pont recommended that the plant's power be produced onsite in dispersed units for economy, self-sufficiency, and defense. During the site selection process, power was to be purchased from offsite sources. In response to the Du Pont recommendation, the AEC again modified the scope, allowing the construction of powerhouses at the heavy-water production plant area and at the first four reactor areas.[5] South Carolina Electric & Gas was to furnish the remaining power needed. Other changes included the elimination of funds for U-233 separation and a possible sixth reactor—a heavy-water model of advanced design that was scratched in November 1952.[6]

The general scope of work for the Savannah River Plant required constructing research and development laboratories and process and service buildings for producing heavy water, deuterium, plutonium, tritium, and special products. Reactors, separations canyons, power plants, cooling basins, waste tanks, and a wide variety of administration and ancillary buildings would be needed. As construction proceeded, manufacturing and service or ancillary facilities would be added, deleted, and modified.

Du Pont designers accomplished their goals using a "flexible design" approach. This approach operated at two levels: the first entailed postponing design decisions until the best design could be determined by research or through consultation, and the second was to build in the potential for future design options should AEC policy change. In the first scenario, Du Pont designers based some design decisions on their experience from previous construction projects for atomic energy plants and from scientific research completed at AEC's national laboratories. This allowed them to move forward with production in some areas while researching alternative design choices for others. In the second scenario, design was necessarily postponed as part of the current and future client-contractor relationship. AEC directives, based on Department of Defense guidance on what product or product mix was needed for its weapons program, directly translated into design decisions. Du Pont recognized this as an integral feature of their contract and responded with aplomb to an evolving scope of work. Their ability to do so was characteristic of the firm's management.[7]

Despite this fluidity in the design context and Du Pont's flexible approach, the end goal—providing plutonium and tritium for the nation's defense—was still to be accomplished on schedule. "The Korean Conflict, the possible imminence of World War III, and a national consensus that sacrifices were needed to stop the Soviets, all created, at the national level of the Atomic Energy Commission, an atmosphere of urgency and commitment."[8] Thus, R Reactor went from conceptual design in December 1950 to an operating reactor in December 1953, an incredible feat of engineering completed with breakneck speed. All contributed to create this success story; however, Du Pont's organization and system of departmental checks and balances and procurement strategies figured prominently in this success.

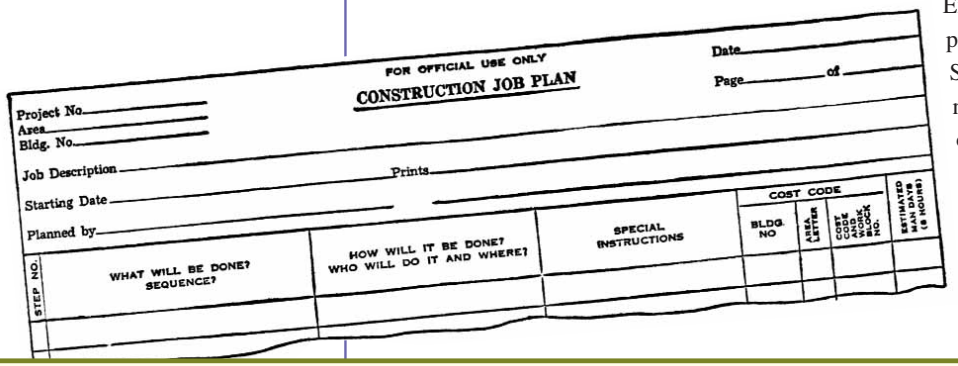
(Opposite Page) This cartoon, rendered by Site artist and cartoonist J. Cauthen, shows stages in Bob Mason's life. It playfully shows his rise in the Du Pont firm from a rodman to Field Project Manager of the largest construction job undertaken by the AEC in 1950. The cartoon was created as a memento to Mason on his departure from Savannah River and his return to Wilmington as a District Superintendent up until 1955. Source: Oral history interview, Mrs Letitia Mason, July 1999. SRS History Project. Cartoon courtesy of SRS Archives, negative M-3962-1.

PLANNING IN SECRECY

Du Pont's invading army was well organized. Planning began in June with intensive planning starting after August 1, 1950, the date that Du Pont accepted the job formally. On October 11, the AEC issued a letter contract that was accepted on the 17th by Du Pont. The letter contract was effective retroactively on August 1.

Through the summer, the Du Pont team took shape. Those selected, the majority of whom had played roles in Hanford's construction and design, were assigned to the newly established Atomic Energy Division (AED) within Du Pont's Explosives Department. The Explosives Department was given prime responsibility for the Savannah River Project, beginning with developing the scope of work and the specific process requirements needed to complete it. The AED's management team consisted of an Assistant General Manager and three managers responsible for the AED's three subdivisions: Technical, Control, and Manufacturing.[9] R. Montgomery Evans was chosen as Assistant General Manager. Evans, who had acted as an informal point of contact between the AEC's Carleton Shugg and the Du Pont firm on the developing expansion program prior to Du Pont's re-entry into atomic energy development, was a logical choice.[10]

The Technical Division was charged with acquiring technical and scientific data and with developing and evaluating process requirements. Once known, these requirements



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CONSTRUCTION JOB PLAN

Project No.
Area
Bldg. No.
Date
Page ____ of ____
Job Description
Prints
Starting Date
Planned by

STEP NO.	WHAT WILL BE DONE? SEQUENCE?	HOW WILL IT BE DONE? WHO WILL DO IT AND WHERE?	SPECIAL INSTRUCTIONS	COST CODE: BLDG. NO	COST CODE: AREA LETTER	COST CODE: COST CODE AND WORK BLOCK NO.	ESTIMATED MAN DAYS (8 HOURS)

Construction Job Plan used in Project 8980. A written plan was created for work units with cost code data and estimated man-days. The work plan was later compared with the performance record to assess productivity. Source (text and image): *Engineering News Record*, "How H-Bomb Construction is Controlled," June 26, 1952.

"Plan Your Work. Work Your Plan."

Bob Mason's job as construction manager for the plant was awesome in its scope. *Engineering News-Record* wrote a feature series on "How H-Bomb Construction Is Controlled" in June 1952, and Bob Mason with his hardhat graced the magazine's cover. While the article is written from a construction worker's perspective, it conveys a sense of how Mason and his cohort of managers did their jobs. Planning, scheduling, reporting, and analysis were the steps followed. Two hours or less was spent in the project's "chart room" where the labor of 15 men and women who gathered data on the project's progress, costs, and schedule, was assembled into vast and detailed charts that allowed the top managers to see at a glance project trends. Much of the overall project analysis was completed in Wilmington. Typically there were 150 charts and graphs for review at a time. From this information and project analysis, data was shown for the overall project, the progress within each building area, and finally progress on individual buildings or facilities within areas. The area concept structured the construction, with each area having what amounted to an individual work plan. Forecasts were made on a weekly basis that provided the area engineers with a sense of what was immediately ahead. The weekly schedule was established from the forecast at conferences that were added to the regular Friday afternoon safety meetings of area craft superintendents and their foremen.

Concrete scheduling was critical and was handled separately from other scheduling. An average of 20,000 cubic yards of concrete went from the batch plants to building areas. A scheduling meeting was held daily in addition to the weekly forecast to determine the mix needed, the number of trucks, the plant the concrete was to come from, and the time and rate of delivery. A weather-forecasting service established on site helped the construction force with their schedule, particularly the concrete workers.

From the use of stiff-legged derricks to two-way radios, Mason and his managers used a variety of techniques to get the job done and, in Du Pont style, to learn how to do it better. Performance analysis and field ratings were completed to see whether the construction plan worked and whether estimates of time, manpower, materials, and money were actually met. Mason was also credited with innovative construction solutions that included learning about safety-net techniques from the Ringling Brothers to prepare SRP's "high-wire" riggers for their work on the 400 Area towers.

were relayed through the Production Division to Du Pont's Engineering Department's Design Division. The Technical Division was also responsible for SRP's research laboratories, once they were in operation.

The Manufacturing Division (also known as Production) was responsible for maintaining good communication with Du Pont's Engineering Department and for final approval of basic plant design. This division's responsibilities increased immeasurably after construction; its staff would supervise the overall operation of the plant. Finally, all administrative, cost control, accounting, and office management fell to the Control Division.[11] Two members of Du Pont's Treasury Department were assigned to the AEC project on October 16; five days later $4 million were transferred to Du Pont's account to fund the project start.[12]

AED Management Team, 1950

Assistant General Manager	R. M. Evans
Administrative Assistant	D. F. O'Connor
Atomic Energy Division Manager	B. H. Mackey
Manufacturing Division, Director of Manufacture	W. C. Kay
Control Division Manager	F. M. Burns Jr.
Technical Division Manager	Lombard Squires
Assistant Manager	J. E. Cole
Assistant Manager	Hood Worthington

The management team was expanded quickly to include V. R. Thayer, J. C. Woodhouse, Dale F. Babcock, and C. W. J. Wende as members of the Technical Division's Research staff. W. H. Holstein and J. B. Tinker became members of the Manufacturing Division's Production staff.[13]

The construction men came from Du Pont's Engineering Department, a group that typically built Du Pont's commercial operations, but were assigned to design and construct the new plant. Headed by Chief Engineer Granville M. Read, the overall department embraced several divisions: Design, Construction, Development Engineering, Engineering Service, and Control.

Cognizant of the complexity that lay ahead, Du Pont created a new office on August 9 within the Engineering Department. The new office, Atomic Engineering, was responsible for coordinating all the engineering tasks conducted by Du Pont and coordinating with the federal agencies and all other Du Pont departments. This group would be enlarged as the project developed. The complexity of the design work ahead also made for further internal change. A manager, aided by two assistants—one to manage Du Pont industrial work and the second to manage the AEC project—headed the Design Division. The magnitude of the proposed work necessitated the use of five subcontractors for a major part of the design effort. This added a number of voices to the design environment and, as the home offices of the selected subcontractors were distant from Wilmington, communication would also pose problems. In response to these challenges, Du Pont stationed design and procurement personnel at each of the subcontractor's home offices. These men acted as liaisons for the design team, funneling design data and drawings between the offices. The design information-exchange pool widened in August 1951 when a field design group was established. The Design Division field group, composed of engineers and draftsmen, was

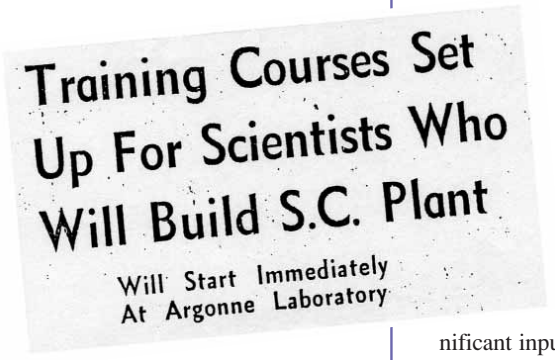
sent to South Carolina to handle engineering and design needs that required field-review prior to construction.

Under the eyes of the Resident Design Engineer, the Du Pont field personnel and a member of each subcontractor's staff were given significant authority for field decisions. Effectively, they were point guards for the overall design process, keeping the Design Project Manager informed on field progress, obtaining AED and AEC decisions and approvals at the field level, handling special design services, attending construction meetings to provide information on design, providing the necessary approval for construction to move ahead, and approving field work requests. The importance of the field design group only heightened as construction progressed. Their presence allowed for last-minute changes and test programs that were needed to make scheduled startup dates.[14]

Du Pont's system for design and construction worked. Authors Carlisle and Zenzen point out:

> Reflecting its experience in private-sector chemical engineering, the corporation was quite capable of sorting through difficult design decisions. Du Pont efficiently solved design decisions internally by a system of checks and balances between its own divisions and departments. Du Pont handled liaisons with other parts of the growing nuclear establishment with a minimum of bureaucratic delay, arguing successfully with AEC procurement officials that emergency conditions should allow for non-competitive purchasing of key components. Good scheduling, spurred by a sense of urgency, allowed planning and design work to be done even during construction of already-settled components, probably the greatest single contributor to rapidity and efficiency.[15]

Dr. Walter H. Zinn, Argonne's National Laboratory director, carefully announced to the Chicago press corps that Du Pont had entered into a new agreement with the laboratory that was, in essence, a renewal of an old partnership forged during World War II. The article noted that although the AEC's plans were not made public, the new plant would be based on designs perfected at Argonne for making tritium, hence the need for an Argonne based training program. Source: Roy Gibbons, "Training Courses Set Up for Scientists Who Will Build S.C. Plant," *The Record*, December 4, 1950.



Training Courses Set Up For Scientists Who Will Build S.C. Plant

Will Start Immediately At Argonne Laboratory

DESIGN SOURCES

Hanford, Argonne National Laboratory (ANL), Oak Ridge National Laboratory (ORNL), and Knolls Atomic Power Laboratory (KAPL) had significant input into the proposed plant and its processes and the initial training of designers and, later, operations staff. The national laboratory system was a design source from which Du Pont initially drew upon to accomplish their objectives.

To some extent, Hanford was a model for the Savannah River Plant because the plants shared broad objectives and a common builder. The Du Pont construction history observed that the Hanford construction historical narratives were intensely reviewed by Du Pont staff members over the summer of 1950 to refresh the memories of those returning to the field of atomic energy and to cull any lessons learned from the earlier Du Pont effort. Limited data from Hanford's reactors was useful to the Du Pont engineers, who were to design and construct heavy-water-moderated reactors. However, some of the modified Hanford facilities that corresponded to proposed SRP facilities provided direct valuable design information, mainly in the processes needed for canning of fuels, separations, waste disposal, and service facilities.[16] Hanford also was valuable as a training ground for SRP employees. As early as August 1950, Du Pont approached General Electric (GE) to see if new Du Pont employees could receive short- and long-term training at Hanford.[17]

Reactor studies, particularly on heavy-water-moderated reactors, were centered at Argonne National Laboratory. The conceptual design for the SRP reactors was a product of Walter Zinn's research that had been ongoing through 1950 at Argonne. Du Pont's engineers would take this design and fabricate a multi-purpose reactor that met the AEC's production needs. The AEC had determined that approximately 1800 megawatts of total reactor capability was needed to produce sufficient tritium for the program. The Savannah River reactors, of which there were six originally planned, were each scaled at 300 megawatts.

Argonne's Stuart McLain coordinated the SRP laboratory R&D program at ANL and acted as liaison with Du Pont on technical details. The research effort was focused primarily on metallurgical studies and tests for fuel elements, working on fuel fabrication and investigating how various alloys behave under irradiation. The decision to clad SRP's fuel elements in aluminum would stem from such tests. Although necessary, these reactor tests called for about 25 tons of heavy water that Zinn pulled from various sources. An adequate supply of heavy water would not be available until the Dana Plant went into operation in January 1952.[18]



Milton H. Wahl led Du Pont's Argonne training group. Dr. Wahl, shown here with an uncharacteristic smile, later became the Savannah River Laboratory's first director, building the foundation for the research and development program the laboratory would pursue. Courtesy of J. Walter Joseph.

Sixty-six Du Pont employees were in residence at Argonne by August 1951 to receive training in physics, physical chemistry, chemical engineering, and inorganic chemistry. Milton H. Wahl, who later became the Savannah River Laboratory's first director, led Du Pont's Argonne group. The trainees grew in number over the next year into the hundreds; 75 were in attendance in just the last quarter of 1952, and, in 1953, 317 trainees were expected. The projection for the number of ANL trainees in 1954 decreased to 18, reflecting the new presence of operating and training facilities in South Carolina.[19]

Another source of reactor design data within the early planning period came from Eugene Wigner and John Wheeler. "In one 1950 throwback to the earlier (MED) use of the wisdom of renowned physicists, the AEC consulted with Eugene Wigner and John Wheeler, veterans of the MED effort."[20] Historians Carlisle and Zenzen describe the physicists' input as enthusiastic, but note that the inclusion of non-industrial individuals within the design context was unusual this time around.

Girdler's Dana Plant would contribute significant design information. When Du Pont accepted the plant project, the Girdler Corporation was already under contract to build a pilot plant and a large-scale plant on the old site of the Wabash River Ordnance Works near Dana, Indiana. Girdler, as a Du Pont subcontractor, completed the construction of the Dana Plant which, as Du Pont historian Bebbington points out, became SRP's first operating area, despite its distance from South Carolina. The Dana Plant had its own area office that reported to Curtis Nelson. "Dana gave SRP a running start that significantly advanced the date of the first SRP plutonium production."[21] The "GS" or Girdler Sulfide process used at Dana was used at SRP's heavy-water production area that was added to Du Pont's project scope in January of 1951. The problems met in bringing the GS process on line were handled at Dana, providing the design team for the SRP heavy-water area with solutions to potential operating problems. Also, the core group of SRP's heavy-water operations staff was trained at Dana, greatly shortening their learning curve.[22]

Separations design was based on data provided by KAPL, ORNL, and Hanford. At Hanford, plutonium was separated from uranium by the bismuth–phosphate co-precipitation process, which was dependable and expedient. While the process worked well in

recovering plutonium, large quantities of uranium were squandered when the uranium and highly radioactive wastes went into the waste tanks. To correct this, Hanford's engineers worked on the Redox solvent extraction process but information from the Hanford plant, which went into operation in August 1951, was too late for the SRP design.[23]

KAPL and ORNL had developed the alternate solvent extraction process, Purex, that used a less flammable solvent and produced a substantially smaller volume of liquid wastes. Although the Purex process had only been tested in the laboratory, Du Pont chose it for SRP. Accordingly, Du Pont sent a contingent of engineers to ORNL and KAPL to establish research and development programs. The number of Du Pont's ORNL trainees under instruction by Luther Peery and Bob Martens reached into the hundreds in 1951 and 1952. In 1953, 213 Du Pont trainees were sent to ORNL and the next year, only 18 were sent. The decreasing numbers shows the learning curve of the Du Pont engineers. A similar pattern occurred at KAPL with 84 trainees in 1953 and just 7 a year later.[24]



Du Pont wrote a letter of intent to the American Machine and Foundry Company on November 1, 1950, for special equipment design, development and testing services for Savannah River. This firm was responsible for the reactor's complex charging and discharging machines shown here. Discharge Machine, 105-R, 1953. Courtesy of SRS Archives, negative DPESF-1000-15.

The design input from the above resources as well as from private sources and consultants was unquestionably important to SRP's development. In addition to the training program, Argonne operated six programs in support of Savannah River on a $2.7 million budget for FY 1953. Knolls ran two programs for SRP support, one for Purex development at a projected cost of $1.8 million in 1953 and a second for a tritium program at $208,000. ORNL's work on separation studies was forecasted at $400,000 for 1953. While the total cost for these support programs appears substantial, when compared to hundreds of millions of dollars spent by Du Pont just to construct SRP's five reactors, the contributions from outside sources appear less significant. After learning the conceptual designs chosen by the AEC and developed at the national laboratories, "thousands of engineering details, from the concept to the final device, were left to Du Pont."[25]

SUBCONTRACTING DESIGN

After World War II, Du Pont experienced a company-wide expansion and modernization program. The Engineering Department expanded to handle the expansion. In order to meet the construction demands, the department after judicious investigation would use outside engineering firms to supplement their project needs. Du Pont reserved all planning, evaluation, and basic engineering on these projects for their own personnel.

This course of action was selected for the AEC contract, as all involved admitted that no single firm could supply all the different services needed. Du Pont established five criteria for selecting subcontractors: proven record for successful teamwork, the ability to perform unusual engineering tasks on process engineering projects, a large and well-trained staff, prior experience with Du Pont, and home offices in proximity to Du Pont's Wilmington's office. Using these criteria, Du Pont investigated over forty firms prior to the November 28 announcement. The following were selected.

American Machine and Foundry (AM&F)—On November 1, 1950, Du Pont wrote a letter of intent to American Machine and Foundry for special equipment design, develop-

ment, and testing services for SRP. While their services were used at all areas, AM&F's contribution in fabricating each reactor's charge and discharge machines was notable. The firm described themselves as manufacturers of machines for industry. In 1950 they were considered the world's largest manufacturer of cigarette- and cigar-making equipment. However, they had begun a program in 1948 to capture military contracts for equipment manufacturing. Their acceptance by Du Pont as a subcontractor indicates they were successful.[26]

The Lummus Company—This firm was requested to design and partially procure six "GS" units (towers 116 feet high) including the defense waste and finishing plants for the heavy-water production facilities. Du Pont's letter of intent was dated January 13, 1951. This firm brought strong petroleum, petrochemical, and chemical experience to the project. Self-described as a network of men, minds, and machines that were dedicated to transforming ideas and capital into profit-earning processes and equipment, the Lummus Company was expert in the design of distillation processes. International in scope, the firm was headquartered in New York in 1950. Savannah River's heavy-water production area design benefited from an agreement between the Girdler Corporation, which had designed the Dana Plant, and the Lummus Company. Girdler provided technological information gained from the Dana Plant to the heavy-water plant built at SRP.[27]

Blaw-Knox Company—This firm was responsible for architectural engineering services needed in the design of SRP's separation facilities. Blaw-Knox was issued a letter of intent on November 16, 1950.

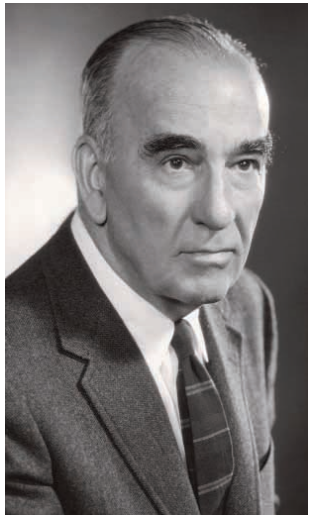
Gibbs & Hill, Inc.—This firm was responsible for design of steam, water, and electrical facilities for process areas and overall plant. The New York-based engineering firm was subsumed by Dravo Corp of Pittsburgh in 1965, then later sold to Hill International, a New Jersey-based firm. Du Pont issued their letter of intent on December 12, 1950.

Voorhees, Walker, Foley & Smith (VWF&S)—This firm, headquartered at 101 Park Ave., NY, was responsible for the design for all "service" buildings and for site layout. This included roads, walks, fences, and parking areas; the manufacturing buildings in the 300 area; laboratories; some design work for 200 areas; and overall site clearance at SRP. VWF&S had a strong track record with the MED. The firm's architects redesigned Columbia University's laboratories for early atomic-energy research in the early 1940s. Strong adherents of the flexible-modular concept for industrial architecture, their 1937 design for Bell Telephone's laboratory at Murray Hill, NJ, was hailed as the country's first modern research structure.[28]

VWF&S was also responsible for Du Pont's Experimental Station in Wilmington where it had worked cooperatively with the chemical firm's organization in designing the modern laboratory complex.[29] For Du Pont's rural headquarters project, VWF&S, under the guidance of senior partner, Perry Coke Smith, designed immense H-shaped buildings that featured a "space unit" design. This design hinged on a unit of space—a floor or a wing—that could be subdivided in whatever manner the client needed. This functional modular approach and their past corporate experience with Du Pont made VWF&S an easy choice for architecture and engineering. VWF&S received a letter of intent from Du Pont for general architectural-engineering services on December 4, 1950.

New York Shipbuilding—This firm was responsible for fabricating SRP's reactor vessels under the NYX Program. This effort produced the top flow distributor chamber of the reactor vessels (the plenum), the reactor vessels, and the primary piping. Organized in

Perry Coke Smith, project manager and senior partner for Voorhees, Walker, Foley & Smith of New York in 1950. The New York based firm, now under the moniker HDL International, was responsible for the design of the site's non-process buildings and its layout. A graduate of Newberry College, SC, Smith went on to study chemical engineering at the University of Wisconsin. After serving in WWI he received his degree in architecture from Columbia University. Smith was so "sold" on Transite™, used uniformly as the chief external wall sheathing material at the site, that he later went on and designed a residence clad in Transite™. Courtesy of HDL International.



1899, New York Shipbuilding was located on the banks of the Delaware River in South Camden, New Jersey. The firm brought its experience in the fabrication of heavy industrial equipment and machinery to the task. A company brochure notes that the firm had taken on such projects to stabilize their work load and as "a public service where the facilities of the Yard provided the only available means for constructing unusual items. Its location on tide water, with weight-handling equipment up to 300 tons, makes it possible to load assemblies which may be beyond the size or weight limitations for shipment by rail." These qualities were probably well known to Du Pont who also had a plant in the Camden, New Jersey area.[30] The SRP reactors were transported by barge to the South Carolina site.

Source: Engineering Department, E. I. du Pont de Nemours & Co. *Savannah River Plant Construction History*, Volume I, Report No. DPE (1957).

Construction Consultants

Academy of Natural Sciences - Performed biological survey of the Savannah River to assess the general health of the river in the plant area and to establish the nature of the aquatic environment.

Amman & Whitney - Responsible for the evaluation of structural design in respect to static loading for reactors.

Dr. George S. Benton - Responsible for meteorological study to determine stack gas dispersion patterns.

Franklin Institute - Performed research on expansion joint fillers and caulking compounds.

General Electric Company - This firm was to provide technical advice in the construction and design of SRP's tritium-extraction facilities.

The Girdler Corporation - Girdler's expertise gained from their construction of the Dana Plant was to be shared with the Lummus Company for their work at SRP's heavy-water facility.

S. Logan Kerr - Mr. Kerr provided his services as a hydraulic turbine engineer. He examined an early proposal for the use of hydraulic turbine drives for the heavy-water pumps in the reactor buildings. He also advised Du Pont on design and test procedures for the river-water supply and distribution system and the reactor cooling-water systems.

Elson T. Killam - This firm provided hydraulic and sanitary engineering for the buildings designed by VWF&S.

Paul F. Kruse - Mr. Kruse aided Gibbs & Hill in their design of a water-distribution system that was protected against water-hammer surge.

Dr. Charles E. Lapple - An Ohio State University professor who had worked with Du Pont at Hanford, Lapple brought his experience with gas filtration to the separations areas, helping to design the sand filter beds.

Dr. George S. Monk - Dr. Monk was a specialist in optics who had studied the effects of radiation on optical materials at Argonne National Laboratory. Monk would help Du Pont select optical viewers for the process areas that could withstand high levels of radiation and the development of non-browning glasses.

Moran, Proctor, Mueser & Rutledge - This firm provided advice on the soil-boring study carried out by the Army Corps of Engineers, helping Du Pont with foundation studies for the process buildings. In addition to other contributions, they also developed the cell-type foundations for the GS towers used by the Lummus Company in the heavy-water area at SRP.

Sheppard T. Powell - Mr. Powell's expertise was needed for design options for the facilities that treated plant effluent and sewage.

Phillip Sporn - Mr. Sporn, president of American Gas & Electric Company, reviewed the overall electrical supply system that was under development for the plant.

U.S. Army Corps of Engineers - The COE completed a soil-boring study to inform Du Pont on the nature and character of the subsurface areas in proposed building areas so they could better design and construct foundations. The COE also gathered considerable hydrological data on flow, water temperature, river stages, and sediment analysis that helped decision-making on the river water supply system.

Eldridge A. Whitehurst - Mr. Whitehurst, Director of the Engineering Station, University of Tennessee, and Director of the Tennessee Highway Research Program, was retained by Du Pont to provide guidance on the sonic method of concrete inspection to detect voids in poured concrete. This method was not successful at SRP, and Du Pont's engineers chose to pour concrete under the most favorable circumstances so that the possibility of voids would be minimal.

Other specialty firms figured prominently in the plant's construction. B. F. Shaw Company was responsible for piping, Miller Dunn for electrical work, the Arma Corporation for reactor machinery, Johns Manville for thermal insulation, the Green Construction Company for excavation and earth moving, the Kolinski Company for concrete mixing and placement, and the Pittsburgh Testing Laboratories for x-ray examination of welds.

Consultants also supplemented the experience of Du Pont's engineers and their subcontractors in areas that ranged from meteorology to engineering studies of static loading. The participation of these individuals and their organizations show the holistic approach adopted by Du Pont and its adherence to good design.

OVERSIGHT—SAVANNAH RIVER OPERATIONS OFFICE

Overall guidance for the plant's construction and later its operation rested with the new AEC operations office established at the plant, the Savannah River Operations Office (SROO). This office consisted of the Office of the Manager, Public Information, and the Assistant General Counsel. There were two adjunct offices, one at Dana and a second at Wilmington. Curtis Nelson was manager through the construction period; Bob Blair, his deputy manager, became Nelson's successor. Their job was to ensure the success of contracted operations and to advise the Director of the Production Division in Washington concerning SROO programs.

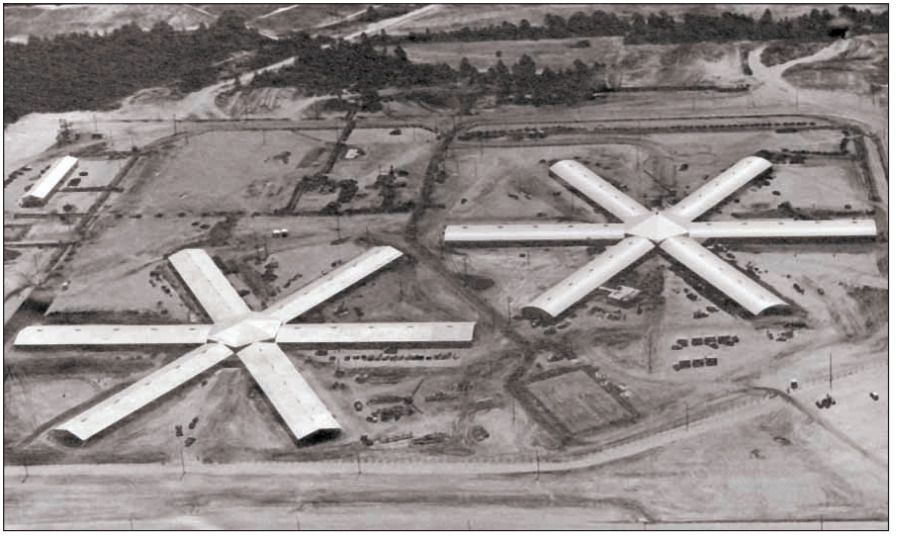
Once construction started, the AEC managers divided their time between recruiting office personnel, monitoring the acquisition program, handling public affairs and the housing problem, and overseeing Du Pont's workforce as they transforming the chosen site into an industrial complex. Six divisions helped the Manager with these goals: Organization & Personnel, Security, Budget and Finance, Administrative, Engineering and Construction, and Technical and Production.[31] The number of AEC personnel would grow from 170 to 352 at the height of construction in 1953. The number of AEC employees decreased to 260 in 1954 and by 1960 leveled out at 228 workers.[32]

ON THE GROUND AND RUNNING

The day after the announcement, basic equipment arrived. Three hundred and fifty typewriters, ordered in September, arrived on December 1; millions of dollars worth of automotive equipment quickly followed. The General Services Administration in Atlanta cooperated in the effort, providing furniture for the first temporary offices. Excess construction equipment at Hanford was identified, slated for reconditioning, and shipped to South Carolina.

Secrecy had required that no offices or warehouses be obtained prior to the announcement. Despite the problems this would make for the construction force, this policy was followed to prevent rumors and land speculation. The staff was located at the Richmond Hotel until temporary space was obtained at Bell Auditorium in Augusta. The Augusta City Council also made space at the "Old Filter Plant" at Augusta's waterworks at 2822 Central Avenue. Both Du Pont and the AEC rented space there on a monthly basis. By

December 19, the employment, medical, investigation, and housing offices were housed at the auditorium. Purchasing, receiving, accounting, transportation, time, and payroll were situated at Daniel Field. An employment office was set up in Aiken's already established federal employment office. The Augusta offices remained open until May 28, 1951, after which the Du Pont construction personnel reported to two temporary construction buildings, designated TC-1 and TC-2, on the site. AEC personnel remained at the waterworks until June 11, after which they reported to Wings D and E of TC-1.[33]

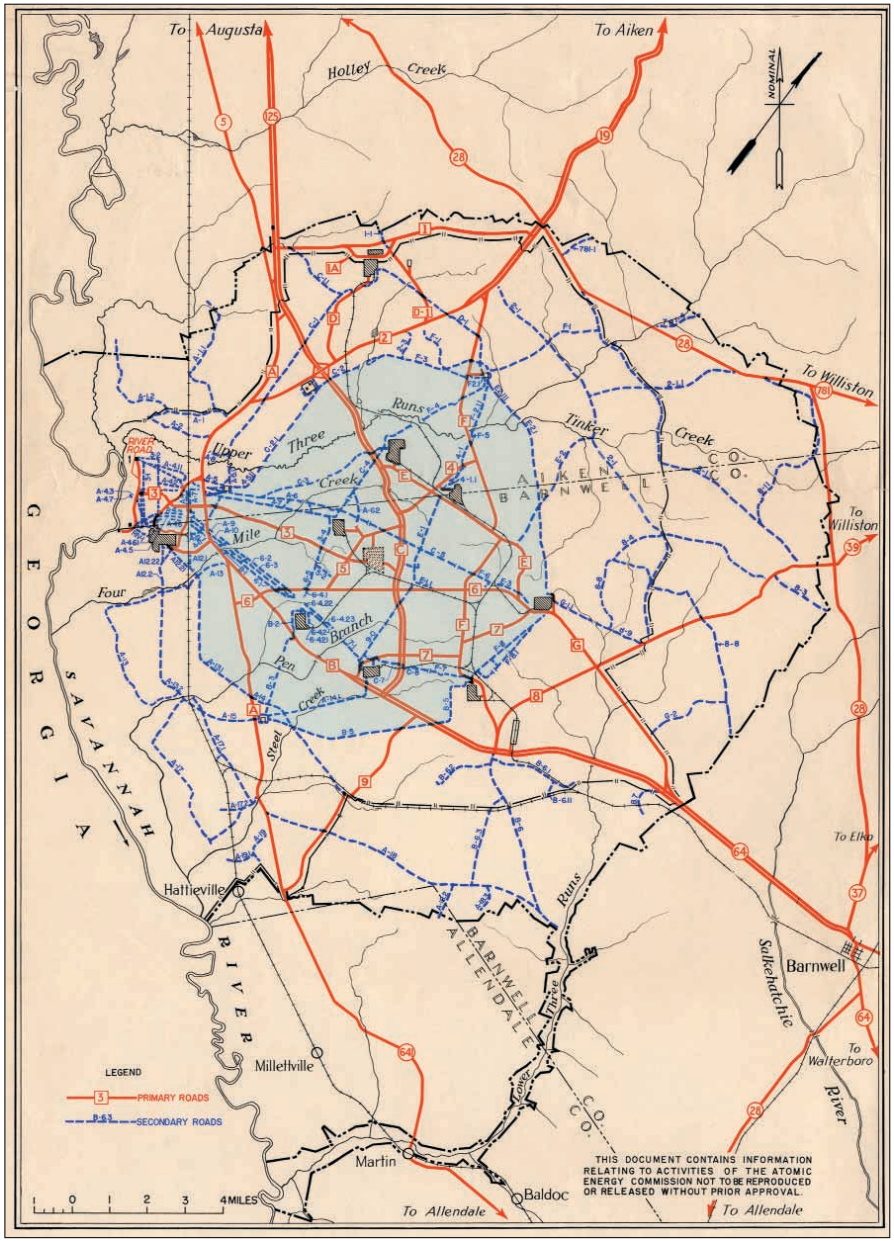


Aerial view of Temporary Construction buildings, TC-1 and TC-2, during construction era. These unique buildings were laid out in "TC" Area now known as B Area. The cart-wheel-shaped steel frame buildings were each constructed of six prefabricated buildings joined to a central rotunda. The TC Area was designed and laid out by an Augusta architectural and engineering firm, Patchen and Zimmerman. Their interesting design, particularly from the air, invited conjecture on their function with many believing that the various wings housed "bomb making" equipment. The buildings were actually used for administrative purposes until the permanent buildings were placed into operation. Courtesy of SRS History Project.

Field supervision occupied buildings rented or purchased from former residents in the plant area. The Bush House temporarily served as the Field Construction Office and a tenant farmer's dwelling was adapted for use as the Field Cost Office. The Grace Fields home, the Cato home, Ellenton's Agricultural Building, the Buckingham property, Cassels Electrical Warehouse, and H. W. Risher Warehouse were also rented for construction field personnel use, as were Dr. Brinkley's warehouse, drugstore (second floor), and six metal buildings. By January 15, the first major construction equipment began to arrive in Ellenton, signaling a new reality to the townspeople there.

With machinery arriving and employment offices opening their doors, the contingent responsible for the overall plant layout were hard at work. A work diary written by Du Pont's A. J. McCullin between November 30, 1950, and August 1954 indicates that general layouts were drawn using three scenarios. The first scenario used the manufacturing boundaries initially published in the newspapers, the second moved the boundaries of the manufacturing area closer to the river, and the third was focused on a "canal scheme." The need for alternatives stemmed from the disagreement between the AEC and Du Pont on appropriate reactor spacing, land necessary for an exclusion area, and the necessity for moving so many towns. By December 19, the Du Pont team in the field got their answer. The manufacturing area was to be moved slightly west, and the towns of Jackson and Snelling were to be excluded. T. J. Conroy reported from Washington that the area between reactors was to be 2.5 miles and that they should be situated in a circular fashion. The distance between any reactor and the property line should be six miles. The area between separations buildings should follow the same interval as reactors but they could

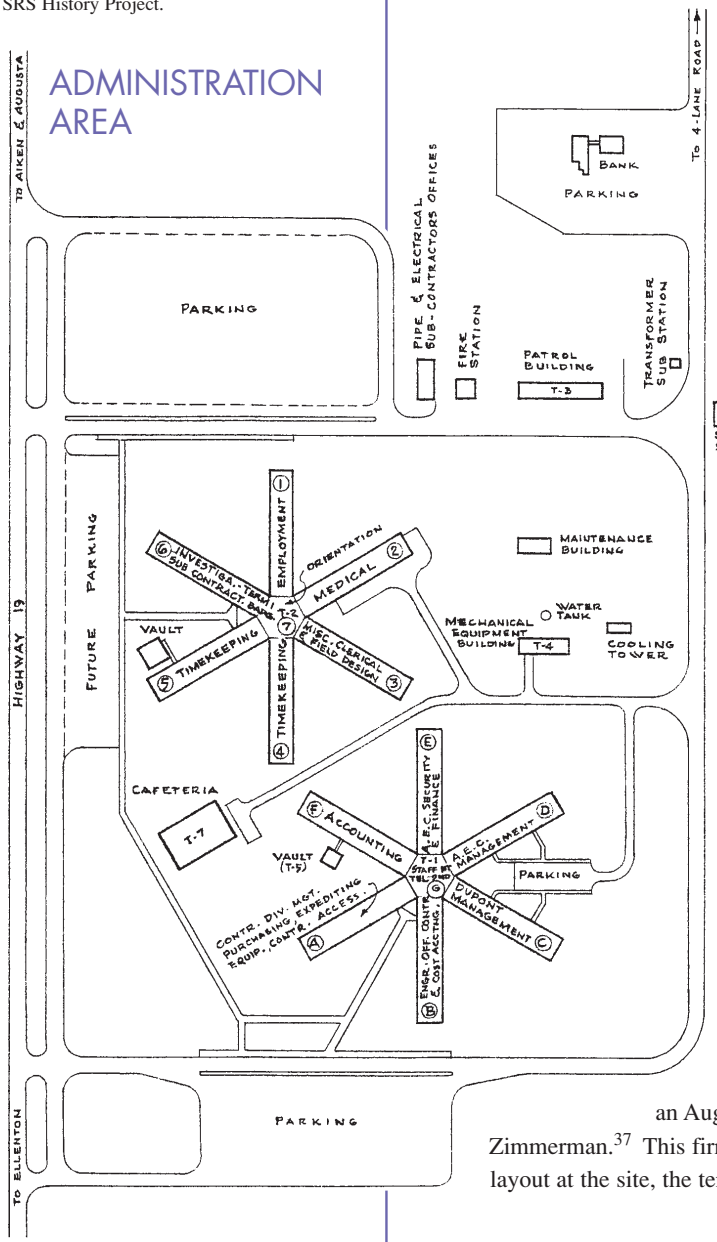
be situated within five miles of the property line. The test pile should be located two miles distant from the property line. With these parameters finally specified, Du Pont's Monte Evans, J. B. Tinker, A. J. McCullin, and G. W. Dutcher, along with James Brooks of VWF&S, created a tentative layout.[34]



Savannah River Plant, 1956. This map show the basic layout of the new plant. The manufacturing or process area (blue) was at the center of the plant area surrounded by a six-mile safety envelope. The building areas are shown hatched. Courtesy of the SRS History Project.

These men had few cartographic sources available to them, and those that were available were out of date. A War Department topographic series from 1921 had no record of the road improvements or growth that had occurred since the 1920s. A 1950 South Carolina State Highway Department map did not provide sufficient topographic data for

The TC buildings were extremely functional, housing each administrative department in a separate wing. The area also included a number of ancillary buildings including a fire station, bank, cafeteria, and patrol building. Source: Pamphlet titled "Savannah River Plant Temporary Construction Area Layout," hand drawn and undated. Courtesy of the SRS History Project.



either the real estate acquisition program or for overall plant maps, but at least had the current roads and communities. Accordingly, the civil engineers responsible for laying out the plant used the highway map for their first attempts and would try to use the earlier topographic series until new information was available. Map 3303, the General Plant Layout, was generated and given to the site surveyors.

The sparse cartographic record changed rapidly as Aero Service, a Philadelphia firm, was brought on board to photograph and map the plant area with two- and five-foot contour intervals, establishing a permanent grid system. The plant area survey was under way in late December 1950. Five Aero Service teams conducted field surveys to establish the reference points needed to anchor their aerial photography. The McCullin diary notes that the COE advised Du Pont that the state of South Carolina was covered by the U.S. Geological Survey Lambert projection system, and asked that the survey's coordinate system be consistent with this known system. The survey team also prepared a separate map set for the COE land program using that system.[35]

Within 7 days of starting to work, Aero reported they had 49 miles of bench levels completed, 128 benchmarks set, 38,000 linear feet of permanent baseline in place, and 5.5 miles of traverse complete. Even State Senator Edgar Brown got into the act, helping the surveyors locate old boundary monuments in Barnwell County. "He was told a geodetic marker buried by the U.S. Corps of Engineers about 100 years or so ago was important to the development of the facility. 'What the government wanted the marker for I never knew for sure but I got hold of the county engineer and we found it.' He said it was found in the old Greendale district above Dunbarton."[36]

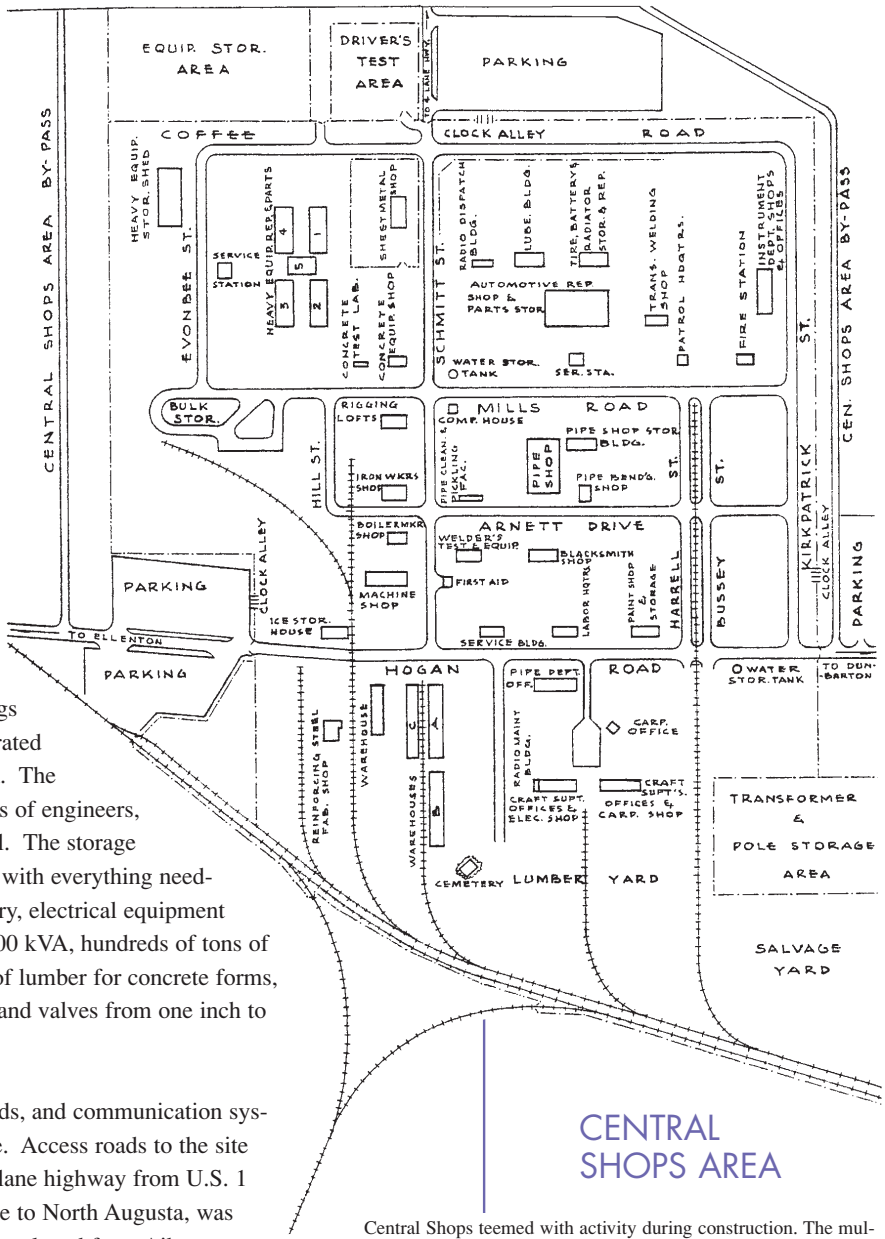
The aerial photography began on January 4 and continued through January 10. Using photogrammetric methods, Don McKay, C. Hodell, and others from the Philadelphia firm created a series of topographic maps that covered the project area and produced a relief map. By December 3, less than a year after the start of their work, they had completed the survey and mapped the entire project area. Like the acquisition team, the surveyors worked within priority areas first. As their work came together, the site was like a jigsaw puzzle with some pieces completely finished while others were still incomplete until data came in.

The need for an immediate construction area and buildings while Du Pont was organizing led to the hiring of an Augusta architectural and engineering firm, Patchen and Zimmerman.[37] This firm's inventive design work created the most recognizable area layout at the site, the temporary construction or TC Area, which would later be

known as B Area. The TC Area was placed at the juncture of existing highways and in proximity to the new cloverleaf intersection, which was also designed by the Augusta firm. The focus of the new area was two massive cartwheel-shaped steel buildings, each constructed of multiple prefabricated Butler and Braden buildings joined to a central rotunda building. Due to their unusual design and their easy identification from the air, these buildings became symbolic of the site. VWF&S laid out Central Shops on a 100-acre tract strategically located in the heart of the plant area. Every brand of metal, rectangular, gable-roofed prefabricated buildings and structures could be found in Central Shops, where massive buildings housed men of all crafts, warehouses were filled with supplies, and streets arranged in a grid teeming with cars, trucks, and heavy machinery.

Components of plant equipment were fabricated in several large shops, some enclosing as much as two acres. These buildings were essentially factories and operated 24 hours a day, seven days a week. The buildings also contained the offices of engineers, foremen, and supporting personnel. The storage yards were enormous and stocked with everything needed—thousands of tons of machinery, electrical equipment with transformers as large as 10,000 kVA, hundreds of tons of reinforcing steel, great quantities of lumber for concrete forms, pipe of many materials and sizes, and valves from one inch to several feet.[38]

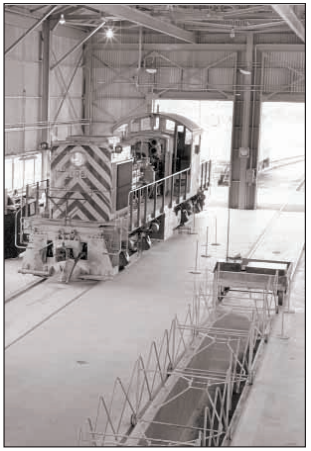
The plant's infrastructure—roads, railroads, and communication system—was also targeted for immediate change. Access roads to the site were improved with federal funding. A four-lane highway from U.S. 1 outside Augusta to the site, with a feeder route to North Augusta, was completed in six months. Highway 19 was four-laned from Aiken to the new plant site. Highway 64 was widened from Barnwell to the plant, and Perimeter Highway in both Aiken and Barnwell counties, a two-lane thoroughfare, was completed. Inside the plant area, 410 miles of county and state roads were in place before the plant, and most remained unchanged in their course. Temporary roads were built to three areas and other existing roads were widened and surfaced. A by-pass road was created around Ellenton to



CENTRAL SHOPS AREA

Central Shops teemed with activity during construction. The multitude of shops needed to construct the plant and warehouses filled with the requisite building materials and tools were encompassed within its grid of named streets. Prefabricated steel frame buildings of every size housed the shops and craftsperson's offices. Lumber, storage, and salvage yards surrounded the building area and the site railroad and its spurs linked the Central Shops' warehouses to the building sites. Source: Pamphlet titled "Savannah River Plant Temporary Construction Area Layout," hand drawn and undated. Courtesy of the SRS History Project.

diffuse some of the early construction traffic and Hogan Road, which led to Central Shops, was widened. The Du Pont construction force maintained all roads within the plant's boundaries. Bridges were an initial concern because only the Sand Bar Ferry Bridge (S.C. 28) and the Fifth Street Bridge (U.S. 1) connected the plant traffic to the Augusta area. Although these bridges were beyond their capacity in 1950, no replacement or additional





(Above) The Locomotive Shop was equipped to accommodate four engines, and all maintenance work. Courtesy of SRS Archives, negative 1785-3. (Right) Aerial view of Railroad Classification Yard. Courtesy of SRS Archives, negative 1746-2.

bridges were added.[39] Talk of a new bridge did occur, but Governor Jimmy Byrnes opposed its construction, calling it an extravagance. This decision helped to keep development on the South Carolina side of the river.[40] When the plant was closed to the public on December 14, 1952, all the road names rich in local history assumed an alphabetical anonymity at the plant boundaries. Only the streets in Central Shops, the milieu of the construction men, would have place names, and in some cases building names, that carried meaning.

First Days on the Job - Julius W. Horvath

After waiting 10 months for the United States Security people to investigate me, I received a letter to report to the Employment Office of the Savannah River Plant in December 1952. The letter came just in time, as we had finished the tool and die work for the Strata-Jet Bomber at the city airport, Macon, Georgia, and the Tumpane Company was going to send me to Atlanta to work with them.

I packed my tools and took off for Aiken. I reported on Monday and was told not to bring my tools on the plant site. I was told to report to 717-A machine shop as a supervisor. I was also told I would be there until the shops in the 773-A Lab would be ready to install the machinery. I would then report to Ray Hale as he would orient me with the different shops and the building. After the introduction with the employment office, I was walking on cloud nine on my way to the 717-A machine shop, where I introduced myself to Floyd Almon. After he talked to me, and pointed out what was expected of me, I came off of the cloud in a hurry. The first thing I was oriented on was "SAFETY COMES FIRST AND ALWAYS, and please see to it the machines are kept clean of chips and absolutely no chips on the floor." When Floyd finished his Safety and Cleanliness lecture I knew right then that Du Pont's motto was Safety First. Now as I look back to all of my days with Du Pont, I will remember that every time a mechanic needed a new job, we would sit together and talk over items of safety pertaining to the job.

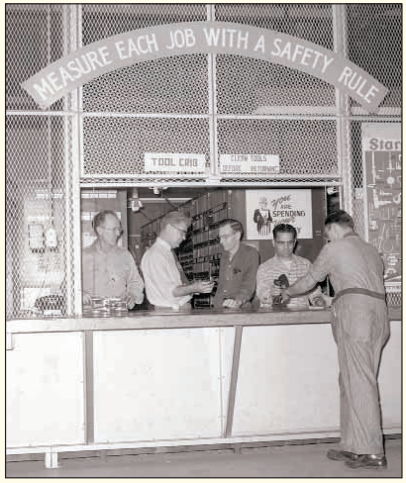
One Monday morning when I arrived at work I was asked to report to Ray Hale at 773-A Laboratory. As I started through the 773-A gate house I was stopped by a security guard who was looking at my badge. He asked who I was going to see and I said Ray Hale. He asked me to wait. While he was making a phone call I was trying to figure out what I had done wrong or was I sure this was the right place. I felt better when the guard came back and said Ray's secretary Eleanor, would meet me at the front door and take me to his office. While we were walk-

Both railroad companies within the area were expanding their services at the time of the announcement. After early briefings, they revised their expansion programs to complement the construction program. The C&WC expanded their track at Ellenton and built a spur to accommodate a concrete batch plant set up in Ellenton. While 6.5 miles of the ACL main line had to be rerouted, this firm rebounded by expanding its services at Dunbarton, transferring 400 hopper cars for use by Du Pont to bring aggregate into the plant area, and supplying 1,000 covered cars for concrete. The William A. Smith

Source (Oral Account): SRS History Project. (Photo Inset) Interior view of window in Stores showing safety signage, circa 1955. Courtesy of SRS Archives, negative DPSPF 2035-1.

Continued ing to the office I asked Eleanor if we were always watched by security people because I was still shaking over my encounter at the gate. I had never worked before under such close security. She said everyone working here inside of the fence has a job to do and I would find after I had been here a day or two that I would have so much to do that I would not have time for anything but my job.

Eleanor explained to me that there would be exotic materials plus classified nuclear materials that the machinists would be machining for Lab samples. She explained that I would go to her with a signed form and she would unlock the cage door for me. With some materials we would record the weight before it was taken to the shop and then after it was returned. The finished product, plus all the chips, would be weighed, for a final weight to be recorded. This was to be standard procedure to the machine shop only.



Ray Hale introduced me to the Technical Instrument Development machine shop and to the shop where we would be machining nuclear materials. There was also a carpenter's shop where special rubber glove boxes would be developed and built. Most of the time we would be working from pencil sketches and prints, so we would need to confer from time to time with the engineer in order to understand what his thoughts were so we could help him with his project, since he would be developing remote control equipment for inside the hot caves. Also during this period we would be supervisors of Technical Maintenance in this building until we could put more supervision in the building.

Ray then showed me the Health Physics office where, after lunch, I would be oriented on the proper clothes and shoes that would be furnished clean each day, and what color coveralls each shop would wear. They would also show me how each mechanic would monitor himself before entering and leaving the shop. On my way over to the cafeteria I turned around and looked back at the building and I said to myself "You surely will have to say a lot of prayer to help you and the men, because you just heard only the beginning and it will not end until you hear the fat lady sing".

After lunch, Health Physics began to explain their daily routine of checking the shops each day with paper smears, and also checking the halls to the change room to make sure we controlled our machining of nuclear materials and what type of film badge were needed for certain types of material and how much radiation each mechanic was allowed per week. I asked them if each morning I could have a list placed on my desk which would include the type and amount of radiation each machinist received the day before and also for each mechanic who did maintenance work in the building. They promised to do this and remarked that we were starting off on the right foot together, and we would be like one big family in that building, and I assured them that we would grow together and win together.

The next day I spent looking over the drawings of each shop, as they were placing equipment and the electricians were wiring them up. In going over the prints for one of the shops, I noticed the machines and a large floor space between them. I began to ask questions about it and found certain procedures would have to be written ahead of time in the hot shop on how to handle and machine certain types of material the shop would be handling and also the proper clothing to be worn in the shop. After the procedure was written it would be checked over by Health Physics and okayed to proceed to machine. It was evident that a schedule would have to be set up a week ahead of time, so that each machinist would be properly oriented in safety procedures before starting a new job.

It wasn't too long before the machine shops were ready and mechanics and machinists began to move in from 717-A. Floyd Almon was supervisor of all shops in 773-A. I was assigned the job of Craft Foreman of the Technical Instrument Development Machine Shop and the Carpenters shop, where special glove boxes were developed and built. We worked from pencil sketches and some prints to help Technical develop remote control equipment for inside hot caves during this period. I was also supervisor of Maintenance Equipment in the building. During this time the shop personnel needed extra training in machining, which I personally provided.

(Opposite Page) Training the sizable workforce was a challenge. Du Pont's engineers fabricated a mobile training program complete with changeable graphics and loudspeakers so that training could occur in all the building areas and that the whole construction population could be reached. Courtesy of SRS Archives, negatives 1209-1,9,8,10.

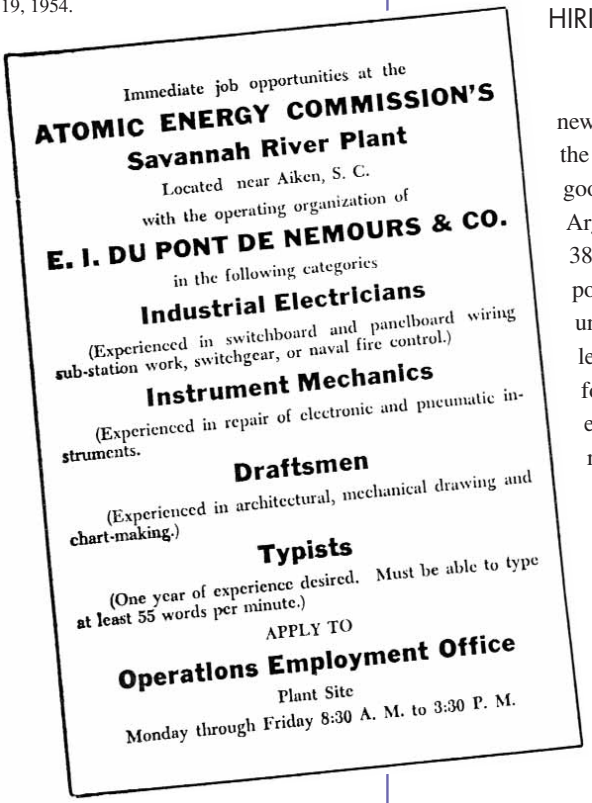
(Right) Hundreds of potential workers queued up at the entrance to the plant's Operations Employment Office in TC-2 for job interviews, August 1951. Three supervisors and 120 employees were responsible for the hiring of employees. By August 1952, they would conduct a record 73,000 interviews. Courtesy of SRS Archives, negative M-245-8.

(Below) Active recruitment for employees was carried out through newspapers, college placement programs, and trade journals. Source: *Aiken Standard and Review*, February 19, 1954.

Construction Company built sixty miles of railroad track at SRP at a cost of $80,000 per mile, and a classification yard with a 350 car capacity was also constructed.[41]

Another important step toward plant self-sufficiency was the installation of telephone and teletype systems. Cassels Telephone Company did the preliminary hookups for telephones but was supplanted by Southern Bell, who recommended that Du Pont place a cable from Augusta to the site for their permanent phone system. In 1950, Augusta was a terminal point of the New York-Miami coaxial cable. The teletype provided a direct link to Du Pont's Engineering Department in Wilmington and a second to Western Union in Augusta. The plant's telex capability was in place by the end of May 1951.[42]





Immediate job opportunities at the

ATOMIC ENERGY COMMISSION'S

Savannah River Plant

Located near Aiken, S. C.

with the operating organization of

E. I. DU PONT DE NEMOURS & CO.

in the following categories

Industrial Electricians

(Experienced in switchboard and panelboard wiring sub-station work, switchgear, or naval fire control.)

Instrument Mechanics

(Experienced in repair of electronic and pneumatic instruments.

Draftsmen

(Experienced in architectural, mechanical drawing and chart-making.)

Typists

(One year of experience desired. Must be able to type at least 55 words per minute.)

APPLY TO

Operations Employment Office

Plant Site

Monday through Friday 8:30 A. M. to 3:30 P. M.

HIRING AND RECRUITING THE WORKFORCE

Early employees came from nearly every state in the nation to work at the new plant. In 1953, "every state in the Union, except Utah, is represented in the list of immediate former addresses of plant personnel. And added in for good measure are Washington, DC, Alaska, Panama, Cuba, Okinawa and Argentina."[43] Peak employment at the Savannah River Project would reach 38,582 during the construction period as laborers, both skilled and unskilled, poured into the Southeast to work on the project. Craftsmen alerted by their unions about job opportunities, engineers recruited out of school and college-placement services, and Du Pont personnel blended into the first workforce. In 1955 when the project was essentially complete, 87,265 employees had been hired and the monthly quit rate, or job turnovers, never reached ten percent of the total force.[44]

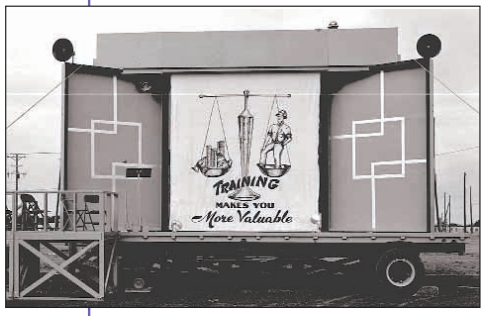
The first hires were non-manual employees: typists, stenographers, clerks, buyers, custodians, and patrolmen. Clerical workers were scarce; Camp Gordon had drained the available labor pool so clerical help had to be recruited.

Even more serious was the lack of engineers. An active recruitment program for engineers was launched in June 1951. Recruiters from the Wilmington office developed applications for professional agencies and engineering societies located throughout the eastern United States, college placement offices, and state employment agencies. Blind ads for

positions and advertising in *Engineering News Record* was used to lure young engineers to the plant. A booklet was produced that showed amenities in the Aiken-Augusta area, to introduce the new plant area to the engineer and his or her family. The recruiting office staff grew to 15 as the need for qualified engineers mounted. The recruiters first worked "Region Five," which included South Carolina, Georgia, Florida, Alabama, Mississippi, and Tennessee. The region was later expanded in January 1952 and the expansion paid off. In the month of February 1952, 59 engineers were recruited, and March brought 77 more to the plant. The recruitment effort was most successful in June 1952 when 149 engineers were hired.



In February there were 260 AEC and Du Pont personnel assigned to Savannah River. Hiring began for manual laborers once the Department of Labor formulated wage determinations on February 9, 1951. The range of hourly pay went from a high of $2.60 for plumbers and steamfitters to the lowest rates of $0.90 or $1 for laborers and truck drivers. Approximately a thousand workers were added to the rolls each month through September, when there was a slowdown in hiring because construction got ahead of design. By November 1951, nearly three-fourths of Du Pont's total construction force were manual workers (11,441) and gang foremen (1,198). The trades represented were carpenters and laborers (over 3,000 each); ironworkers, teamsters, and operating engineers (over 1,000 of each); plumbers and steamfitters and electricians (over 600 each); and bricklayers and cement finishers, boilermakers, sheet-metal workers, and painters (over 100 each). The hiring of asbestos workers had just begun. Two-thirds of the needed force for laborers, teamsters, and operating engineers had already been hired. Also onsite were individuals (about 1,000) within specialty crafts working under specific contracts.[45] Employees of B. F. Shaw Co. (piping), Miller Electric Co and Dunn Electric Company (electricians), Johns-Manville Sales Corporation (insulators), Interstate Paint Company (painters), Combustion Engineering Superheater (boilermakers), and Pittsburgh Testing Laboratory (inspectors and testers) fell into this category.



Augusta's Municipal Auditorium housed the first employment office until it was moved to TC-2. Three supervisors and 120 employees comprised the Employment Group in charge of hiring in 1951. In general, a potential employee had to be between 18 and 64 years of age. There was a pre-interview, interview, and physical examination to pass before a new employee could sign up. A prospective employee could be turned back for medical reasons, lack of qualifications, or because they did not pass the security requirements. By, August 31, 1952, the employment office had conducted a record 73,000 interviews.[46]



If hired, an individual was assigned a payroll number, photographed for a badge, and fingerprinted. Further forms were required for a necessary security clearance. All workers received a mandatory half-day orientation on safety and security. For some that was just the beginning of the training program. An extensive supervisory training program was in effect, on-the-job training was available to office personnel, and a short-term skill improvement training program was instituted for 107 apprentices in the electrician and ironworkers crafts.[47]



Manual construction labor was recruited through the American Federation of Labor building-trades unions, with two exceptions. Displaced residents of the project area were given priority in hiring and between 20 and 30 previous residents were

hired.[48] Du Pont also ordered a specific number of workers to be hired "at the gate." Despite this official policy, hiring at the gate rarely happened. Typically, the unions would fill labor "requisitions" prepared in advance by Du Pont; therefore, the company ended up hiring only union-referred workers. Even with this advance notice, the unions were also forced to recruit as the local availability of various craftsmen and their experience level varied tremendously.[49]



"Lunch Box" cafeteria in 300/700 Area, 1951. Air conditioning was limited. Only the administration buildings and the bank were cooled. First-aid stations, drafting rooms, and "lunch boxes" were cooled with room air conditioners. Courtesy of SRS Archives, negative M-280.

WORKING LIFE

Workers traveled to the plant by car pool or by bus at first to start an 8-hour work day, 5 days a week. Highway 19 brought workers in from Aiken while Highway 28 brought workers in from Jackson, Beech Island, and Augusta. As work progressed, shifts were added and workweeks extended to keep the project on schedule. On May 14, 1951, two shifts were added so that work proceeded around the clock. The workweek was extended to 45 hours of five 9-hour days in August. Between March 25, 1952 and September 27, 1953, a 54-hour workweek was observed, consisting of six 9-hour days, Monday through Saturday. Peak employment was reached in September during the 54 hour work week. By March 1954, the 40-hour workweek was reinstated.[50]

Thirty-seven pre-existing buildings were adapted for use, including a school building in Dunbarton that was converted into a weather station.[51] Historic views show the juxtaposition of uses, such as a photograph of hordes of workers in hard hats in front of the

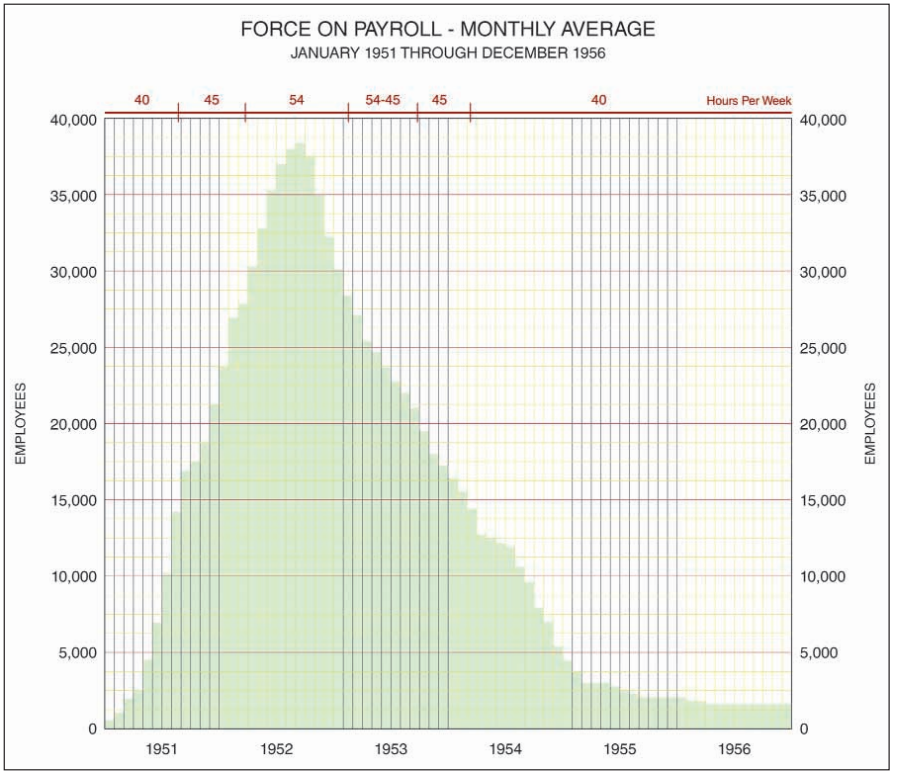


Chart showing the construction era workforce which reached its height in September 1952 when 38,582 men and women labored at the facility. Source: Engineering Department, E. I. du Pont de Nemours & Co. *Savannah River Plant Construction History*, Volume I, Report No. DPE (1957).

(Opposite Page) Interior view of Cassels' Long Store in Ellenton. Courtesy of SRS Archives, negative DPESF-6702. Source (quote): SRS History Project.

columns of the stately Buckingham House. In contrast, the new architecture of the construction era was temporary, simply designed, and expedient. Metal prefabricated buildings of every conceivable size and configuration and simple wood-frame sheds and shops with celo-siding walls and metal roofs contained shops and work stations, and stored building materials and supplies. Air conditioning was scarce. Only TC 1, TC 2, and the bank were completely cooled. First-aid stations, drafting rooms, and "lunch boxes" were cooled with room air conditioners. Otherwise fans did the job. Safety signs, slogans, and security reminders abounded, and area signs showed work accomplishments.



Twenty-five long wood-frame clock alleys through which each worker passed were used to keep hours at construction areas. A cafeteria was constructed at the TC administration area, and stationary and mobile field canteens served the roving construction forces. Between 1951 and 1953, Nilon Brothers Catering of Chester, Pennsylvania, operated the plant's food service. The concession firm kept records of their sales during the peak of employment, citing sales in the millions for sandwiches, cartons of milk, cigarettes, and candy bars.[52] Forty-three field canteens were in business at the peak of construction.

In addition to each individual's work place, there were community facilities on the plant to promote morale and to provide some conveniences for the workforce. The South Carolina National Bank of Columbia provided onsite banking for the construction forces in a temporary building in the TC Area and a check-cashing annex was added to it. A temporary check-cashing facility was also made available in the Dunbarton area. Three recreation areas were built out where team play of all types and craft or "area" picnics could be held to foster plant community. Pecan Grove Park was located near the intersection of Road C and Road 1, Pine Grove Park was located on Road 1, and Oak Grove Park was situated on Road B. Each park had playgrounds, two softball diamonds, two baseball diamonds, ovens and barbecue pits, volleyball courts, and horseshoe courts.[53] Two parks were closed after construction, and the third was later turned over to Operations.

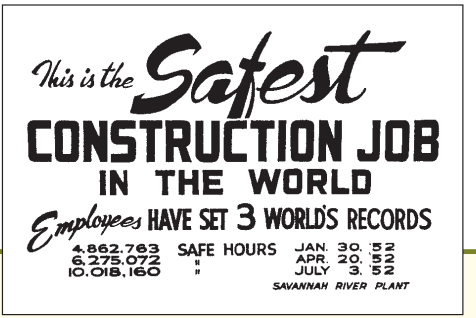
Safety and security played a large role in the life of every construction worker. From their hiring, a positive and proactive mindset on safety was inculcated in each employee. The initial safety briefing was followed with regular seminars and talks that stressed work safety. Large area safety meetings were held at intervals with Du Pont's safety superintendent and other Wilmington staff, and a competitive program for safety suggestions and slogans in which winners received cash awards was launched. This suggestion plan "encouraged each employee to think constructively about his work, and to seek new, safer, or better methods, materials, and tools." An idea program was also sponsored under the suggestion program in 1953 that allowed employees a two-week window of opportunity to submit ideas on a cost-savings drive. A total of 27,747 ideas were submitted, financial awards totaled $78,125 when the suggestions were acted upon, and their ideas saved the project $2,430,000.[54] The suggestion program fostered the involvement of all employees in the plant and how it was run.

The Original Cafeteria

"When we first started to work on the Plant site back in December 1950 and January 1951, there was no formal eating places operated by the company as yet. Mike Cassels ran a general store in Ellenton. Every day a lot of the workers went there to buy lunch. Mike seat up a long counter for them to wait on themselves. He put loaves of bread, cold cuts, cakes and soft drinks (pop) out for them to wait on themselves. They would make their sandwiches. Mike sat at the end of the counter and charged them according to their 'fixens.'"

- W. A. Monihon

The need for industrial safety was immense, and Du Pont brought a well-developed "safety culture" to the plant. The construction forces would win a world safety award for the construction industry for 4,862,763 safe exposure hours in January of 1952.[55] A second world's safety record was set in April, and a third, of 10,018,160 hours, in July.[56] These awards and subsequent recognitions were well-publicized in the site newspaper and local newspapers to reinforce Du Pont's safety ethic among the older employees and to set expectations for the new person at the plant.



(Right) Billboard sign located at the plant announcing that the employees had set a third world record for safety, 1952. Courtesy of SRS Archives.

Operations Recreation Association

A front-page banner headline in the *SRP News and Views* for July 3, 1952, notified employees that recreation areas were to be established, on site property just outside the perimeter fence. They would provide areas for "baseball, softball, volley ball and horse shoe pitching," as well as children's playgrounds and picnic facilities. The Operations Recreation Association (ORA) was established in early 1953. Relying on proceeds from soft drink machine sales and nominal membership fees ($1.50), the ORA managed what would become "one of the largest recreational programs for any one plant in the world." The first outing was held at Lake Olmstead and it featured sack races, broom balancing and a tug of war. Some of the participants wore a coat and tie. Later activities included not only athletics but also picnics, dances, and a variety of other entertainment events like a boxing exhibition presented by world champion Beau Jack or top name big bands such as Tex Beneke and Blue Barron.



Sultan of Magic cast at SRP's Musical Varieties, sponsored by the Employee Recreation Associations and held at Augusta's Bell Auditorium on three consecutive nights in March 1953. Source: *Highlights SRS Musical Varieties of 1953* (booklet). Courtesy of the Mason Family.

There were initially two recreation associations. Set up in August 1952, the Colored Recreation Association provided entertainment for African-American construction employees. When the association was discontinued at the end of 1954, it was noted to have been the largest and most active recreation group at the plant, with a peak membership of 3,358. After 1955, instead of a separate organizations, separate events were organized by the ORA, which had both black and white members. This pattern was influenced by local custom. Many of the hotels, restaurants, lounges, and other venues of recreation activities in the SRP area remained segregated into the 1960s, which would have effectively segregated offsite recreation activities.

From its inception to 1979, Tony Orsini was Executive Director of the association which expanded its programs into golfing, tennis, inter-plant sports competitions, and inter-area teams over the years in response to its membership's interests. R.S. (Joe) Lewis and Don Strosnider, later Executive Directors, helped in this expansion. Presidents Alf Kargaard, Lamar Cato, Vic Johnson, Sally Patterson, Charlie Goforth, F. L. (Speedy) Lee, Andre Holley Gray, Roger Duke, and Jim Crow played a role in building a strong foundation for the association, which won the Eastwood Award as the best recreation association in the country in 1982.

Throughout the Site's history, the ORA has been a community builder. From children's events to Atlanta Braves tickets, it has provided members of the Site community, current and retired, avenues for recreation and fellowship at events throughout the CSRA and the region.

Source: *SRP News and Views*, "3 Recreation Parks Near Completion Big Athletic Program is Shaping Up," Volume 1, No. 11, July 18, 1952.

Security at SRP had many meanings. Entry into the site and information leaving the site had been an issue of control, as required by the Atomic Energy Act and the McCarran Internal Security Act, from the earliest days of design. Stringent security measures were in place during construction and were firmly established by the time operations began. In one history of their efforts, Du Pont described the Savannah River Plant as "one of the key efforts in America's post-war defense program, and probably as the most significant single production enterprise ever planned by a government or private industry…. [For these reasons] design, procurement and construction were by their very nature, secret undertakings, demanding strict security measures."[57] Security issues were pressed not only with Du Pont employees but with all subcontractors. In the beginning this required "constant vigilance to prevent the disclosure of any significant phase of the project to unauthorized persons. The importance of effective security tempered the actions of everyone working on the

SRP News and Views

"I was working in Orangeburg as managing editor of the *Times and Democrat*. And a guy from Du Pont came over to talk to the Rotary Club about the huge new construction project underway not too far from Orangeburg. I interviewed him. And as I tell people, whenever I interviewed anybody I always asked them for a job in those days, because I was working about a fourteen hour day on a daily newspaper. Anyway, as a result of that interview, Howard Miller with Du Pont sent me an application and I filled it in, and about a year later I was called over for an interview. I was hired to start a newspaper for the construction force which got up to about 30,000 people at that time, and so I started up a biweekly tabloid for the construction. It got up to 38,000 and was one of biggest circulation of any paper in the state I guess. And I did that for about two or three years and then I transferred over to Operations. I was editor of the paper for twenty years or so."

Source: Oral History Interview, Don Law, 1999, SRS History Project.



As soon as construction was underway, the plant's first newspaper went into print, and was published on alternate Fridays throughout initial construction. Named the *SRP News and Views*, the construction-era paper was produced to foster plant identity and community. Politics, controversy, private advertising, embarrassing news to individuals, and sensitive issues were to be avoided according to Du Pont policy. When the first issue came out, the masthead featured a large question mark rather than a title. The selection of the new paper's title was used as a way to involve site employees in aspects of site operation that went beyond their work. John Campbell, an electrician with electrical subcontractor Miller-Dunn Electric Company, won a fifty-dollar savings bond for suggesting the name in an employee contest.

Articles included items of interest to locals and new arrivals, from birth and marriage notices to information about places to live. Beauty queens, especially those who worked at the plant, were photographed and interviewed. The recreation association's events were covered in words and in photographs that generously showed their games, dances, and talks. Historical pieces on the surrounding communities and on the pre-federal history of the plant were written. If a Savannah River Plant family was in need, a brief article was written highlighting their situation and informing all where funds could be sent.

Safety was a theme that recurred in nearly every issue. Traffic accidents both onsite and off were noted, and the "Traffic Score" ran in a small box on the front page of most issues, giving the number of accidents, warrants, and arrests broken out by the areas in which drivers worked. Community involvement was also encouraged through the promotion of the Community Chest program. Award winners for the Suggestion program or "Plumbob" award winners were prominently featured. Of a more general nature, events significant to the nation (especially those related to atomic energy) and to Du Pont were covered. Many issues had a "Meet the Management" article, where one of Du Pont's construction managers was introduced. Items of a more specific interest included stories about former site residents, sports scores, and human interest columns like Mim Woodring's "One Gal's Opinion" or "Fin, Feather, and Fur" written by Tom Latsch.

project, limited [the] exchange of information and opinion, and caused some delays. The practice of security became ingrained, however, and as the work progressed, its effect on work schedules was gradually reduced to a minimum."[58]



Security checkpoints controlled traffic at the plant's perimeters. Courtesy of SRS Archives, negative M-2802-2.

Security measures included controlling entry to the installation; issuing clearances to employees, with the type of clearance approved shown on an identification badge; designating restricted-access areas; document classification, control, and tracking; and inculcating personal responsibility for safeguarding sensitive information.[59] Personnel movement onto and throughout the plant was based on a badge system. Each employee was issued a badge after their clearance was approved, which was worn in plain view and displayed the employee's photo, identification details, and level of clearance (either L level or Q level). Visitors were issued temporary passes.



Most if not all employees had to pass through a liminal stage between initial hiring and their admission to the area where their fellow employees were working. This period was used for training in exclusion or limited areas. During this general employee training period, the security check would be conducted. Potential employees who were not cleared were let go after training, the remainder were badged and assigned to an area.



Security reminders were posted throughout the site, even on cafeteria napkins and matchbooks. Source: SRS History Project.

Forgetting a badge caused work delays and was perceived as reflecting a lax attitude toward security. Du Pont worked to make the concept of security a constant companion of employees. Plastic stickers were passed out to personnel asking them "Got Your Badge?"[60] These were placed on walls, beside light switches, on hard hats, and at other places around employees' homes. Patrolman Joe Roberts said that he and all the other persons in his car pool placed their stickers on the dashboards of their cars; file clerk Marjorie Welcher placed one on the car dashboard and another on the mirror of her dresser. D Area project engineer Carlo Frasco also placed his in his car, but on the windshield.[61] Although the first three times employees forgot a badge they were issued temporary entrance passes, they would have to return to get the badge on the fourth offense.[62]



LABOR RELATIONS AND INVESTIGATIONS

Prior to the project, union organization in the Augusta-Aiken area was limited to a small group of building trades in Augusta that were affiliated with the American

Federation of Labor. Carpenters, bricklayers, plumbers, electricians, and painters were represented in this highly organized group. Other unions that supplied workers to the project were chartered nearby, principally in Savannah and Charleston. There was no organized labor outside of these organizations in the project area, although a local organization, the Building and Construction Trades Council, had voluntary membership.

> New union organizational arrangements were made beginning immediately after announcement of the project in November 1950. The AFL operating engineers, teamsters and laborers each set up offices in Aiken. The teamsters chartered a new local, and the operating engineers established a fourth branch office of the local chartered originally in Charleston for the state of South Carolina. The laborers locals in Savannah, Charleston, and Spartanburg were pooled to form a new temporary unit, the Construction and General Laborers Council, with each local maintaining its identity. The boilermakers and sheet metal workers handled union affairs through the Savannah and Charleston locals, respectively. The ironworkers' general executive board set up an Augusta office under an international representative.[63]

Short-duration work stoppages occurred during construction—four in 1951, twelve in 1952, and nine in 1953. A list of reasons compiled by Du Pont shows dissatisfaction with supervisors, grievances over working conditions, the discharge of a fellow union member, and strikes in sympathy with other union groups as the main causes of the work stoppages. No stoppages occurred after 1953.[64]

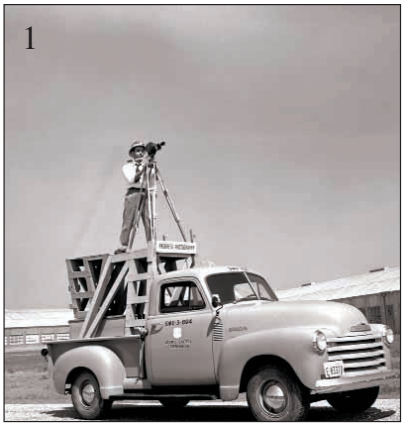
Government intervention in the plant's construction was also a factor, creating "work stoppages" for the AEC and Du Pont managers who had to answer a miscellany of charges from overlapping investigations of conduct during the plant's construction. The first investigation occurred as a result of Congressman W. M. Wheeler (D-GA.) and his assistant's unofficial visit to the plant on August 28, 1951. "Wheeler, on a recent trip to the plant area, donned overalls, brogans, and khaki shirt so as not to be recognized and spent a day going over the project."[65] The Georgia congressman, in a UPI interview, said that he would ask for a full-scale investigation of "loafing on the job, wasted manpower, feather-bedding and labor union racketeering" at the Savannah River Plant. Wheeler's charges began a series of investigations. Du Pont, the AEC, and the Joint Committee on Atomic Energy issued statements welcoming competent investigations and extending cooperation. "The plant site was crawling with investigators. They came from the House Appropriations Committee, the Senate Appropriations Committee, the Senate Banking and Currency Committee, the Joint Congressional Committee on Defense Production, the Joint Committee on Atomic Energy, and the House Committee on Labor and Education. There was no doubt that Washington



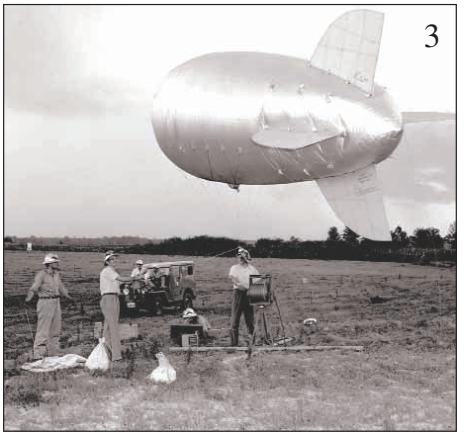
During the construction era, the Savannah River Project was visited by a number of federal investigators. On February 21, 1952, U.S. Senate members came to inspect the plant, its progress, housing and finance issues. State representatives joined them. Left to right: U.S. Senator Wallace F. Bennett, Utah; S.C. Senator Edgar A. Brown; U.S. Senator Homer E. Capehart, Indiana; U.S. Senator J. Allen Frear, Jr., Delaware; U.S. Senator Burnet Maybank, South Carolina and Chairman of the Banking and Currency Committee; and Winchester Smith of Barnwell. Edgar A. Brown Collection, Mss 100. Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

1. Negative M-849-5. 2. Negative M-578-2. 3. Negative M-157-8. 4. Negative M-1257. 5. Negative M-1193. 6. Negative M-477. 7. Negative DPESF 733-1. 8. Negative DPESF 1-663. 9. Negative DPESF 5285-3. 10. Negative M-902-1. 11. Negative M-542. 12. Negative 3434. 13. Negative M-3411.

An Era Captured on Film











1. Photographer documenting construction progress, May 1, 1952. 2. Safety Meeting, D Area, February 28,1952. 3. Onsite weather forecasting, June 21, 1951. 4. Tool Box Meeting at 681-G, speaker Joe Hutto, August 17, 1952. 5. Nilon Cafeteria workers in training. 6. Rigger at work. 7. Check cashing at Dunbarton, April 11, 1952. 8. Building K-Area powerhouse, December 16, 1952.



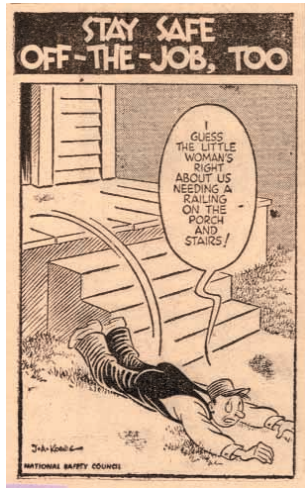














Traffic Score

Area	Ac.	Wa.	Ar.	To.
5-6-8-900	0	0	0	0
100-C	0	1	0	1
300-700	0	1	0	1
400-D	0	0	1	1
200-H	2	0	0	2
100-L	0	1	2	3
Adm.	0	**1**	**2**	**3**
100-P	0	2	2	4
200-F	1	3	2	6
100-R	1	0	7	8
Central Shops	2	3	4	9
100-K	1	3	8	12

(Ac. — Accidents; Wa. — Warnings; Ar.—Arrests; To.—Total — The traffic incidents are listed according to the area in which the drivers work.)





9. New Badge. 10. P-Area master welders and brothers E. H. Davis (center), and Eugene Davis Jr. (right) were SRP's only movie stars, having performed in the film, *The Wizard of Oz*. Fire Inspector R. J. Dorsey, Jr to the left, June, 1952. 11. The family contribution of the Adams-Smith clan- five Adams brothers, and their brother-in-law, made news in February, 1952. Left to right, Grady Adams, heavy equipment; Alvin Adams, electrical helper; Raymond Adams, electrical foreman; Jack Adams, electrical clerk; Joseph L. Smith, electrical foreman; and Clyde Adams, boilermaker. 12. Interviewing for a summer job, June 4, 1956. 13. Colored Recreation Association Officers, April, 1954. First row from left, M. E. Cummings, 100-K Labor, treasurer; Hoover Utley, Central Shops Transportation, vice-president; J. A. Washington, Central Shops Labor, president; and A.C. Wright, 200-H Labor, secretary. Standing, Directors George Gray, Administration Labor; J. A. Gadson, Central Shops Transportation; Walter Singleton, 100-K Labor; Nathaniel Johnson, 200-H Labor; J. F. Washington, 100-C Labor; and J.Q. Miller, 200-F Labor. Newspaper clippings from *SRS News and Views*.

was interested in the political gold in the Savannah River Project."[66] Ray Shockley, State News Editor for *The Augusta Chronicle,* was invited to the site to report Du Pont's side of the story. Shockley's article was the first rebuttal to the Wheeler charges, noting that without a visitor's badge one really couldn't get a sense of the project. Congressman Wheeler, due to his disguise and his explanation of his purpose, did not have entry to "where the real work was going on."[67] The Shockley article helped with Du Pont's damage control.

Senator Burnet R. Maybank of South Carolina, the Chairman of the Senate subcommittee in charge of appropriations for the AEC, took responsibility for the developing inquiry. Reports were filed that dispelled Wheeler's allegations concerning the engineering and construction work. However, Du Pont's hiring practices still drew fire from the Special Subcommittee of the House of Representatives, who held five days of hearings in Augusta in November 1951. Referred to as the Barden Committee after its chairman Rep. Graham A. Barden (D-NC), the committee heard testimony from AEC SROO Manager Curtis Nelson, Du Pont's Bob Mason, officials from the state employment offices, and representatives of the labor unions.

Nelson stated that due to the urgency of the project the AEC "could not run the risk involved in deviating from the normal practices which prevail in the construction industry."[68] The committee's report was not favorable. It characterized the hiring practices for manual labor at SRP as preferential towards union labor, as no hiring at the gate actually occurred and testimony indicated that qualified non-union labor was turned away. In their opinion, Du Pont was running a "closed shop." They understood the vital need and urgent schedule for the project that led to this situation, but recommended that the AEC and Du Pont correct the situation.[69] Du Pont took the Wheeler charges very seriously, mounting a campaign from Wilmington that refuted the claims made after Wheeler's "over the fence" inspection.

Perhaps the most important of the investigations was focused on racial discrimination. The Savannah River Project attracted and held the attention of the NAACP and the National Urban League's Southern Field Division from December 1950 onward. The federal project was a window of opportunity for change for African Americans in the South and particularly in South Carolina. Clarence Mitchell, the Director of the Washington Office of the NAACP, wrote, "It is very important that the Federal Government make certain that the racial patterns of the State of South Carolina will not be imposed in the territory which is used for the production of the H Bomb."[70]

Mitchell, in a letter to Carlton Shugg of the AEC dated December 1, 1950, asked specifically about employment policies and housing at the new plant. Before responding, the AEC conducted a survey of "conditions and practices" in the plant area. Before this was carried out, Mitchell visited the AEC's office in Washington to raise questions concerning segregation in housing, transportation, restaurants, and other eating facilities. He firmly let all AEC members present know that such matters were the domain of the AEC, not Du Pont. Mitchell also advised the Washington office that he had set up an appointment with Arthur Tackman, the AEC personnel officer at SRP, to speak with AEC and Du Pont officials in Augusta in January. He set an agenda that covered fair compensation for land owned by African Americans in the project area, as well as discussion of fair hiring of skilled labor.

Sumner Pike, then Acting Chairman of the Commission, wrote to Mitchell stating that a visit by both AEC and Du Pont men had been made in the plant area to collect informa-

tion that was now under consideration. He further stated that no community buildings were planned, and that the Commission's contractor was responsible for the employment of both the construction and operating staff for the new plant.

Between January 3 and 5, 1951, AEC officials from Washington and Savannah River visited the area's federal reservations, Camp Gordon, Clarks Hill Dam, the Augusta Arsenal, and Fort Jackson. Their survey showed that the Defense Department's policy of complete integration was upheld at Camp Gordon and Fort Jackson. Even the civilian organizations on the posts conformed to this policy. While skilled and unskilled laborers made up the majority of the workforce, African Americans were certified for civil service positions at both installations. On Fort Jackson, all transportation was integrated; however, the bus system that serviced the post was segregated in accordance with South Carolina law and custom.

Camp Gordon, served by a privately-owned bus company, had integrated transportation on and off the post. Augusta Arsenal was in the throes of desegregation, but no problems were found there with this change. Clarks Hill had only a few African Americans on the payroll and the facilities were segregated. The survey notes finished with a list of South Carolina's African American construction workers that were taken from the South Carolina State Employment Service on January 1, 1951. There were 788 skilled workers, the majority of whom were bricklayers, carpenters, cement finishers, and painters. Semi-skilled laborers included 1,444 individuals and unskilled laborers were in the majority with 4,177 individuals.

By March 23, R. W. Cook from the AEC's Production Division Headquarters sent recommendations to Curtis Nelson on fair employment in response to Nelson's queries from the field office. Nelson was advised that federal law did not tolerate discrimination in hiring construction or operations staff and that a policy of "eventual" employment of African Americans for office staff was not following the law. Cook also recommended that no signs denoting a segregationist policy appear at the plant, and that transportation in the area should be integrated.[71] South Carolina state labor laws were at odds with these recommendations. Under labor laws structuring the textile manufacturing business, segregation was mandated. Du Pont seems to have straddled the issue at least initially. There were separate toilet facilities identified in the TC Area, but there does not appear to have been signage.[72]

The Wheeler charges in August on hiring spiraled into charges of segregation and racial discrimination in hiring and promotion. When the members of the Joint Congressional Committee came to the plant in September, hiring practices for African Americans were a topic of discussion. It was essentially the same argument but with a racial twist—that by working solely with the AFL, the site did not consider African American union member and others for employment.

During his presidency, Truman had formed an eleven-member presidential Contracts Compliance Committee charged with watching for racial or religious discrimination under federal contracts. When the charges against the Savannah River Plant were made, Vice President Richard Nixon had become chair of that committee. When the committee met on September 15, 1953, the NAACP filed a protest against the AEC for discrimination in hiring. Savannah River management sent an immediate return volley that denied the charges. Curtis Nelson once again was called in front of an investigating committee. Having adopted the earlier recommendations from headquarters, he stated that the AEC

had a firm policy against discrimination and that over 5,000 African Americans were already employed at the project. This information quelled the immediate discussion but debate would continue through late 1953.

The plant was built during a time of great social change and its presence, along with other federal projects and military installations, contributed to that change. It is ironic that Du Pont, in addition to the discrimination charges discussed above, was also the subject of discrimination charges made by the Grand Dragon of the Associated Carolina Dragons of the Knights of the Ku Klux Klan for its hiring practices.[73] Change may have not been immediately discernible or fast enough, but there is no doubt that the plant was a prime mover in changing race relations in the region.

SAVANNAH RIVER PLANT GEOGRAPHY

In the geography of the plant, "areas" are the important organizing concept. Buildings or facilities are located within areas. Each building area was given a number and a unique letter designation. Function is reflected in the area numbers; letters identify site geography. This code, used first at Hanford to identify building areas and their associated facilities, and the road-lettering system heightened the anonymous and utilitarian character that evolved at the Savannah River Plant.

The numbering system reflected the building types and their function. The 700 building series, for example, housed administration, safety, and support functions. In this series, specific duplicated building types, such as gatehouses, were all referred to as 701 buildings, and a suffix (such as the -5A in 701-5A) indicated its geography and the number of gatehouses in a building area. This numbering system allowed for expansion should more of a given building type be needed. With the exception of the 700 and 600 buildings, the hundreds place in each buildings' three digit number indicated a process area. The remaining places in the numerical label indicated a building's function. Thus, a powerhouse in 100-R Area was 184-R, a cooling tower 185-R. The same building types in the 700 Area were labeled 784-A and 785-A.

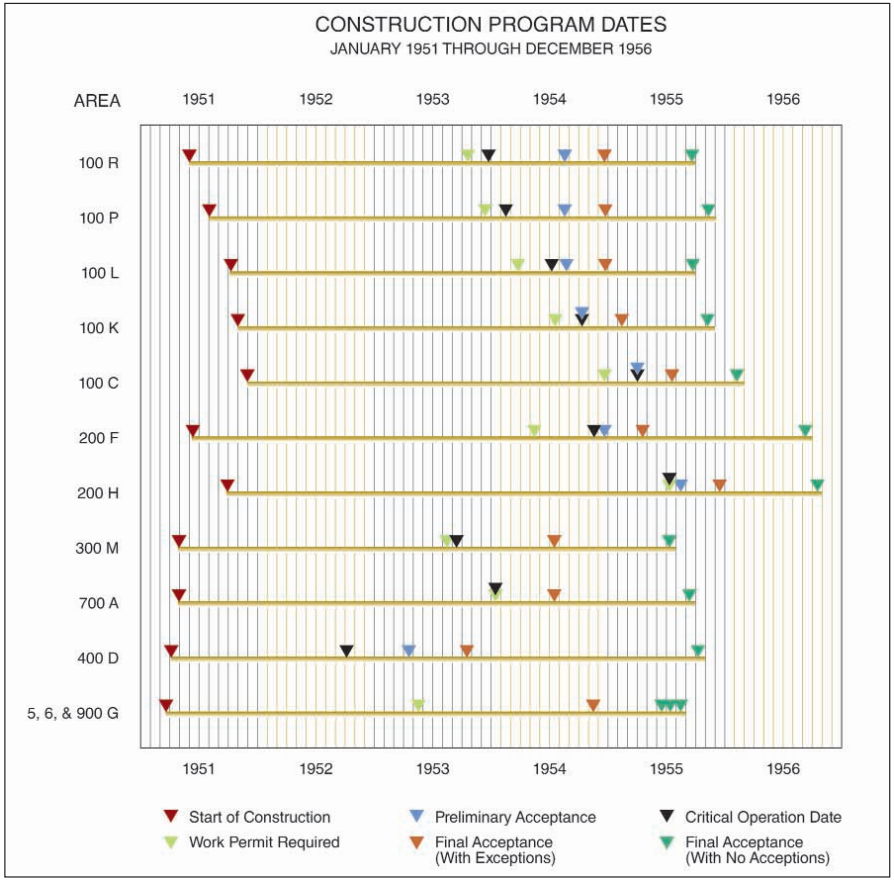
100 - Reactor Area	100-R, P, L, K, and C
200 - Separations Areas	200-F, H
300 - Fuel and Target Fabrication Area	300-M
400 - Heavy Water Production Area	400-D
500 - General (lighting, transmission lines, substations, etc)	500-G
600 - General	600-G
700 - Administration Area	700-A
900 - General	900-G

The plant was originally organized into ten permanent areas that included nine integrated but self-sufficient manufacturing areas, (R, P, L, K, C, D, F, H, and M) and a central administration area (A). The two "temporary" building areas known as the Temporary Construction Area (TC Area) and Central Shops are discussed above. All building areas were linked by a well-designed transportation system, that, when completed, included 210 miles of surfaced highways, a cloverleaf that was the first constructed in the state, and 60

miles of railroad track. The plant, a model of functional, clean, energy-efficient, and economical design, incorporated two levels of organization. First and foremost, the basis for the layout was the safety and environmental concerns that stemmed from its unique mission and the risks involved. On a secondary level, the building areas showed good industrial organizational design.

PERMANENT CONSTRUCTION AND SCHEDULE

The G-Area facilities, namely roads and railroads, were built first in preparation for construction. The next construction priority was the Heavy Water or 400-D Area. Construction began in D Area on April 2, 1951. R Area, followed by P Area, were the next priorities. Construction began on R Area on June 1, 1951, and construction of P Area began the month after. While construction began on A/M Areas in May 1951, the administrative area and the fuel and target area were given lower priority. Construction was ongoing but not as pressing. F Area was the next priority after P; and work began in F Area on June 8, 1951. The construction sequence after that was L Area, K Area, C Area, then H Area. Du Pont's engineers then assigned priority to the major process facilities within each of those priority areas. Notably, construction of the reactor or 105 building in each 100 area accounted for 75 percent of the work in the total building area.[74]



The construction schedule was rigorous and the construction of areas staged to meet defense production goals. Thus D, M, R, and F areas were the priority process areas. A and G areas were also on the fast track to support the ongoing construction. Source: Engineering Department, E. I. du Pont de Nemours & Co. *Savannah River Plant Construction History*, Volume I, Report No. DPE (1957).

At an early date the Atomic Energy Commission mandated that all building design conform to its policy of Spartan simplicity in design. This policy required Du Pont and its subcontractors to design facilities with maximum economy consistent with functional requirements and to standardize designs and specifications for buildings and associated facilities.[75] Standardized design saved money, promoted uniformity, and better allowed the construction force to adhere to its tight construction schedule. The plant buildings also had to be strong enough to survive an atomic blast and, in the face of an attack, be so constructed that the facility could either wholly or in part continue to be operated. Professor H. L. Bowman of Drexel Institute of Technology and Du Pont engineers tackled these building criteria. Three types of construction for the plant were developed, and this classification system was codified and placed into a supplement to the Uniform Building Code published in January 1, 1946, which was adopted for plant construction use.[76]



Transite™ was the siding of choice for Savannah River's first generation of buildings. This circa 1950 advertisement extols the advantages of the building material for industrial buildings. Source: *Architectural Forum*, March 1950.

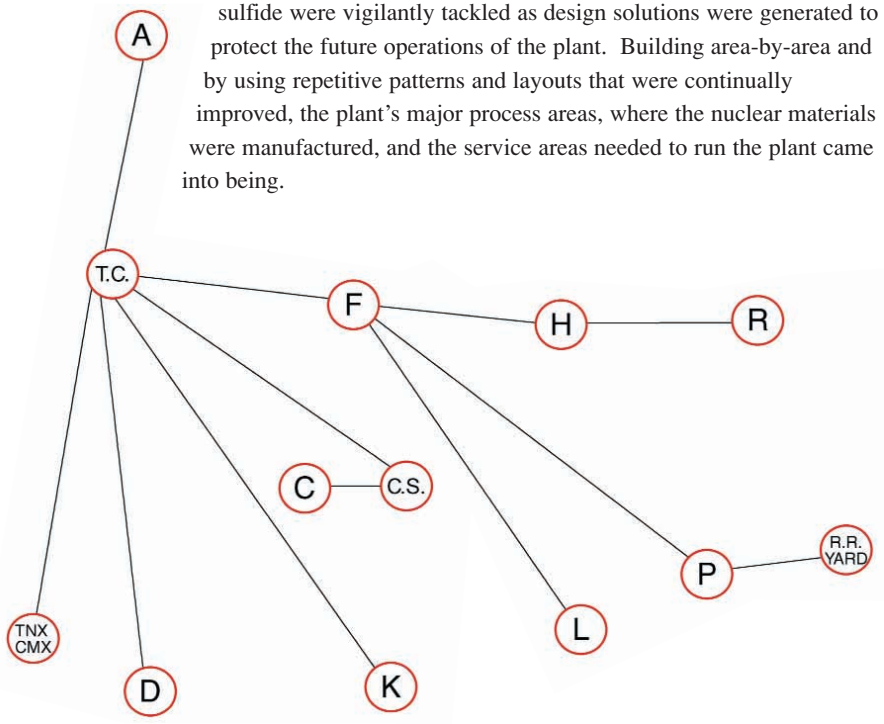
Class I buildings were massive, reinforced concrete, monolithic structures with a static live load of 1000 pounds per square foot. Their exterior walls and roof were poured, reinforced concrete with a supporting frame of reinforced concrete or structural steel. Preferably, buildings such as reactors or canyons should be constructed of blast-proof materials throughout. Reinforced concrete construction was selected for its ability to take stress, the protection it afforded from alpha and gamma rays and intense heat, and the speed and economy it would lend to construction.

Class II buildings were built with a structural frame of reinforced concrete or structural steel and expendable wall materials: if bombed, the structural frame would remain intact. Extensive tests were undertaken at Sandia National Laboratory in New Mexico to identify possible friable wall materials by exposing the candidate materials to TNT explosions that simulated atomic bomb blasts. After analysis, Transite™, a short-fiber, cement–asbestos siding material, was chosen.[77] Transite™ was sold in the form of flat and corrugated sheets. As an exterior sheathing it reduced the load-bearing factor considerably from 120 to 20 pounds per square foot compared to masonry walls. It did not rot, rust, or burn and was impervious to insects and rodents.[78] Advertised as smart, modern, and economical in period advertisements, Transite™ panels became the primary building material for exterior walls on Class II construction.

Class III construction was considered normal construction carried out under the regular building code.

CONSTRUCTING THE AREAS

The scale of the construction of the plant and the wide breadth of talents and skills that were needed are hard to grasp. Du Pont's engineers and their subcontractors designed everything from delicate instrumentation to monumental concrete reactors using the new SRP building code. Hazards from radiation and the use of hydrogen sulfide were vigilantly tackled as design solutions were generated to protect the future operations of the plant. Building area-by-area and by using repetitive patterns and layouts that were continually improved, the plant's major process areas, where the nuclear materials were manufactured, and the service areas needed to run the plant came into being.



SRP Building areas. Source: *Savannah River Site Atlas*. Facilities and Services Site Development Control and Mapping Section, January 1997.

100 AREAS

Five reactor areas were situated in an arc within a 35-mile-square area in the reservation's interior. Each area contained approximately 40 buildings. They were built in a sequence that allowed the first to go into operation while the next was under construction. This method also allowed for lessons learned and cost savings to be applied to the next one built. Thus K and C Reactors included innovative ideas worked out on the first three (R, P, and L). These differences are discernable in the quantities of construction materials used for each.[79]

Area	Excavation Cubic Yards	Concrete Cubic Yards	Reinforcing Steel Tons
100-R	2,300,000	235,500	19,300
100-P	2,325,000	200,600	18,175
100-L	2,051,000	165,700	14,100
100-K	2,145,000	166,750	14,300
100-C	1,470,000	155,000	13,900



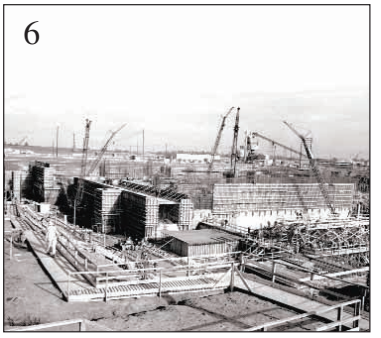
Building a Reactor

1. Corn field occupies 105-R site, May 28, 1951, negative DPESF 1-126. 2. Excavation for 105-R involved moving 2,300,000 cubic yards of earth, August 24, 1951, negative 1-44-1. 3. Reactor building begins to take shape, September, 25, 1951, negative 1-158-1. 4. Below-ground area built and levels above grade are readied for concrete pours, December 19, 1951, negative 1-206-1. 5. Concrete forms and supporting scaffolding on reactor building,











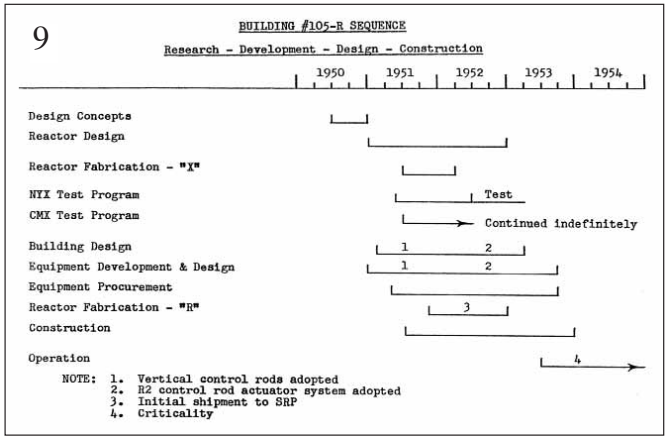
negative 1672-4E. 6. 105-R's construction required 19,300 tons of reinforcing steel and 235,500 cubic yards of concrete, June 28, 1952, negative 1-206-1. 7. Construction proceeds around the clock, June 16, 1952, negative 3692. 8. Completed 105 building, April 30, 1953 and timeline of the entire process involved from conception to start of operations, negative 1-855-2. 9. Source (graph): Engineering Department, *Engineering and Design History,* Vol. II. E. I. du Pont de Nemours & Co., 1957.



8



9



Building a Canyon

1. Excavation and below grade construction of F canyon, negative 2-135. 2. Sectional construction above grade, April 23, 1952, negative 2-212-1. 3. South end of F canyon railroad car portal in place, April 23, 1952, negative 2-212-2. 4. North end of F canyon, negative 2-297-1. 5. Concrete shell completed. North end of canyon shown, February 29, 1953, negative 2-554-1.

All photographs courtesy of SRS Archives.

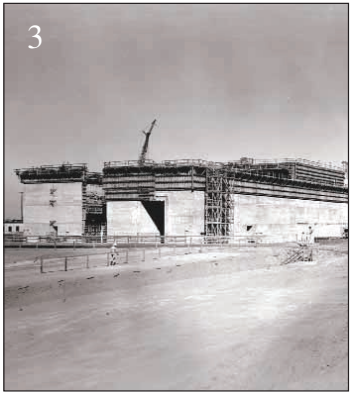
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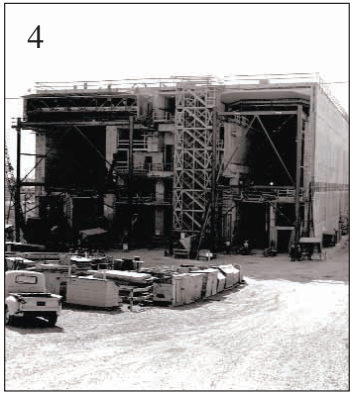
2



3



4



5



The Corps of Engineers took soil borings at each reactor area to determine subsurface conditions in preparation for reactor building construction. Where soil zones were encountered that contained porous ground, concrete grout was used as a filler to prevent building subsidence. Excavation for the 105 buildings was extensive, measuring approximately 610 feet by 725 feet. The excavation area was comparable to an average-size stadium. As concrete pours required shadow-free work areas, flood lighting akin to stadium lighting was installed. The planning, construction, erection, and stripping of concrete forms for the 105 buildings required a prodigious effort. Concrete was typically placed through pumpcrete lines supplied from a batch plant.

The installation of heavy equipment had to be planned well in advance, and the 105 building's permanent cranes were used for installation during construction. Given the height of the reactor building as construction progressed, cranes were lifted from level to level by other boom cranes to facilitate construction. Stiff-legged derricks with a 15-ton rated capacity and 100-foot booms were used at the 105 areas to handle the placement of material and equipment for the telescoping actuator system through construction openings. A variety of materials entered the building in this manner; openings left in the buildings allowed materials to be continuously placed in or near their point of installation. The construction histories list the heavy equipment used at the reactor areas: crawler cranes, motor cranes, crawler tractors, roustabout cranes, batch hoppers, boilers, concrete buckets, concrete mixers, conveyors, air compressors, welders, farm tractors, pumpcretes, pumps, derricks, hoists and winches, motor graders, tanks, dragline buckets, and clambuckets.

The construction men working at the reactor and separations areas quickly became familiar with the concept of restricted areas within the work site. Only Q-cleared personnel could work within these areas. Thus, a certain number of men in each craft were targeted for this clearance level when they were hired.

While security was an added work dimension, other construction challenges were met. The need for cleanliness and the application of protective coatings in the 105 buildings was closely followed, and a well point system was placed in excavation areas to help lower the water table. The construction history also states that the specifications for the 105 buildings covering the building layout, instrument placement, and equipment were

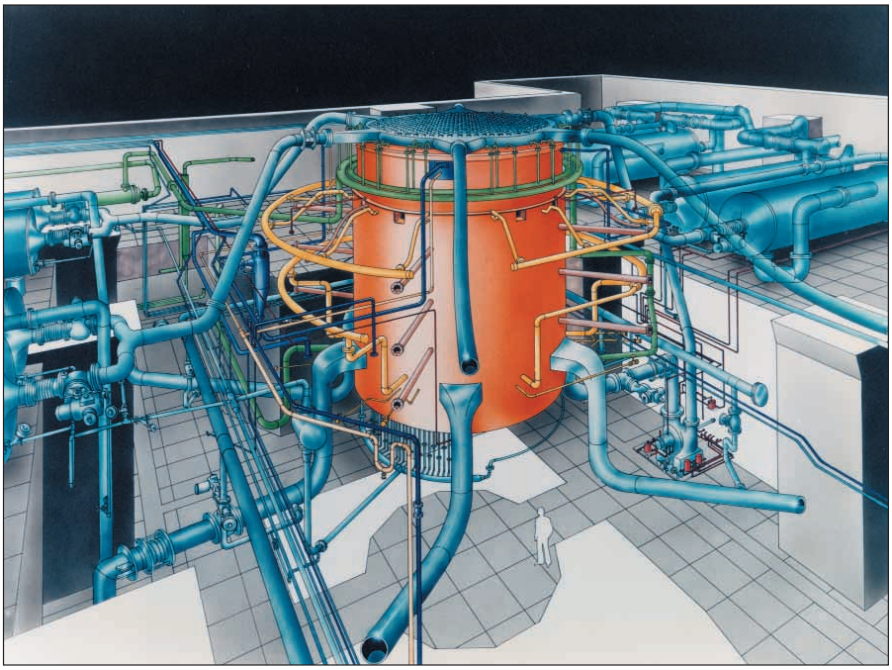


"The first barge shipment of material from New York Shipbuilding Corporation landed at the Savannah River dock at 1:30," August 2, 1952. Source: Engineering Department, E. I. du Pont de Nemours & Co. *Savannah River Plant Construction History*, Volume II, 1957, DPES 1403: 575.

The reactor, the vessel and the plenum, arrived by barge at the plant's Savannah River dock that was constructed for this purpose. A series of photographs document the reactor's progress from the dock to R Area under heavy security. Courtesy of SRS Archives, negative DPESF-1-2227-12.

exacting. Two tools were acquired to achieve the required accuracy: a Wild III, a Swiss precision-leveling instrument, and the British-made Watts "Micropotic No. 2 theodolite," which was ordered from England. These tools were used to provide horizontal control lines on top of the reactor and to precisely install special equipment in the reactors.

The five stainless-steel reactor vessels, fabricated by New York Shipbuilding between 1951 and 1954 under the codename "NYX Project," were shipped to the plant by barge. R. H. Barto supervised the project for New York Shipbuilding. Eleven Du Pont engineers worked with the Camden fabricators, some for the entire project, others for one-year stints. The reactor vessels, composed of a plenum, a top tube assembly, the main tank, and a bottom tube assembly (the plenum, and top and bottom tube assemblies had matching patterns so that tubes could be raised from or lowered into the vessel), were enormous. The approximately 225-ton vessels were unloaded by a stiff-legged derrick at an unloading dock on the river, then transported to each reactor area on "low boys" purchased to handle their weight. R Reactor was shipped from Camden, New Jersey, on August 2, 1952. P, K, and L Reactors arrived in 1953 and C Reactor arrived in spring of 1954.[80]

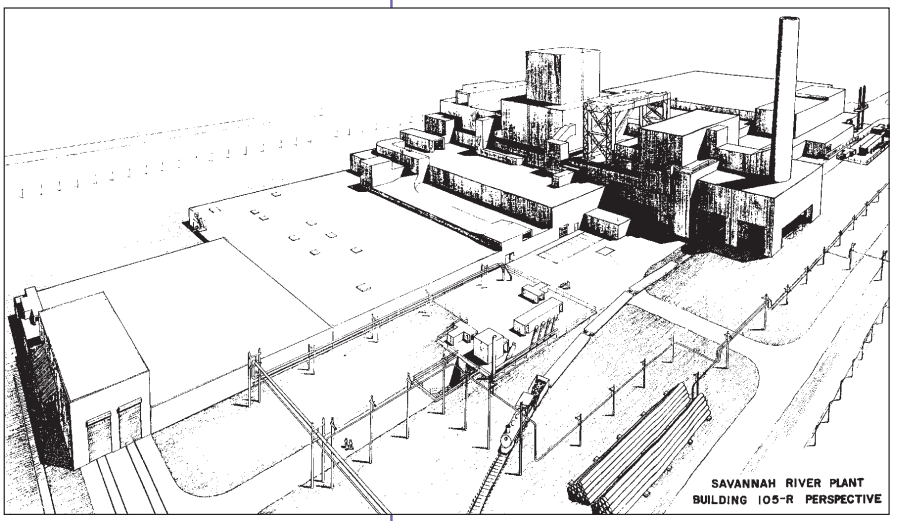


Conceptual drawing of reactor vessel (orange) and plenum, circular sieve-like part at top of reactor vessel, at –40 level, completed circa 1953. Illustration attributed to Voorhees, Walker, Foley & Smith. Courtesy of SRS Archives, negative 43960-6.

The installation of the reactor equipment was also unlike any other job:

> The reactors C and D machines, a 120-ton crane and a purification area crane, were all automatically and remotely controlled, and included complex cable assemblies and the most intricate electronic circuits. Installation of such equipment is not normally encountered on construction jobs. To aid the field force in the interpretation of the design and installation of equipment, vendors provided specialized technical personnel during the final stages of assembly and testing.[81]

When finished, all SRP reactors were multilevel, irregular-shaped buildings primarily constructed of reinforced concrete. From the air, they resemble concrete machines. Only R reactor was wholly built with blastproof construction; the remaining 105 buildings feature both Class I and Class II construction. Their substructures, made of blast proof construction, extend many feet below grade, and the building's overall size at grade varies. The concrete stack at a height of over 100 feet is each reactor's highest elevation.



Profile of 105-R, the largest of SRP's five production reactors and the first to achieve criticality. The reactor building was essentially an envelope covering four main process areas: the assembly area, the process area, disassembly, and the purification area. Source: Engineering Department, E. I. du Pont de Nemours & Co. *Savannah River Plant Construction History,* Volume I, Report No. DPE, 1957.

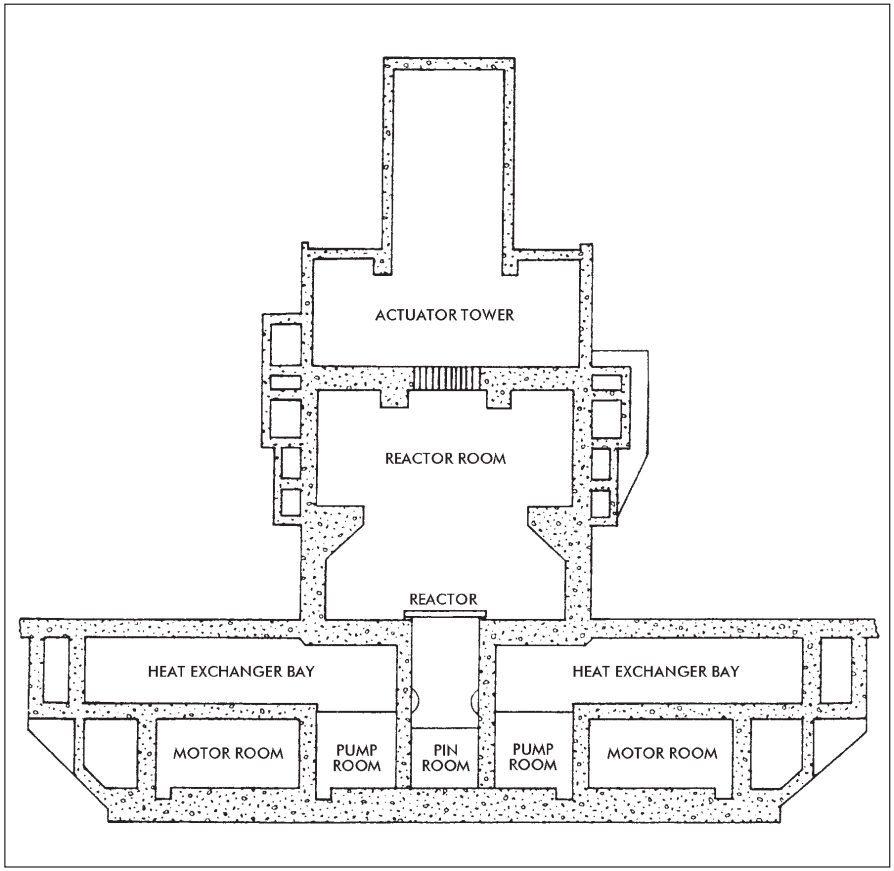
Each 105 building is essentially an envelope covering a group of complex processes, and it was these processes contained in four core areas that created its unusual form and size. The process sequence for reactor materials included preliminary handling, irradiation, disassembly, and purification. Fuel elements and target materials to be irradiated were cleaned, loaded, inspected, tested, and stored prior to use in the reactor in the assembly area.[82] These materials were irradiated in the process room. At one end of the process room, fuel–target assemblies were readied for vertical insertion into 16-foot-diameter stainless-steel reactor tanks. Fuels were loaded and unloaded via charging and discharging machines that transported the fuels to the reactor and placed them in their precise lattice location by remote control. Carried on gantries that extended the length of the reactor room, these robot-like machines found the precisely located holes at the top and pins in corresponding places at the bottom that "accept and hold in place the 'lattice' of fuel, target, control rod, safety rod and instrument assemblies." The "forest," a complex array of control and safety assemblies, was positioned over the reactor's face or plenum; the forest was raised when the reactor was charged or discharged and the reactor room height accommodated this vertical assembly process. A basin was located at the other end of the reactor room to store irradiated assemblies, where a conveyor would transport the spent fuel and assemblies through a canal into the disassembly basin. The process or reactor room area of each reactor is multilevel in profile including a "high hat" to house the actuator when it retracted upward to make room in the reactor room for the charge and discharge machines during reactor shutdowns. A cylindrical cement stack was mounted on the building to exhaust air from the building.

Heavy water was used as both moderator and primary coolant that removed fission heat from fuel elements. The coolant was circulated through heat exchangers, where it was cooled by river water that would be released to plant streams or cooling ponds. The heavy water flowed out of the base of the reactor tank, through the heat exchanger, and then was recirculated to the top of the reactor plenum.

The irradiated materials and the depleted fuels were aged to allow decay of the shorter-lived fission products, disassembled, and transferred in casks for shipment by rail to other plant areas for additional processing. This part of the process took place in the reac-

tor's disassembly area. All work in this area was performed under water with remote mechanisms, as irradiated assemblies were transported through a canal from the reactor room to the disassembly basin. Concrete walkways stretch over the disassembly basin. The fourth process area in the reactor was the purification area. This area contained equipment for continuously purifying the heavy-water moderator and helium blanket gas during reactor operations.

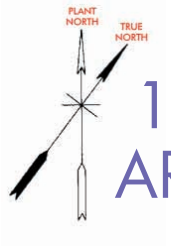
Service facilities, operating control rooms, heating and ventilating equipment, electric equipment, and offices were dispersed throughout the reactor. Personnel areas had their own ventilation systems. Unlike most buildings, reactor buildings are not considered to have stories, instead they have levels or elevations. These elevations are designated by feet above and below grade. Ground surface is designated 0-0; other levels are designated by their distance to and from ground level.



Cross Section of a Reactor Building showing the process area. Source: William P. Bebbington, *History of Du Pont at Savannah River Plant*, (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).

105-R is the largest of the reactors; its design and general configuration were an amalgam of initial design decisions that were later improved to increase production, allow greater flexibility, and to hold costs down. R and P Reactors were the first designed, sharing many design features while L and K Reactors, which were part of the later AEC expansion program, are more alike in design. The design changes in L and K derive from a desire for higher power levels and the use of depleted or enriched fuel types. C Reactor, the fifth to be completed, differed from its counterparts in design changes that allowed the

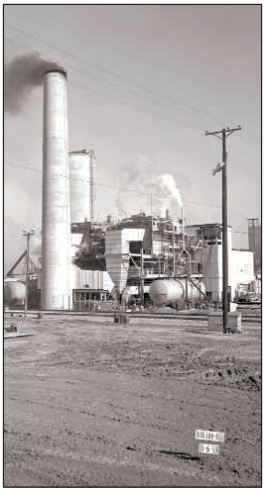
Reactor, negative 1-227-2. Cooling Tower, negative 1-737-9. Pumphouse, negative 1-738-4. Gate House, negative 1-305. 184-R, negative 1-651-7. Administration, negative 1-333-9. Courtesy of SRS Archives. Source: Basic Information Maps, 100-R Area, 1956.



100 AREA



Reactor





Cooling Tower



Pumphouse



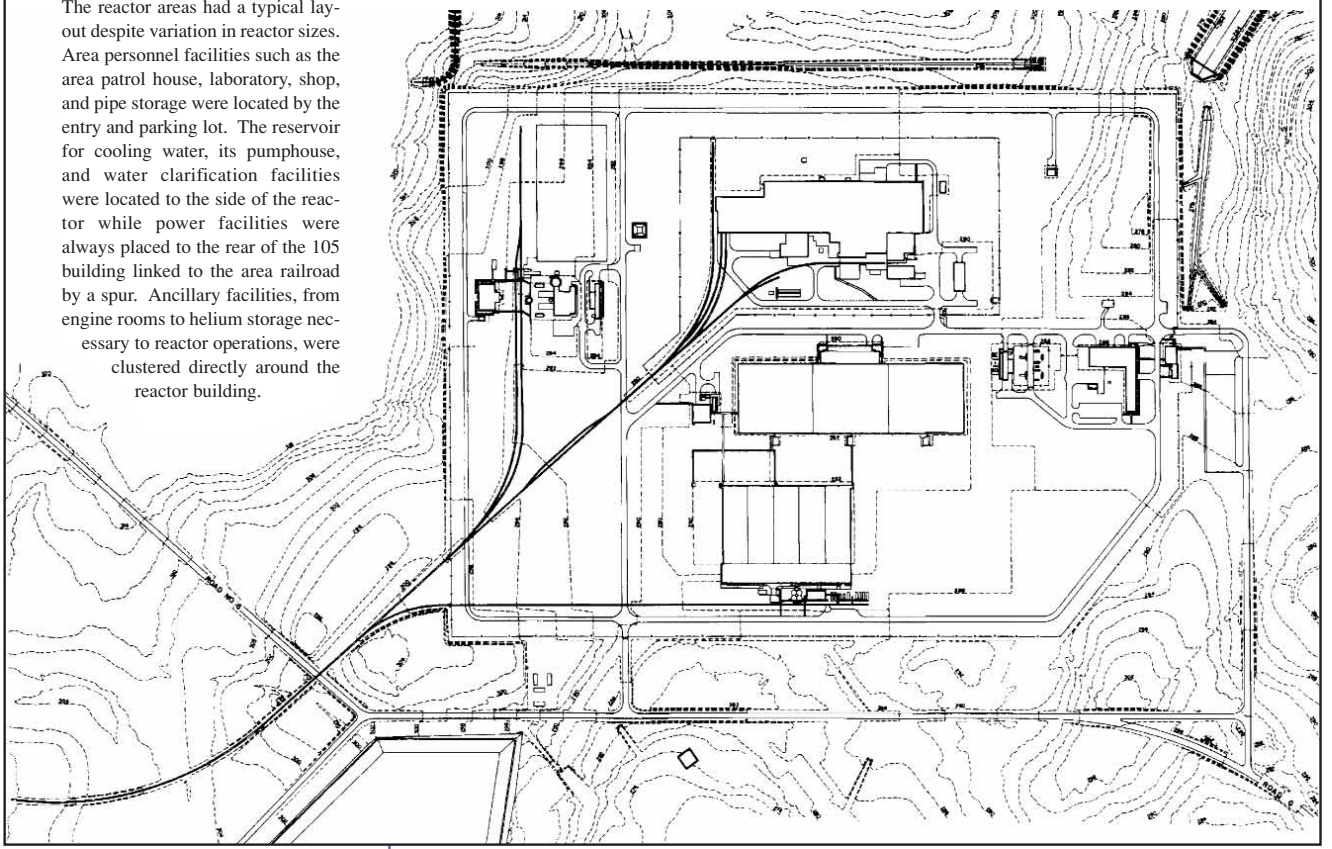
Gate House

Powerhouse



Administration

The reactor areas had a typical layout despite variation in reactor sizes. Area personnel facilities such as the area patrol house, laboratory, shop, and pipe storage were located by the entry and parking lot. The reservoir for cooling water, its pumphouse, and water clarification facilities were located to the side of the reactor while power facilities were always placed to the rear of the 105 building linked to the area railroad by a spur. Ancillary facilities, from engine rooms to helium storage necessary to reactor operations, were clustered directly around the reactor building.



handling of different fuel elements, higher power levels, greater moderator flow and structural changes needed to handle the higher power levels desired.

In each, the reactor room was placed at the center with the assembly, disassembly, and purification areas adjoining. Materials handling, the location of the reactor and heat exchangers and pumping facilities, and positioning of control mechanisms were all design problems that, when solved and refined, would produce compressed disassembly areas. Vertical loading mechanisms and the placement of heat exchangers under the reactor allowed a more condensed reactor layout. Design improvements also allowed changes in the classes of construction to be used in certain parts of the 105 building.

Power-generation facilities, water-purification and -clarification units, a cooling water pumphouse and basin, storage, shops, a gatehouse, and parking lot surrounded each reactor building in a standardized layout. Two river-water pumphouses were also integral to the reactor's operation. Reactors need a steady flow of cooling water both during operation and after shutdown. Each pumphouse supplied the necessary water through a network of miles of concrete pipe to the 100 areas.

Cooling-water basins, containing millions of gallons of water, were also constructed at each area for additional protection. This river water cooled the heavy water that was used as a moderator and coolant for the irradiated fuel elements, and was recirculated through the reactor. When the heavy water was pumped through the reactor's heat exchangers, it was cooled by river water. The pumphouses and water distribution systems, and basins were extremely important facilities within the reactor areas.

The reactor areas were models of industrial efficiency from their well-designed electrical network to the buildings themselves. R Reactor, the first and the largest of the five reactor buildings, was largely completed by the end of 1953. P Reactor was completed in 1954 and the remaining reactors were completed in 1955.[83]



Aerial view of F Area, view to the west, January 1953. The canyon, the focal point of the 200 Area, is the long building to the right of the center. The long excavated area in the front of the photograph is an ash basin (286-F). Courtesy of SRS, negative cy-f-1-1-53.

200 AREAS

Construction proceeded on two separations areas, one fully built out (F Area) and a second integrated but expandable for future needs. The 200 Areas, 200-F and 200-H, were centrally located within the site's core area, approximately 2.5 miles from the closest reactor area and about 6 miles from the project area perimeter. Construction statistics show that 50 major buildings were constructed in the 200 Areas, 300 acres of land were graded, about 2,500,000 cubic yards of earth were moved, and over 300,000 cubic yards of concrete were poured.[84]

The canyon buildings are monumental, reinforced-concrete narrow rectangular structures eight times longer than they are wide. They are four stories in height. The SRP examples owe much of their design to Hanford's canyon buildings called "Queen Marys,"

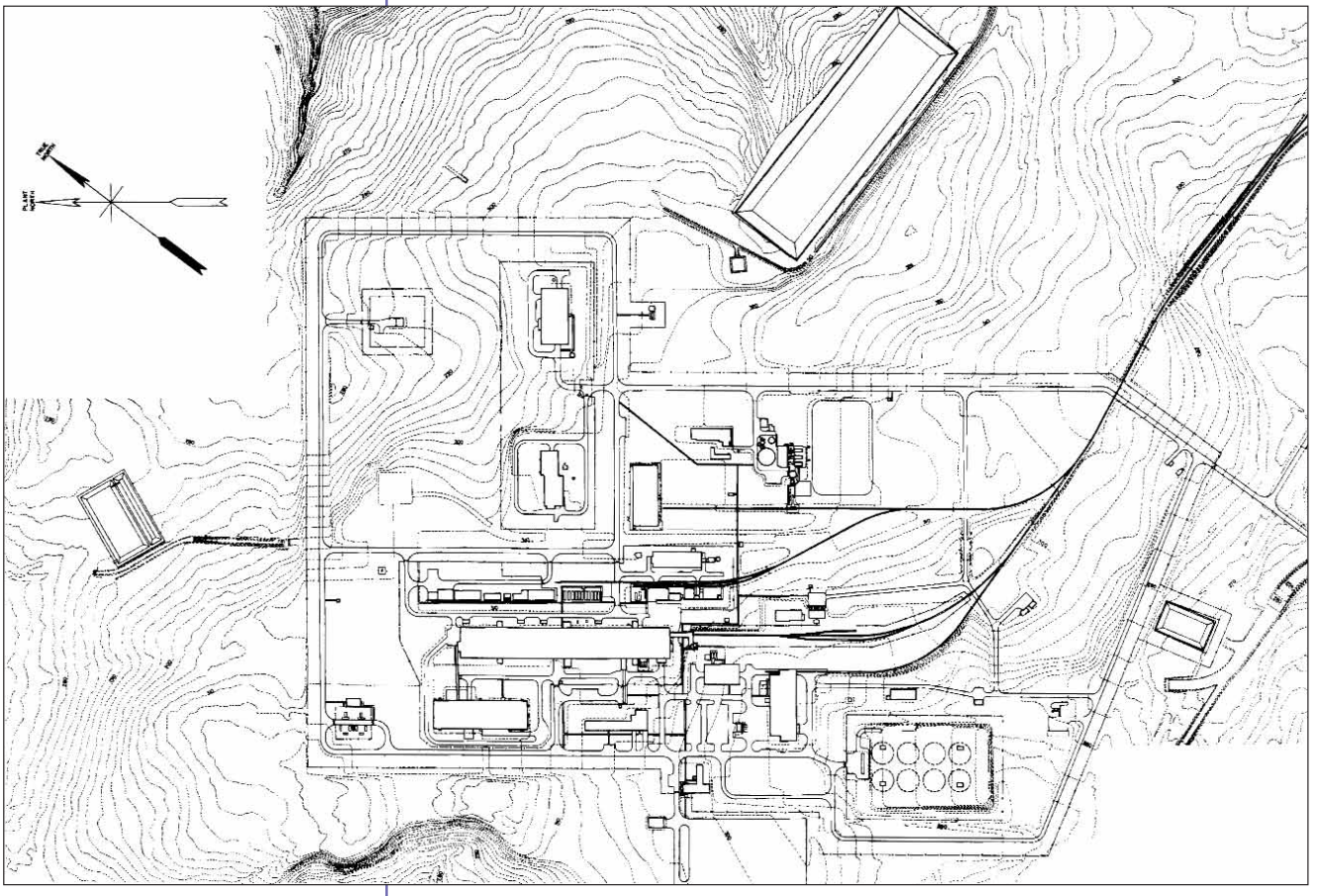
This map shows F Area in 1957 and its linkage to the site railroad which transported irradiated materials to the cargo bay at the south end of the canyon. Personnel buildings were situated to the west of the canyon, power facilities to the southeast. The original tritium facility, a second manufacturing facility, the storage facility for the finished product, were situated in a separate area east of the canyon. The waste tank farm was located southwest of the canyon. Source: Basic Information Maps, 200-F Area, 1956.

200 AREA

and to the first separations building constructed at ORNL. Savannah River canyons are divided into 16 midsections of equal lengths while the sections on both ends are longer to accommodate receiving and shipping.

Inside the building, there are two interior "canyons," stretching the length of the building. The various separation processes took place within these interior canyons. The hot canyon is on one side and materials entered it by railcars; the warm canyon is along the opposite wall. The Purex process called for dissolvers, tanks, evaporators, and mixer-settlers. The liquids were moved from section to section by piping that allowed liquids to flow between equipment elements. Each section of the hot canyon was built as a dimensional duplicate so that equipment could be easily and remotely replaced by crane. Between the canyons is a multistory hall that housed remote handling equipment, a personnel corridor, control room, piping, pumps, etc. The railroad tunnel is located on the south end of the canyon; a shielding door large enough to allow a rail car entry is located at the railroad tunnel entrance.

The canyon buildings were built to house equipment and processes involved in the Purex process, the B-Line, offices, change rooms, and other personnel service rooms. Uranium, plutonium, and fission products were separated to produce plutonium metal buttons and a decontaminated uranyl nitrate solution, which was accomplished by processing equipment in the hot and warm canyons, which were controlled from the first-story central



Courtesy of SRS Archives. Storage Building, negative 2-481-11. Canyon, negative 3771-60. Metallurgical Building, negative 2-364-9. Tritium, negative 2-650-4. Powerhouse, negative 2-509-8. Patrol House, negative 2-228-7. Administration, negative 2-428-6. Fire Station, negative 2-392-8. Shop and Mockup Building, negative 2-234-12. Laundry, negative 2-223-7. Laboratory, negative 2-607-10.



Storage Building



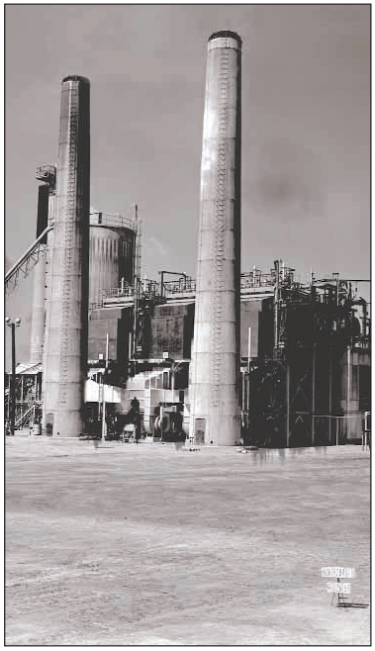
Canyon



Metallurgical Building



Tritium



Powerhouse



Patrol House



Administration



Fire Station



Shop and Mockup Building



Laundry

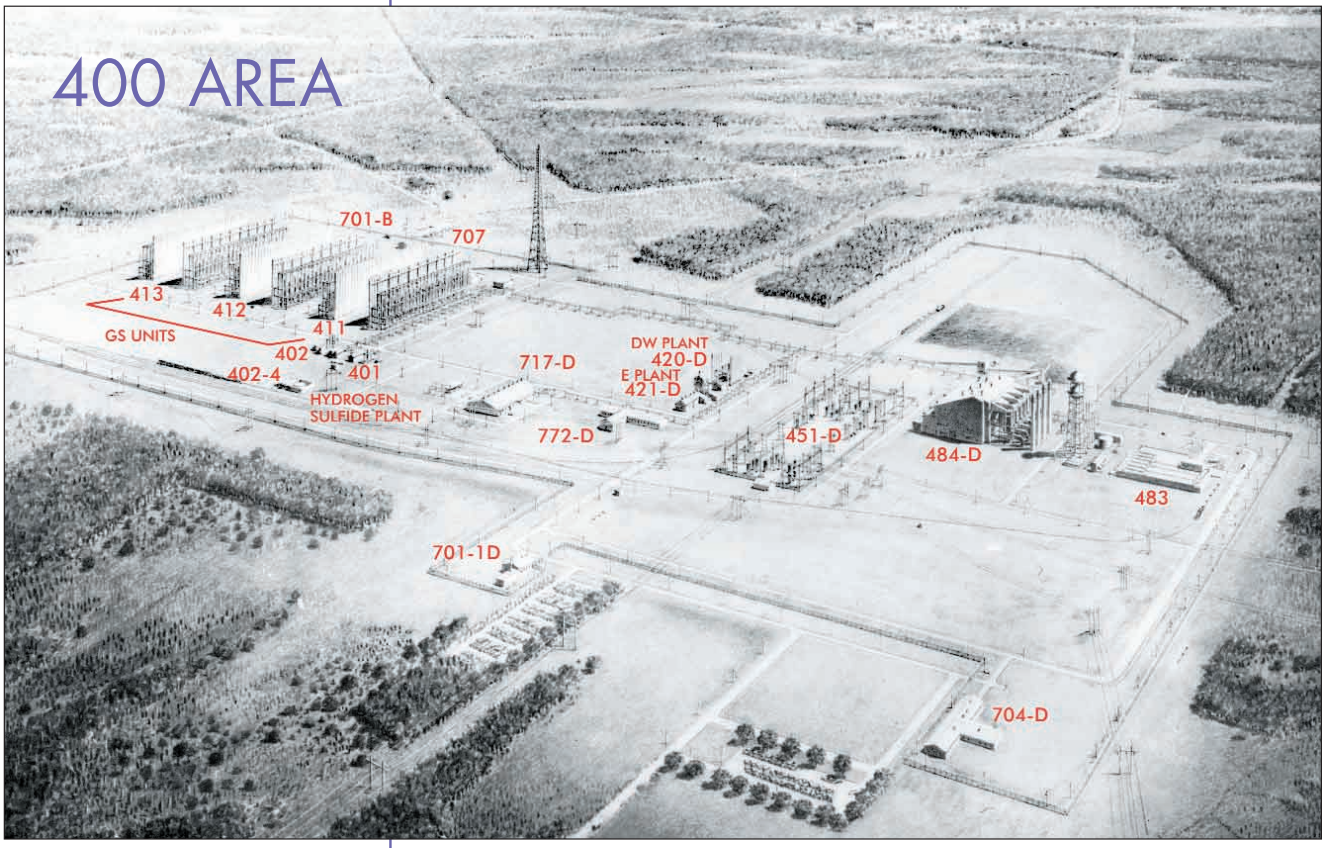


Laboratory

hall. The most highly radioactive steps within the processes were handled in the hot canyon, those of lesser intensity were handled in the warm canyon. Two cranes remotely handled the mechanical operations. Telescopic vision was used initially only on the hot canyon side; direct vision in the warm canyon. The B-Line was a production facility that concentrated plutonium nitrate and reduced it to metal. This was a separate process housed in F Canyon on the third to fourth levels of sections 1 through 4.

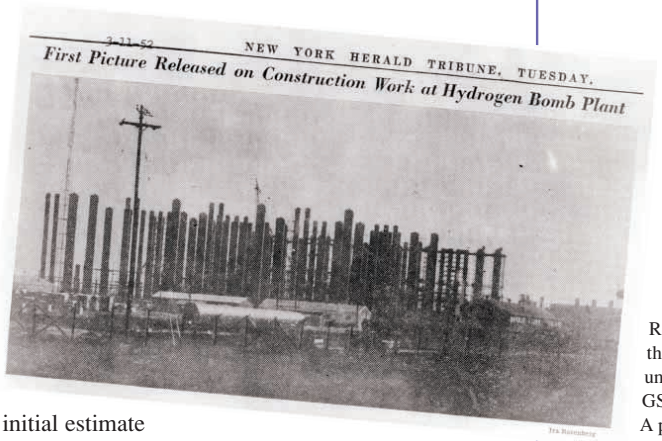
F Canyon was completed first. The plutonium finishing and storage facility, or B-Line, was later placed within a linear enclosed metal structure on F Canyon's roof in the late 1950s. Like the reactor areas, a number of support buildings were constructed at the 200 Areas: sand filters, substations, monitoring houses, chemical feed buildings, basins, power houses, cooling towers, a fan house, gatehouses, administration buildings, storage, a laundry, and a firehouse. F Area originally contained four process buildings and was built to be self-sufficient. H Area did not contain the same complement of process buildings but space was allotted for its future expansion.

Steel tanks were used to store radioactive waste. Tanks were made of mild, carbon steel, and not stainless steel. Consequently, the acidic waste stream had to be treated with alkali to avoid serious tank erosion. Grouped in farms in the separations areas, the tanks were large welded units with internal supports encased in concrete and placed in a steel saucer covered by nine feet of earth. Separate tanks were designed for high-and low-level wastes. Solid wastes were buried in a "burial ground."



Bird's eye view drawing of the 400 Area created by Voorhees, Walker, Foley & Smith in 1953. Building numbers added to original. The architectural rendering shows the GS units and flare tower located at the eastern end of the building area. The hydrogen sulfide plant was located by the GS units while the DW and E processes were housed in buildings 420-D and 421-D. The massive powerhouse, substation, and ancillary facilities were grouped at the western end with the laboratory, rework and storage facilities, and shop in the center. Savannah River 400 Area, No. 14, Env. 14 Courtesy of the Hagley Museum and Library.

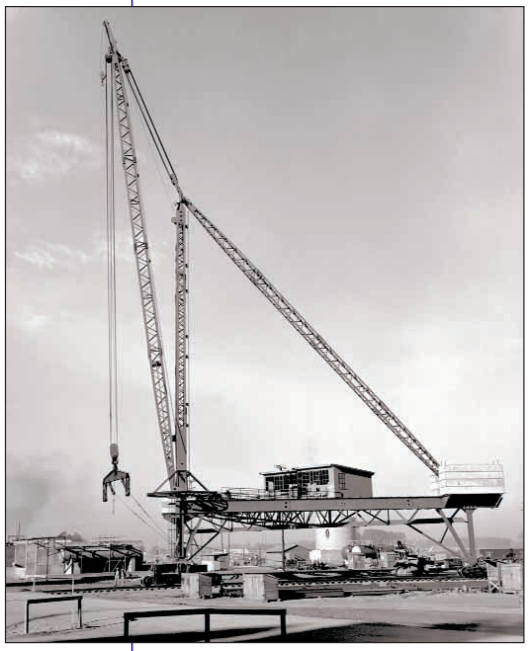
400 AREA AND DANA


3-11-52 NEW YORK HERALD TRIBUNE, TUESDAY,

First Picture Released on Construction Work at Hydrogen Bomb Plant

Reminiscent of an oil refinery in their appearance, the 144 tower units (411, 412, and 413) used in the GS process were 120 feet in height. A photograph taken of them and their control buildings from a window of an Atlantic Coast Line train en route to Augusta made news as "the first picture of actual construction" at the "top secret plant" in the *New York Herald Tribune* on March 11, 1952. Courtesy of SRS Archives, negative 653-1.

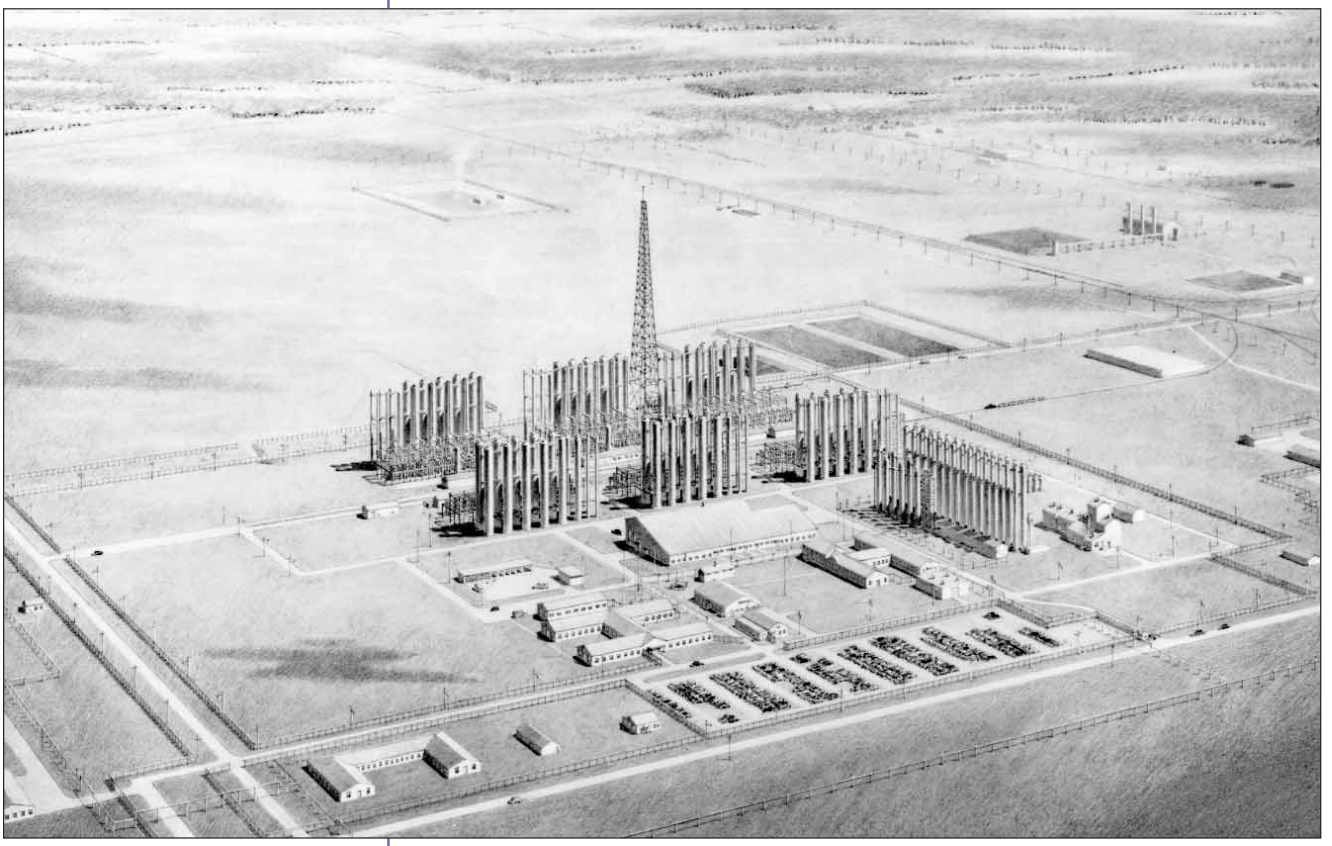
The Dana Plant, or Project 8987, at the Wabash River Ordnance Works in Indiana contained a pilot plant for the dual-temperature process and a supporting laboratory facility for heavy-water production. The Girdler Company of Louisville, Kentucky, handled the design work on a contract that predated the Du Pont contract for the Savannah River Plant. The initial estimate of heavy water needed for SRP reactors was increased when the program was expanded from two to five reactors. The Dana Plant's heavy-water production capacity, built to handle the needs of two heavy-water reactors, was not equal to the task. A second plant was immediately deemed necessary and that plant became SRP's 400 Area. Construction on the 400 Area received top construction priority at the South Carolina project site. Without heavy water, the reactors could not operate. Du Pont shifted gears, and responded to this critical change in scope by hiring the Lummus Company to design the South Carolina heavy-water production facilities. The Lummus Company's learning curve was cut considerably by Du Pont's hiring of staff from the Girdler Company as consultants. Du Pont's designers and the Lummus team pulled extensively from the information that the Girdler representatives provided on the design and operation of the Dana Plant. Particular attention was given to corrosion problems, and two-thirds of the GS towers mounted at SRP had stainless steel rather than carbon steel liners.[85]



This 200- ton machine, known as a stiff-legged derrick, enabled the D Area construction force to lift the GS towers from the railcar and set them on their foundations with unprecedented speed and assembly line precision. Courtesy of SRS Archives, negative M-477.

The 400 or D Area, located near the Savannah River's southwest perimeter approximately 1 mile from the river, housed heavy-water production units (GS units) and support buildings. There were 144 tower units, each 120 feet in height, ranging in diameter from 6.5 to 12 feet. These towers were sent to the plant from various shops completely fabricated via heavy-duty railroad flat cars. The use of a 200-ton stiff-legged derrick to erect these large towers, which were specially fabricated for the job, was a showstopper. The derrick, placed on parallel railroad tracks laid along the ends of and between the legs of the tower, would lift a tower from a car and set it on its foundation. Bebbington states that in one demonstration a tower was erected in six minutes. It was so successful that the erection of the GS units was completed in almost assembly-line style, allowing early operation of each unit as soon as it was completed and the prefabricated piping made in Central Shops was attached. Heralded as a timesaving device, the derrick, created by the vendor, was featured in *Engineering News Record* and in equipment magazines. Gin poles and crawler cranes were used to erect Dana's ninety-six 128-foot-high towers. Like their Savannah River counterparts, Dana's construction force worked faster as the construction of the towers proceeded. The Dana construction history notes that the first tower took five hours while later towers were placed on their foundations in 30 minutes.[86]

The GS units at Savannah River were known as Buildings 411-D, 412-D, and 413-D. The GS towers described above rest on octagonal reinforced concrete pedestals. A control house, substations, breathing stations, maintenance shelter, and an analyzer house complete the facility. The 375 feet high steel flare tower, constructed to burn emergency discharges and routine leakage of H_2S, was situated south of the GS units. While the distinctive GS units and flare tower which could be seen from outside the site boundaries were the visual image that most area residents connected with SRP, other facilities were present. A concentrator for the DW process (420-D), the second step in the heavy water production process was built with twelve distillation towers and support buildings. The towers ranged in height from 78 to 92 feet in height and between 4 and 6 feet in diameter. The finishing of the heavy water took place in 421-D, a multi-level steel frame building that housed the E process equipment. The E process further increased the concentration of plant's heavy water output. Two cylinder-loading buildings were involved in the final finishing and storage of the heavy water. Other area facilities include gatehouses and patrol headquarters, a supervisor's office and first aid building, change house, fire house, and a control laboratory and supervisor's office. A river pumphouse supplied water to 400 Area while steam and electricity was furnished by the plant's largest powerhouse, 484-D. At the time of construction this was the largest powerhouse constructed by Du Pont. It was outfitted with a coal-handling system that could handle 350 tons per hour.



Birds Eye View of Dana Plant, Dana, Indiana. Dana had a more compact layout with the flare tower placed between the GS units. Savannah River, Dana Area, Env. 22. Courtesy of the Hagley Museum and Library.

The Dana Plant was very similar to Savannah River's D Area in its physical organization, particularly in its process area. Dana was composed of six subareas:100, 200, 300, 400, 500, and 600 areas. The 100 area was devoted to auxiliary facilities for the storage of raw materials and generators. Its 200 or production area consisted of six GS units, instrument and switch buildings, mass spectrometer buildings, weigh tank buildings, a flare tower, pilot plant, concentrator building, and an air sampling system. The 300 or finishing and storage area had two buildings: the "E" process finishing building and a storage facility for heavy water. Power-generation facilities comprised the 400 area, electrical lines the 500 area, and the 600 area was composed of general facilities.[87]



River pumphouse supplied river water to D Area. Courtesy of SRS Archives negative 3178-5.

300 AREA

The 300 Area, a linear group of manufacturing buildings, was situated near the northwest perimeter of the plant, where it was integrated into the adjoining 700 Area. The two areas were joined in a U-shaped configuration. M Area contained testing and fabrication facilities for reactor fuel and targets. Across the plant, the buildings and the installed equipment in this area most resembled a commercial industrial plant. These box-like

Building Models

Following an industrial design practice established by Du Pont, three-dimensional models of manufacturing or process buildings were fabricated. Du Pont chose to use building models as an important design source in addition to blueprints in the 1940s. Showing venting, piping and other interior details, these built-to-scale detailed models helped to troubleshoot design and acted as reference guides for future modifications. They could also be used later as explanatory tools to introduce visitors to the plant and its processes. Prior to 1969, all models were constructed in Wilmington. The Savannah River Laboratory's Services Model Shop produced models for Site facilities under the direction of Ray Hale after that date. The Site's inventory of building models shows the transition in model building materials from wood and wire typically used on the first building models to plastic components and miniature parts that allowed the later SRP's model engineer greater design freedom.

Source: "SRL Model Shop No 'Kids' Play," *Savannah River Plant News*, August 14, 1979.



Model of the Heavy Water Components Test Reactor built in Wilmington prior to start of its construction at the site in B Area in 1959. Courtesy of SRS Archives, negative 7081-1.

buildings, both one story and multi-level, are Transite™ and steel frame structures designed to handle initial manufacturing needs and to allow for expansion. Most of the 300 area equipment was produced and acquired offsite, then shipped to the plant, for installation.

300 AREA

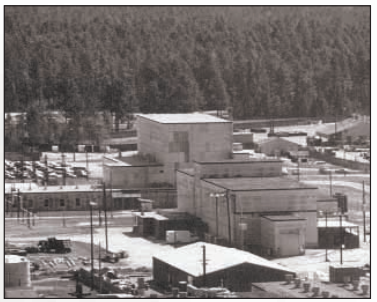
Test Pile, negative 3-205-6. Alloy Building, negative 3-186-7. Physics Laboratory, no negative number. Office and Change House, negative 3-199-6. Manufacturing Building, no negative number. Canning and Storage, negative 3-185-8.



Test Pile



Alloy Building



Physic's Laboratory



Office and Change House



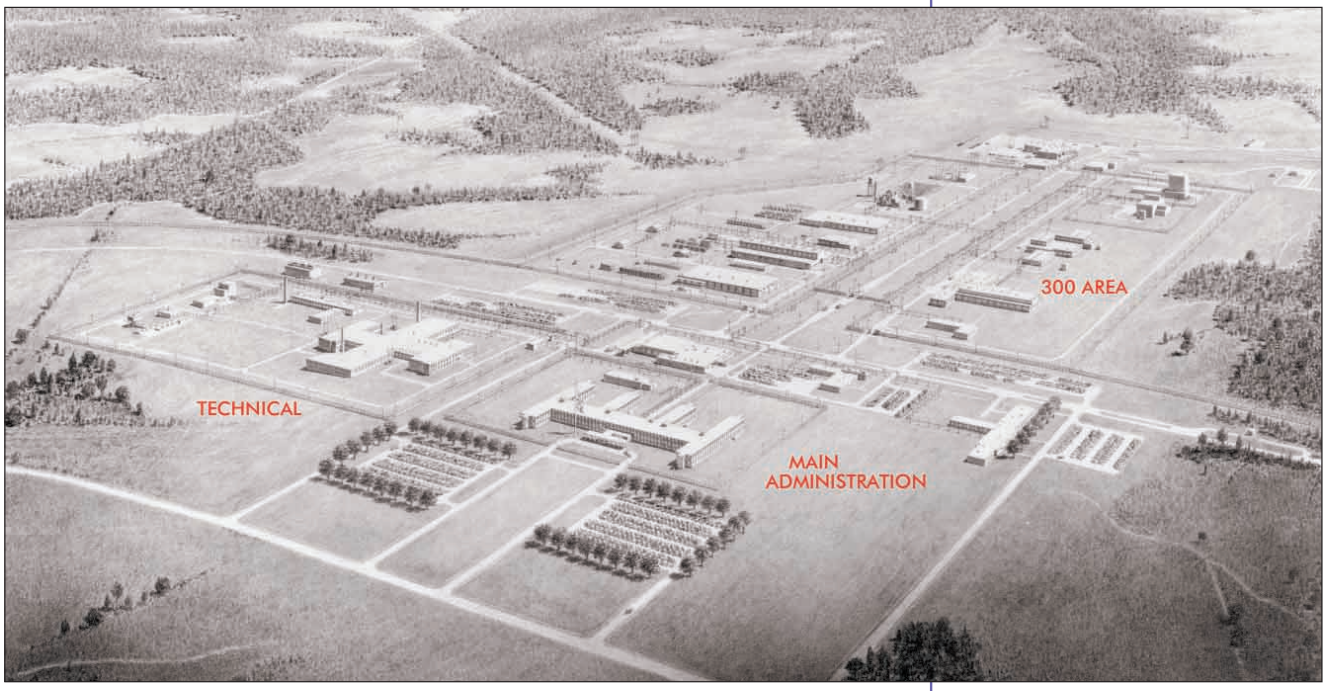
Manufacturing Building



Canning and Storage

Two buildings, Test Pile and the Physics Laboratory, originally contained test reactors that were used to test the components manufactured in the 300 Area and to aid development and testing for SRP reactor design. Both buildings are irregular in shape and were constructed of reinforced concrete and Transite™. The test reactor in the Test Pile

Building was a graphite reactor; 200 tons of graphite blocks machined at Hanford were used in its construction. The Physics Laboratory contained three test reactors as well as a laboratory wing. The 300 or M Area included a canning and storage building for uranium and other slug types, an alloy building in which reactor control rods and blanket rods were manufactured, a large manufacturing building which housed an extrusion press and other process areas, a metallurgical laboratory, substations, a tank farm, gatehouses at both ends of the area, and an area administration and change house. Some of these facilities were added to the 300 Area after 1955 when experiments on the design and fabrication of fuels yielded data on a new fuel element that, if used, would remove previous limitations on the plant's reactor power levels.

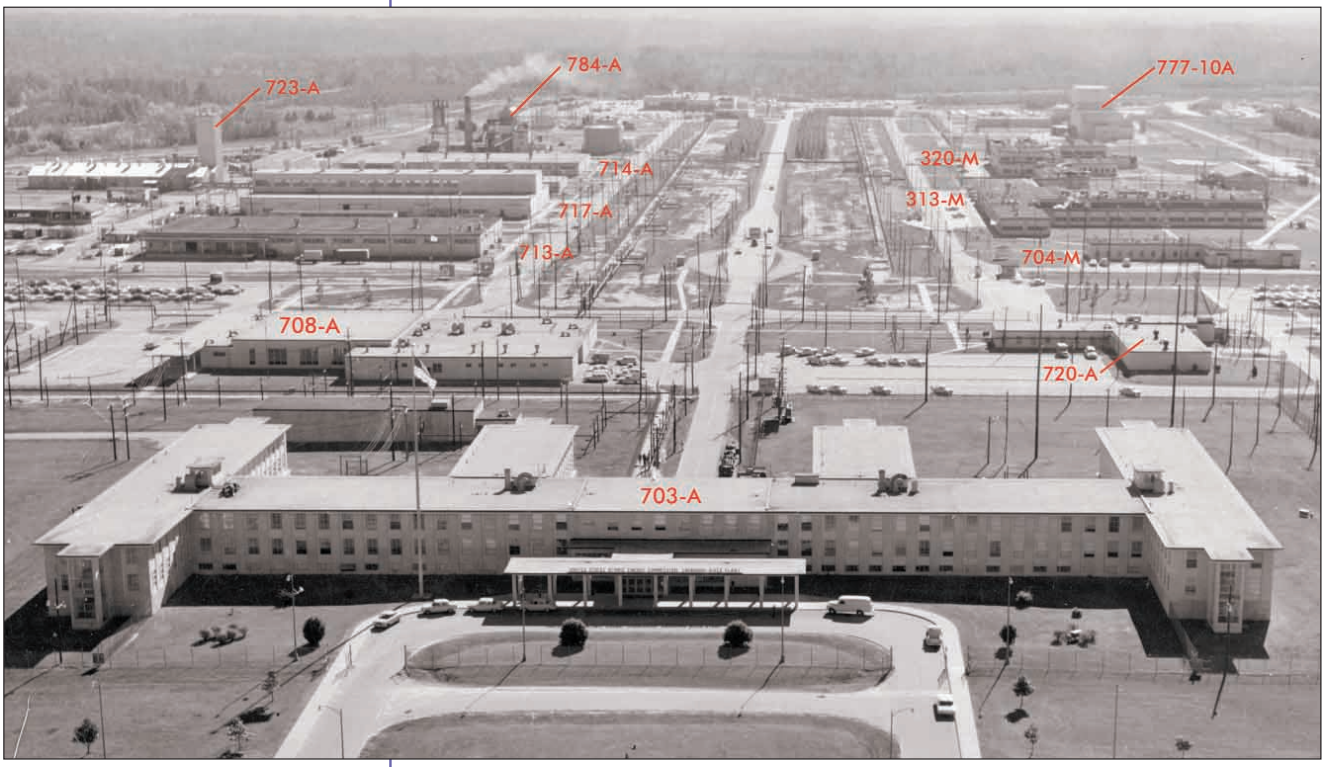


The 300 (manufacturing) Area and the 700 (administrative) Area were joined in a U-shape layout that was military in its configuration. The 300 or M Area buildings were placed in straightforward fashion along Road D in a line. Road D, which leads into the plant, ends at the rear of 703-A, the main administration building. 700 Area support buildings were aligned on the opposite Road D frontage. Administration buildings, including the laboratory area were placed at the base of the U. Expansion for both areas would occur on the outer perimeter of the original U in which the original buildings are situated. Savannah River Building No. 300/700 Env. 30. Courtesy of the Hagley Museum and Library.

700 AREA

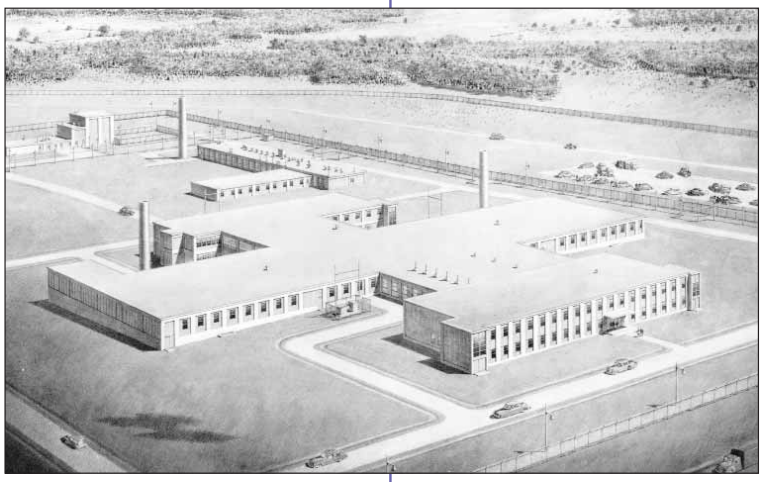
The 700 Area was Savannah River Plant's administrative and "service" center. It contained the main administration building, the medical facility, fire station, communications facilities, patrol headquarters as well as a variety of maintenance, stores, and storage buildings. 700 Area's placement at the plant's northwest perimeter appears to have been deliberate, providing a public face for the Site. Laid out in a U-shaped configuration, the 700 Area is dominated by the monumental main administration building, an imposing two-story building with clerestory towers and four rear wings. The architectural style of both process and non- process buildings was dictated by the AEC, which called for Spartan simplicity in design. The 700 Area reflects this ethic with its simple Transite™ flat-roofed buildings in which form follows function. Behind the administration building, the remaining 700 Area buildings devoted to support functions including stores, warehouse,

facilities, a fire station and transportation buildings, and the 300 Area buildings, already described, line Road D which leads to the heart of the plant, the production area.



Aerial view of 300/700 areas circa 1959 with building numbers shown. Administration Building 703-A's design was simply executed in a modern functional style. Courtesy of SRS Archives, negative 7885-3.

A Area also contains the plant laboratory located to the east of the main administration building in the "technical area." 773-A, the main building of the Savannah River Laboratory, in which plant processes were planned, researched, designed, and tested, and other research facilities are situated in this locale. The main laboratory, designed by laboratory designers Voorhees, Walker, Foley & Smith is a multi-wing, multi-level building covered by a flat roof which has been enlarged over time. Support structures are laid out in a large rectangle of buildings that range from sand filters to ancillary laboratories, chemical feed buildings, a cooling tower, storage and gatehouses.

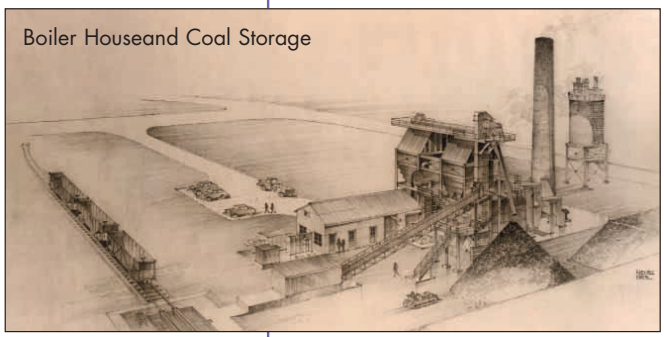


Architectural drawing for Savannah River Laboratory by Voorhees, Walker, Foley & Smith. Savannah River Building No. 773-A. Env. 29. Courtesy of the Hagley Museum and Library.

CMX AND TNX

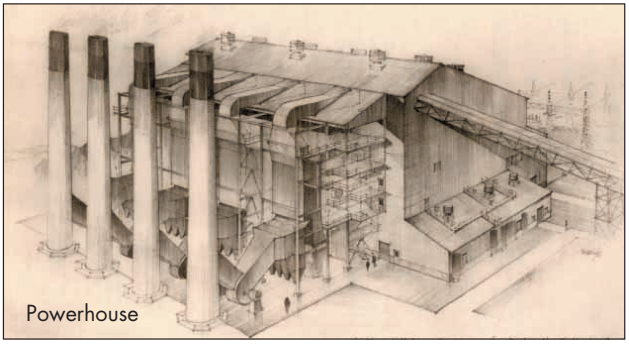
Two research facilities, code named CMX and TNX, were located near the 400 Area. These research facilities, the first completed, were housed in large metal prefabricated buildings. CMX initially housed

reactor-related research into the use of Savannah River water for reactor cooling. CMX provided the project one of its many success stories. Laboratory tests run there to evaluate the effect of muddy river water on the performance of heat exchangers established that there was no impact. This allowed Du Pont to eliminate expensive flocculation and filtration facilities that were constructed in the R Area (183-R) at four of the five reactor areas. As that problem was solved, the facility was used to test new types of fuels and assemblies. TNX was a pilot plant for separation processes, complete with technical development facilities.[88]


Boiler Houseand Coal Storage

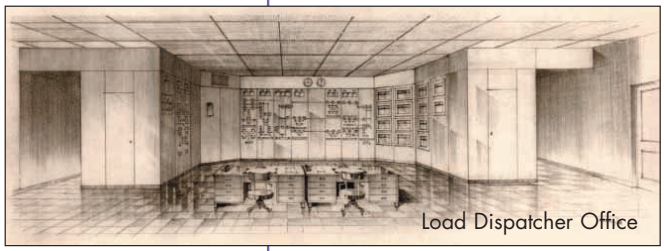
POWER GENERATION

Purchased electrical power was initially preferred over site-generated power. Negotiations with South Carolina Electric & Gas Co. and the Southeastern Power Authority (SEPA) had been ongoing. The latter controlled the distribution of electrical power from Clarks Hill Dam, under construction, and Congressional approval was needed to construct a transmission line from the dam to the site. As the scope of work developed, the need for reliable electricity sources heightened. The addition of the 400 Area to the project called for an immediate power source; no production reactor at SRP would go into production without heavy water, and the 400 Area had been given top priority. Timing did not allow for purchased power and, as a consequence, the 400 Area received its own powerhouse. Other areas were studied to evaluate overall electrical requirements, and the result was a mix of site-generated and purchased power systems running off a central transmission line.[89]


Powerhouse

When constructed, nine coal-burning powerhouses located in building areas supplied steam to the process areas and the overall site. The large pipes that carried the steam were placed above ground, arching over roadways where necessary and paralleling the road system. Outside the manufacturing and service-building areas, general facilities needed for either process support or general site support included the three river-water pumphouses mentioned above and a railroad classification yard.

Gibbs and Hill Engineers-Contractors of New York and Los Angeles were responsible for the site's electric, power, water supply and treatment facilities. Their historical summary of their work for the site is illustrated with colorized line drawings of each of the building/facility types from switchyards to the river pumphouses they designed for SRP. (Above) Boiler House and Coal Storage. (Left) The D Area powerhouse was the largest of nine built at the site. View from switchyard. (Below) Interior view of Load Dispatcher Office and Supervisor's Control Board. All electrical power for the site was controlled through this office. Source: Gibbs & Hill Inc., *Savannah River Plant Engineering and Design History*, Subcontractor for Engineering Department E. I. du Pont de Nemours & Co. Inc. (Five volumes), 1954.


Load Dispatcher Office

MILITARY DEFENSE PROGRAM

Sabotage, defense against possible bombing, and entry from the air was guarded against by extensive antiaircraft emplacements, constructed at several locations around the

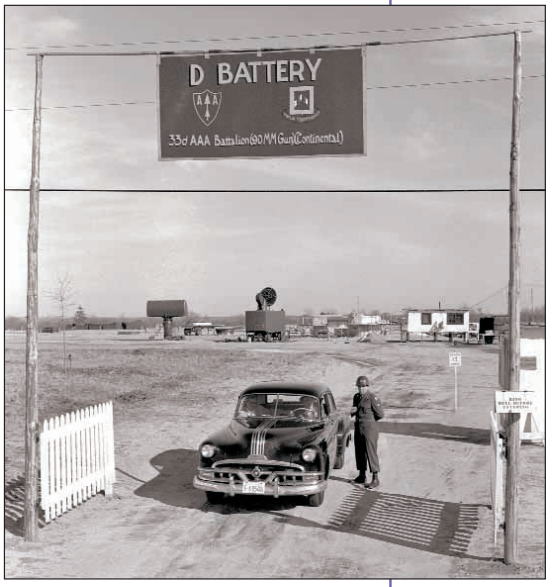
installation and operated by Army troops. Between 1955 and 1959, three antiaircraft (AAA) battalions—the 33rd, 425th, and 478th—of the Army's Antiaircraft Artillery Command's (ARAACOM) 11th Antiaircraft Group protected the Site from air attack.[90] These battalions included 90 officers and 1,023 enlisted personnel.[91]



View of 90-millimeter gun placed on the site for its defense. The gun bears the battalion crest and motto, "Virgilia Triumphamus" (In Vigilance We Shall Triumph). Gun crewman on platform: Corporal Leroy Strain, Ashland City, Tennessee, PFC Rafael De Larosa, Rock Spring, Texas, PFC Oscar McGowan Dallas, Texas, PFC Ernest Guillot, Winnsboro, Louisiana, and, in background, gun commander Sergeant Robert Richardson, Brooklyn, NY. Courtesy of SRS Archives, negative DPSPF–2718-6.

ARAACOM had responsibility for operational planning of the nation's anti-aircraft defenses in 1950 and was charged with defending the nation's Air Force bases of the Strategic Air Command (SAC) and the locks at Sault Sainte Marie, Michigan. The 90-mm battalion was the most common of the units with the ARAACOM, typically placed around urban areas including New York City, Washington, Baltimore, Chicago, Pittsburgh, etc. They were also deployed to protect other sites necessary to the nation's defense such as SRP.[92]

The Engineering Department's Construction History notes that Du Pont's scope of work was enlarged to include the construction of thirty 75-mm and eight 90-mm anti-aircraft gun sites for two lines of defense—the so-called Inner and Outer Rings of Defense—and support facilities for the troops that would be stationed onsite.[93] The two rings of defense were strategically placed so that the guns would be able to hit and destroy incoming aircraft before they could reach the production facilities. They were aligned in two parallel arcs surrounding the production areas.



Entry to the 33rd AAA Battalion's D Battery, one of four on site. Courtesy of SRS Archives, negative M4085-4.

Four 90-mm gun sites were completed by April 1956 and thirteen 75-mm gun sites were under construction by September of the same year. The 90-mm gun sites were designed to house 120 men in concrete barracks. A mess hall, administration building, command post, motor pool area, and gun pads completed this type. The 33rd AAA Battalion with four batteries, four guns to a battery, were the first to arrive in 1955, serving until 1957. This unit was outfitted with 90-mm guns that were controlled by a fire-control system based on air-to-ground radar and tracking radar linked to a computer. Essentially, the radar would identify incoming targets and the computer would generate the needed data to position the guns to destroy the targets. The 425th and 478th AAA Battalions, equipped with 75-mm "Skysweeper" guns, followed the 33rd battalion.[94]

The 75-mm gun sites were to include prefabricated temporary housing for 3 to 11 men and gun revetments. The TC Area was set aside for refurbishment into a military enclave. One of the star-shaped buildings (TC-2) used during construction was renovated for housing and office space for military personnel, and an Antiaircraft Operations Center was built along with additional support buildings. As a cost-saving measure, a number of temporary buildings were readapted for military use.

The historical record does not show that SRP was ever threatened by an air attack, so the guns were not used. Also, antiaircraft guns were considered an interim weapons system that would be replaced in the late 1950s by Nike antiaircraft missiles. The expense of upgrading the Site's defenses was weighed against the potential threat of attack, and the

Department of Defense opted to cancel the program. The two Skysweeper units at SRP were then disbanded.[95] Further construction related to the military program was canceled in 1957. Excess construction materials were transferred to Fort Gordon's Post Engineer, and work on the remaining gun sites within the Outer Ring of Defense was never completed. The Army discontinued use of the onsite facilities in 1960, and SRP management found new uses for the military buildings it had constructed.

The threat of air attack was in retrospect more perceived than real. The site-selection committee had done a thorough job, eliminating the chance of a military attack by virtue of the plant's geography. However, the installation of military units at the fledgling production site underscores its importance to the nation and brings into relief the tension and warlike atmosphere under which the site was constructed.



The last batch of concrete mixed by Kolinski Concrete Company, a firm under subcontract to Du Pont, occurred on December 31, 1954 at 221-H. On hand for the event were from left to right, M. J. Knopf, contracts supervisor; P. J. Masciocchi, assistant engineering office superintendent; R. M. Bigger, chief inspector, Contracts; B. W. Lewallen, Contracts; J. F. Coker, Kolinski superintendent at Savannah River; and W. C. Kidd, concrete control inspector for Pittsburgh Testing Laboratories. The truck driver on the far side is L. Prosser. During the three years the Kolinski firm worked at the site, it was reported that it batched 1,470,401 cubic yards sufficient concrete "to build a modern highway from SRP to Key West." At the close of the Kolinski subcontract, future concrete mixing at the site was handled by Du Pont. Courtesy of SRS Archives, negative 3745-8.

PROJECT CLOSES

The Savannah River Project lasted for five years. By the close of 1955, all areas were in operation. Seventy-five percent of the overall construction occurred in 1952 and 1953 during the 54-hour work-week phase when the construction force was at it's peak.[96] The plant was considered essentially complete by January 1, 1956, at a total cost of $1,065,500,500. The Dana Plant, or Project 8987, was also complete by 1956. Curtis Nelson passed control of the new plant over to Robert Blair, ending his five years at Savannah River. He moved on to Washington, where he became the first Director of the Atomic Energy Commission's Inspection Division, a division newly created under the Atomic Energy Act of 1954. Du Pont's Field Project Manager, Bob Mason, would also take his leave in 1955 with the close of construction, heading back to the Wilmington area. Don Miller would steer the plant during startup and first operations. Both Nelson and Mason would be invited back on numerous occasions to celebrate their accomplishments as the plant went into operation.



(Inset) Entry sign prior to closing of site area on December 14, 1952. Courtesy of SRS Archives, negative 6709-1.

At project's end, the plant area was transformed and a new identity rooted. This new identity became a force of change that spilled past the plant perimeter and into its surrounds. Savannah River's "one mighty force" needed to be housed, their children educated, and the community's needs met. This construction force came with families. The town of New Ellenton was born and Aiken, Augusta, North Augusta, Williston, and Barnwell begin periods of vigorous expansion and change. The area's politics and economy would shift as South Carolinians and residents of the CSRA eagerly adopted science and atomic energy as the way of their future.

10 Transformations

Final stop for Train No. 50 at the Ellenton, SC, station, April 12, 1952. Atlantic Coastline Conductor J. Bratney and Porter Mon Curry were joined by Du Pont Construction Division's C. L. Watts, Traffic Supervisor and R. J. Snapp, Jr., Traffic Superintendent for this historic view. Passenger train stops were eliminated at points within the plant area and the Jackson, SC, station was used solely for employees and visitors traveling to the Savannah River Plant. Courtesy of SRS Archives, negative M-741-1.



The 1952 photograph, "Final Stop for Train No. 50," taken at Ellenton's depot, is deeply moving. Men in hardhats and ties, symbolizing the new, stand beside the uniformed Atlantic Coast Line railroad men, who dominate the photograph as icons of the past—Ellenton's and that of the railroad itself. Despite the vigor of their pose and the drama of the locomotive behind them, the railroad men became part of history.

This transformation was one of many that would occur in the 1950s in the CSRA. Some changes were immediate, others less so, as the area began to expand with newcomers, new schools were constructed to handle the influx of children, neighborhoods and communities were established, and service industries burgeoned. Politics changed as Lester Moody predicted. The "new people" brought different attitudes to the CSRA, and many were involved in establishing the Republican Party in Aiken County and helping to make political change on the other side of the river. Historian Jim Farmer suggests there was a collision of cultures in the 1950s as the incoming "forces" began to square off with the area residents. While the initial impact of the collision may have been difficult, the newcomers were atomic homesteaders who came with their families and were eager to set down roots. Through extensive public relations work, involvement in community programs and in atomic energy education, the AEC and Du Pont strove to make themselves, the plant, and its employees working members of their new community. Biographical details of the plant's managers show a keen interest in all aspects of community life, from work with the area's boards of education to the Knights of Columbus. Individually, plant families joined area churches; embraced community service, golfed, shopped, played Little League, and generally became part of the social scene. The AEC's decision not to create a government town was a success story at Savannah River.

A larger transformation also occurred that was inspired by South Carolina's aspirations toward industrialization and technology, the political astuteness of the state and

region's political leadership, and the positive force of atomic energy development nationally in the 1950s and 1960s, which promoted nuclear energy's peaceful uses. The concentration of engineers and scientists in the CSRA encouraged the establishment of local branches of national professional associations, academic programs at area colleges, and science fairs for high school students. No longer solely known for its textile mills, South Carolina was on the cutting edge of a new industry. The Savannah River Plant was perceived as the vanguard of future atomic energy development for the state and region, and similar projects would follow if a concerted effort by individuals of influence could be launched. Also, solidarity was needed to guard state authority against total Federal control over the developing industry, particularly in the areas of public health and safety. The outcomes of this effort included the Southern Interstate Nuclear Board and a compact among Southern states on the development of the nuclear and space industries within the region.

IMMEDIATE IMPACTS

The decision to rely on local communities and private enterprise for the essential housing and community services for the Savannah River Project was a major step for the AEC. Initially, their hands-off policy seemed a neat solution, allowing them to concentrate on building the production facility rather than dealing with the construction and administration of a government town, and with all the problems in such a town. Its stated policy was to estimate the projected workforce and its character for local community leaders, so that they could plan for housing and for providing services. The AEC would also call for help from sister Federal agencies that specialized in housing and in developing funding for community services in defense areas. The AEC would then provide data from past AEC installation experience, cooperate, and informally expedite the "program."[1]

While this policy sounded practical, the "program," without any central authority to orchestrate it, wasn't really a program. The AEC began taking the heat for the housing situation early in 1951. An exasperated AEC staff member wrote, "The hard fact (is) that in the minds of the people of this area, the AEC is responsible for the whole impact of this Project. It is to the AEC that these communities look for action, and it is the AEC that has been, to date, the recipient of the 'gripes' and criticisms that arise. To them, the AEC is the government, so far as this Project and its impact are concerned."[2] To be successful, the

"Fellows Pouring In From Every State"

Mrs. Mattie Hall, an antique dealer in Aiken, believes that the mere arrival of the construction workers from other parts of the country has had as reassuring effect on the population as the government's carefully worded statements. "At first, everybody wanted to run away," she told me. "Then we saw these fellows pouring in from every state and we changed our minds. We decided that living here couldn't really be so dangerous if all these men were coming in with their families. Maybe they won't stay on when the plant is built and starts to operate, but it doesn't seem likely they'd have brought their families with them unless they planned to stay. By now we've convinced ourselves that the plant's going to be protected all day long by Air Force planes and that we'll all be terribly safe."

Source: Daniel Lang, *The New Yorker*, "Camellias to Bombs," July 7, 1951.



Views of license plates of cars parked in an Augusta store lot, November, 1951. Source: *Business Week*, "New Atomic Bomb Plant Hits Augusta with a Bang," November 10, 1951.

program called for a coalition between Du Pont, the Federal Housing Administration (FHA), Housing and Home Finance Agency (HHFA), private builders, and local planning agencies to provide the needed housing and services. Such a coalition was not occurring naturally, so the AEC, trying to move forward, recommended that Du Pont take the lead. The contractor was asked to estimate the project's impact on the plant communities; these estimates were to be based on manpower requirements for building the plant and for later operating the plant.

The Government Hates Government Towns

In an article published in *The New Yorker*, Arthur Tackman, an AEC spokesperson, explained the drawbacks in building and maintaining a government town.



"They had to be built because everything was so secret during the war, but in general the government hates government towns," Tackman said. A government town, he went on, has to start from scratch, and entails the great expense of houses, churches, schools, streets, and police, and fire forces, and there are so many headaches connected with running a town of that sort that the officials in charge are apt to be distracted from their main job of turning out weapons. "You paint somebody's house first and everybody else starts squawking," Tackman said. "Some people want Venetian blinds, others won't stand them. And everybody has the same landlord—the government itself—and the government gets kicked around enough even when it's not a landlord. Also we don't think it's a good idea for people who work together to have to live together. You might work all day alongside someone you didn't like and then have him as a neighbor at night. And a man who loses his job in a government town loses much more than that. He has to get off the reservation in thirty days, and that means losing his home, his wife loses her social circle, his kids lose their school. Besides Americans just don't like to live in government towns. It makes them feel deprived of some of their independence, and that's not solely because they don't have any municipal elections to vote in. It's an intangible thing. I don't believe Americans are even keen about living in enormously privately owned housing projects."

Source: Daniel Lang, *The New Yorker*, "Camellias to Bombs," July 7, 1951.

Children playing in front of community housing at Oak Ridge, circa 1944. The AEC's decision not to build government towns in association with their new Cold War expansion facilities was a major departure from previous production facilities built under the Manhattan Project that included government communities. Photographer: E. Westcott. Courtesy of NARA.

All agreed that housing problems for the labor force were twofold. First, housing was needed for the temporary population increase engendered by construction. Du Pont forecasted that 17,000 temporary employees would need housing by August 1951; 24,000 by October 1951; 31,000 by January 1952; 34,500 by April 1952; and 36,000 by June 1952. Second, housing was needed for the operation staff. Thus, the following incremental forecast was made for permanent employees: 250 by January 1952; 3,300 by July 1952; 5,100 by January 1953; 5,600 by January 1954; and 6,000 by July 1954. To better shape the forecast, several other assumptions were made about the incoming forces. Sixty percent would have families; the remainder of the workers would be single. Local labor would supply only one-third of the workforce. One-third of incoming families would be trailer owners. Many of these variables were based on data from other AEC sites.[3] With the determination of engineers used to problem-solving, housing estimates were formulated using the best data at hand. Well-reasoned, but incorrect, they simply did not reflect the many possible variables, cultural and economic, that could be involved in how a family or individual picks a home. Du Pont's housing personnel did the best with the resources at

hand, but the overall effort and the coordination among federal agencies needed to provide the needed housing and community services was not in place.

HOUSING PROGRAM

The program was up against difficult odds. A pre-acquisition survey indicated that not only was area housing limited, but that it was also considered substandard. Fifty-three percent of Augusta's 21,000 residential units were considered substandard in a report titled *Consolidated Report on Savannah River Plant*.[4] Other area communities were similarly evaluated. Given the number and location of bridges over the Savannah, Augusta was the only likely Georgia community to absorb some of the workforce. However, the simultaneous expansion of Camp Gordon, Oliver General Hospital, and the Augusta Arsenal actually put military personnel in competition with the plant personnel for housing. Regulation X, issued by the Federal Reserve System in September 1950, was a critical thorn in the AEC's battle for housing. Underneath that regulation, strict limits were placed on residential real estate credit, thus creating a tight mortgage market and extremely unfavorable lending circumstances for developers or builders. The Federal Housing Administration only insured 58 mortgages in Aiken, Allendale, and Barnwell counties in South Carolina, and Richmond County, Georgia, in 1950.[5]



Broad Street Augusta, 1952. This view captures the commercial boom that Augusta enjoyed as a result of Savannah River Plant. Source: *Burroughs Clearing House for Bank and Financial Officers*, "Augusta, Georgia: The H-Bomb Brought a Boom," February 1952.

Augusta and Richmond County had active planning and zoning commissions with funding for full time-staff in place. A city–county zoning plan was under development and city–county subdivision control was in effect shortly after the plant selection announcement. In addition, the city and county had enforced trailer-park ordinances. Augusta and Richmond County were better equipped to handle the change ahead. The South Carolina communities were not. A state act passed quickly after the plant announcement that allowed counties, that had a sudden influx of population, to establish planning commissions with limited zoning powers. Aiken revised its zoning ordinances and adopted trailer-park regulations, with cooperation from a representative of the Trailer Coach Manufacturer's Association.[6]

The ability of local resources to respond to the housing problem was limited. The efforts of the Western Carolina Council were notable. This organization, formed in May 1951, represented the interests of eight of South Carolina's counties within a 50-mile radius of the plant. John A. May was the president of the council.[7] While the Council was effective as a pressure group lobbying for federal funds, it did not rally local or state resources to help with the approaching housing shortage. An Area Defense Mobilization Committee organized by the Office of Defense Mobilization (ODM) was short-lived and ineffective. While the ODM designated a local official to coordinate the federal programs of housing and

community services, the position was not backed by congressional authority. Rent-control legislation was enacted and federal programs that would assist with transportation, health, and welfare issues were also invoked. The real problems—housing, community facilities, and local planning—could not be really addressed without federal legislation and appropriations.[8]



"Men's Dormitory" circa 1951. Allendale's Hotel Cleveland offered accommodations with weekly rates for incoming construction men. The first floor was used as a gas station, café, and lobby while the second floor was probably reserved for lodging. Courtesy of SRS Archives, negative M-895.

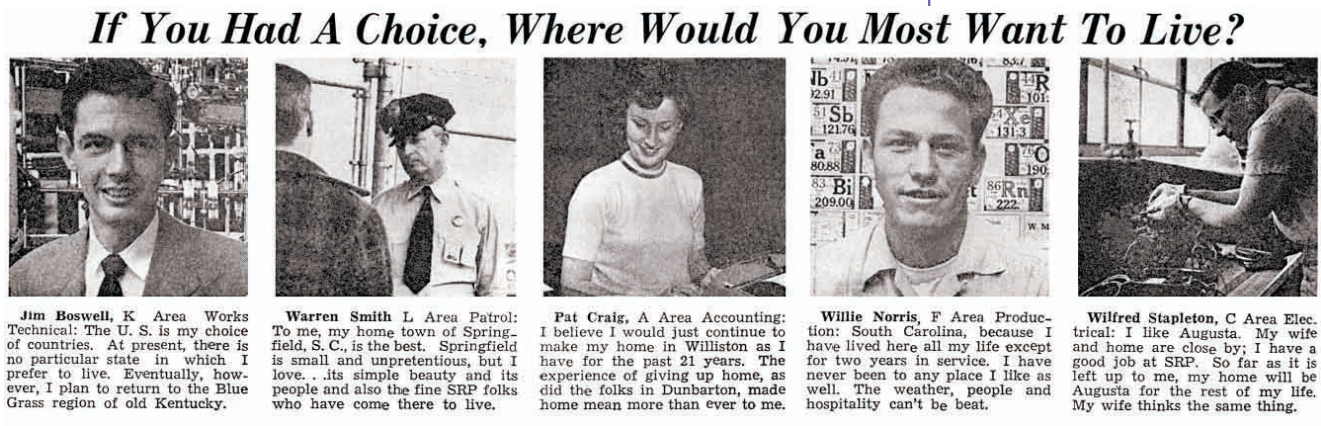
The AEC requested that Du Pont find temporary housing for the incoming force; in response, Du Pont hired a housing specialist. Du Pont's housing personnel, working through newspaper advertisements, room-scouts, and word of mouth, had been successful in finding rooms and houses for the first newcomers, but by mid-July these resources were running dry. Early progress reports for October and December 1951 show that incoming employees for Du Pont were staying at the Bon Air Hotel or in private homes while they waited for available housing or loans to buy a home.[9] Approximately 80 hotel rooms and 100 homes were leased to Du Pont to handle immediate housing. The AEC's request for the FHA and the Office of the Housing Expeditor to waive veteran's preferences on 182 existing units had been granted, and Du Pont had reserved these rentals for AEC and Du Pont personnel. However, in order to hold these units, Du Pont was forced to pay rent on those that were unoccupied. The AEC had also requested the Army restrict any further expansion of Camp Gordon.[10] Despite working all of these angles, the shortage of housing units in comparison to the forecast of incoming laborers was grim.

True relief came with the passing of Public Law 139, *The Defense Housing and Community Facilities and Services Act*. Enacted late in 1951 by the 82nd Congress, it authorized the expenditure of $100 million and later appropriations equaling $28,625 million for housing and services in critical defense areas across the nation. The benefits of the act, which did not include local planning assistance or field interagency coordination, were available through June 30, 1953; Public Law 94 of the 83rd Congress extended the 1953 deadline. The housing provisions of this act primarily benefited defense workers and, in the CSRA area, it was used to provide housing for the operations staff. The act first called for the designation of a critical defense-housing area. In the project area, the critical defense area was defined as the counties surrounding the plant: Richmond County, Georgia, and Aiken, Barnwell, and Allendale counties in South Carolina. The area was later expanded to cover all of Columbia and McDuffie counties in Georgia; Militia District 9 (Wrens Town) in Jefferson County, Georgia; and Bamberg and Orangeburg counties in South Carolina.

Within the defined area, the act allowed for the relaxation of credit controls on residential construction, provided special FHA mortgage-insurance terms on certain types of new sale and rental housing to be "programmed" by HHFA for the area, and offered spe-

cial FNMA mortgage purchase assistance. With such enticements available, it was hoped that private builders and developers would meet housing needs. If they did not after 90 days, the federal government as a last resort could construct and operate housing. The latter did not occur in the CSRA for housing targeted for the permanent work force. The HHFA administered the housing program funded under the new legislation; approximately $6 million dollars of aid was spent in the CSRA. A total of 3,225 rental units and 625 sale units were built in the CSRA; 78.9 percent were constructed in Augusta/North Augusta/Aiken and the remaining number were distributed among the other towns.[11]

New residential housing in the project environs began to appear as the assistance programs provided under Public Law 139 got under way. By 1953, the FHA was insuring mortgages for 3,319 homes; two years earlier that number stood at 58. A University of North Carolina study group estimated the number of new dwellings, programmed and non-programmed, at 8,690.[12] Most incoming personnel moved into rental or programmed housing initially, then bought or built houses when they were able.[13] A 1953 AEC study showed that there was an overwhelming preference for the Aiken area. Sixty-seven percent of AEC and Du Pont workers who lived in programmed housing settled in Aiken. The distribution of programmed rental housing by town showed Augusta with 1,090 units, Aiken with 875 units, North Augusta with 578 units, Barnwell with 287 units, Williston with 186 units, Blackville with 123 units, and Allendale with 85. In addition, there were 625 housing units constructed for sale.[14]



SRP News and Views' roving reporters from the different operations areas queried employees on their living arrangements. These verbal snapshots provide opinions from native South Carolinians to new transplants. Source: *SRP News and Views*, July, 1955.

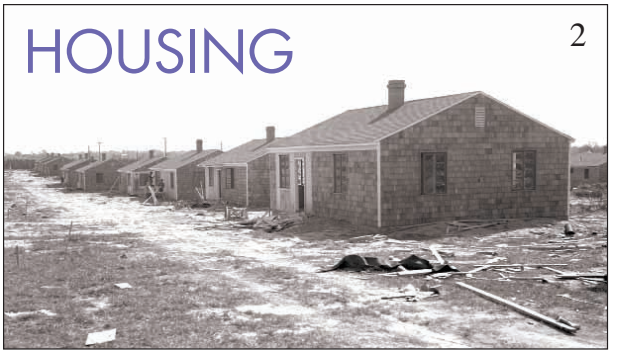
Two- and three-bedroom units were preferred, and those who had large families and were in need of four-bedroom homes had difficulty finding the needed space. According to the UNC study, one-bedroom units typically rented for $60 a month, two-bedroom units for $65, and three-bedrooms units for $75. These rents were usually the maximum allowed by HHFA regulations. A Du Pont monthly report to Wilmington for October 1951 states that the "popular demand appears to be a 3–4 bedroom single house renting at $100 to $125 per month."[15] This is considerably higher than the monthly rate identified by the UNC study. In some cases, members of the construction force were in a better financial position to pay such rentals than were some of the incoming operations workers. About 73 percent of the incoming construction force interviewed by the University of North Carolina study made $500 a month or more. Only 38 percent of the operations force interviewed made $500 a month or above.[16]

HOUSING

1



2



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4



5



6



7



Ranch housing set on curving streets and "boxlike" dwellings regimented in a line characterized the majority of the early 1950s housing. Courtesy of SRS Archives.

1 - "Buy or Build," Site for Lynnhurst Housing Development, North Augusta, 1951. Negative DPES-F-6962.

2 - Operations housing,Williston, 1951. This type of housing was also constructed in neighboring Barnwell. Negative M-700-3.

3 - Operations housing, Crosland Park, Aiken, 1951. Negative M-725-3.

4 - Housing constructed by Creadick, Aiken. Negative M-639.

5 - Savannah Heights, Augusta, 1951. Negative DPES-F-6963.

6 - Housing units for African-American employees, Williston. Negative M-1354.

7 - Pine View Annex, Knox-Carolina Homes, 1951. Negative 6989-1.

Between November 28, 1950, and January 1953, a total of 5,465 non-programmed houses were also constructed. The FHA financed some, but many were financed through other means. Augusta had the lion's share at 2,700, then Aiken at 1,420. North Augusta, Barnwell, Williston, Allendale, New Ellenton, Blackville, and Jackson had 620, 225, 140, 120, 105, 70, and 65, respectively. In addition, the town of New Ellenton, just established, had 195 homes that had been moved from the plant area. A total of 132 additional homes were moved to Jackson from the plant area. Also the Hollow Creek section on Highway 781, about six miles west of New Ellenton, and a settlement north and west of Ellenton became home to concentrations of African-Americans households. The majority of homes in these new settlements had been moved from the plant area. Barnwell, Williston, and roads that led to the plant were also venues where plant area homes had been relocated.

A summary of plat information for available lots or homes under development in the early 1950s was compiled by the Du Pont Housing Office to apprise new personnel about potential housing.17 Most of the plats show high-density expectations with average lot sizes of 70 x 125 feet. The SRP plat book provided the basic information on what individual subdivisions, currently under development, had to offer for prospective owners/renters and identifies the developers within the area. Unfortunately, there was no notation within the plat book that indicated which, if any, of the developments were considered programmed housing. However, the UNC study did state that the residential developments in areas other than Aiken and Augusta received more federal help than the two more urbanized areas. The identification of owners/developers shows some firms had multiple residential developments and that at least one firm had multiple programmed housing for sale. Articles from the area newspapers and from the plant newspapers helped flesh out the plat book information.

The plat book cites Richmond Hills, Kendon Park, Forest Hills, Thomas Woods, Glendale, Walker Villa, and the Marion Homes as possible home locations in Augusta for the permanent work force. Eugene Martini built the Marion Homes subdivision off Sand Bar Ferry Road in Augusta. This subdivision contained 120 single-family homes and 40 duplexes on its seven blocks. Martini, an Atlanta-based landscape architect and owner of the Marion Homes Corporation, was associated with the Virginia Acres development in Aiken and also the Glendale subdivision in Augusta. Thomas Woods, located off Deans Bridge Road, contained 123 lots within an eight-block layout. The South Carolina firm of Lyles, Bisset, Carlisle & Wolff and Emory Holyrod Jr. Associates of Columbia were credited with its development. Kendon Park was located near Bungalow Road, Forest Hills near Deans Bridge Road, Richmond Hills near Whiskey Lake, and Walker Villa by Laney Walker Boulevard. Not mentioned in the plat book were Richmond Apartments near Fleming Heights by Knox Homes of Thomson, Myrtle Court by Sherman and Hemstreet, and Golf Court by Blanchard and Calhoun.[18]

Only two new North Augusta subdivisions were shown in the SRP plat book: Summerfield by the Knox Corporation and Green Acres by John McDonald. This suggests that both were programmed housing. Lynnhurst, Hammond Hills, Washington Homes, Savannah Terrace, Smithfield, Mayfair, Belvedere Ridge, Fowke Hurst, Mealing Heights, and Lakewood were other North Augusta subdivisions associated with the 1950s housing expansion.





McClain Home Place, Hawthorne, Aiken County, SC. Some of the historic residences, like the McClain home, were transplanted to new surroundings, acquiring new lives and associations.

(Upper View) George F. McClain Homeplace in Hawthorne in its original location, circa 1925. Courtesy of the McClain Family.

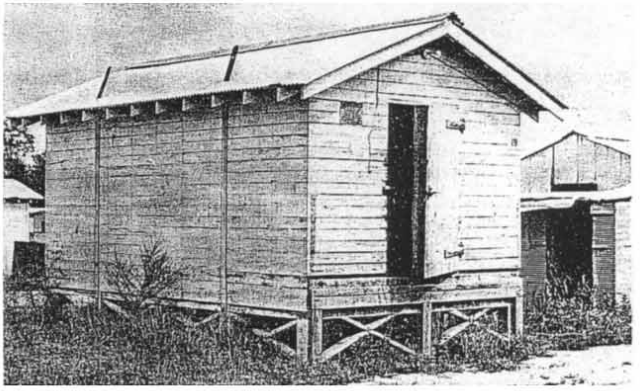
(Lower View) The L-shaped cottage with its front bay window was sold out of the family during the acquisition program. The new owners removed a rear ell and moved the house to its present location on Highway 278, north of SRS. Photographed by New South Associates, 2000.

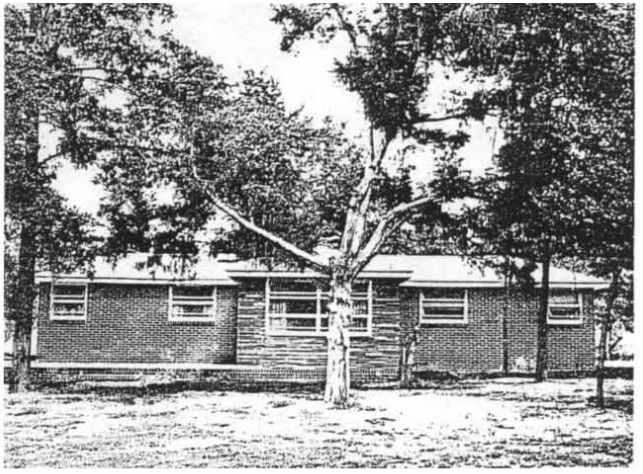
From "An Ice House" To "A Nice House"

Always ready to present articles which will show the resourcefulness, ingenuity and ability of our employes we offer for your inspection the home of Mr. and Mrs. John Brannon which is located in Jackson, S. Carolina, a stone's throw from the outer perimeter of the project.

A few months ago John had an opportunity to purchase three of the excess ice houses used on the project and he had them hauled to his lot in Jackson. The ice houses were used by the Brannons to form the nucleus of a new home and by dint of hard work they have succeeded in building a 'real beauty'. Personally we think the brick, permastone and frame structure is one of which anyone can be proud.

John is employed by the Heavy Equipment Craft in their Lubrication Shop in the Central Shops Area.

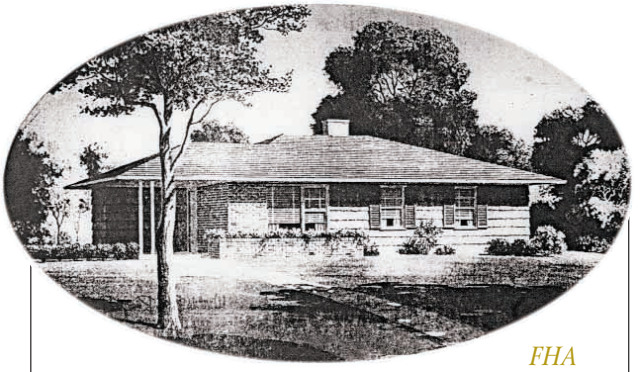




GROSS-MORTON

PROUDLY PRESENTS

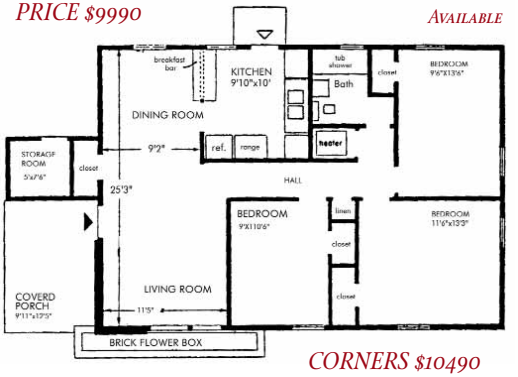
A New Group of 3-Bedroom Homes in Aiken, S.C.



FHA

Financing Available

PRICE $9990



CORNERS $10490

Homes are For Sale
To any person permanently employed or permanently in business in the area.

Gross-Morton, whose outstanding building record during 56 years is known throughout the country, now proudly presents a new home community in the South.

They offer you a really large, complete modern home at an exceptionally low price…ideally located only 15 minutes from the new Savannah River Plant and less than five minutes from the center of Aiken.

Come out right now and see the exhibit homes for this great new community- CROSLAND PARK by Gross-Morton!

Source: *Aiken Standard and Review*, Friday, February 22, 1952.

(Left) Some incoming operations personnel chose housing in professionally designed and built subdivisions such as Crosland Park in Aiken while others built their own homes in popular 1950s residential architectural styles for economy or as a personal preference. Articles in the plant newspaper highlighted many of the "do-it yourselfers." The Brannon's home in Jackson, built using three ice houses excessed from the plant, was a ranch style rendered in brick, frame, and permastone. Others such as the Hensley home in North Augusta on Atomic Road (opposite page) were brick cottages. Source: *SRP News and Views*, September 9, 1955.

Aiken's largest subdivision was Crosland Park. This programmed development was designed by the architectural firm of Lyles, Bisset, Carlisle & Wolff, Emory Holyrod Jr. Associates of Columbia and built by Gross-Morton on an approximately 200-acre tract north of Aiken. A total of 542 homes were constructed, of which 437 were rented at $75/month to Savannah River Plant employees. The remaining homes were sold to qualified buyers at $9,990. The setting for Crosland Park was described as a rolling wooded tract on York Street a half mile north of Aiken's business district. The one-story homes were of "modified Colonial design including eleven different elevations and three different floor plans." This subdivision won nationwide recognition when Gross-Morton received an award for outstanding achievement in home design in the Merit Award Program of the National Association of Home Builders. The judges noted that the homes "present a lot of livability in a small area."[19]

The same architectural firm was responsible for Virginia Acres, which featured one-story duplexes and single homes located south of Aiken's business district along Highway 19, and also Thomas Woods on Dean's Bridge Road in Augusta, Barnwell Heights in Barnwell, and Williston Woods in Williston. While no documentation was found, it is probable that Virginia Acres also represented a second programmed development. The duplex apartments in Virginia Acres were popular due to their proximity to the plant and their low rental costs per month. Remnants of this subdivision still exist around the H. O. Weeks Recreation Center. Barnwell Heights, designed by the Columbia firm, was a programmed housing development.

Dartmoor Acres located near Aiken's South Boundary Drive had 64 lots with " Lovely Pine and Magnolia Trees Restricted to Homes of 1200 square feet or more. Custom Built to owner's plan or to ours." Aiken Heights, built by E. A. Kundinger on a 50-acre tract located south of Old Trolley Line Road, featured "practical" house types "to accommodate a good-sized family and within the price range of the average family." Their model home,



(Above) "Johnny (from Operations) and Beth Gilmore (from Receiving and Stores), work on the fireplace surround in their seven-room brick home they built themselves in the country between North Augusta and Clearwater." *SRP News and Views*, "They Built Their Own Homes in the Country," Friday, March 25, 1955.

(Below) *Savannah River Plant News* highlighted the housebuilding efforts of Roy Hensley and John Lemaire, both in SRP Maintenance in 1955.

EMPLOYEES FIND IT'S PROFITABLE FUN TO.....

DO IT THEMSELVES



ROY HENSLEY, Maintenance, "Did it himself." Roy's home is located in North Augusta, just past Summerfield. Roy is now working on a garage, partly shown above.

Just as homemade ice cream tastes better, so homemade homes "live" better, say SRP's growing number of employees who have built or are building their own homes. The desire to live in homes built by their own hands leads home builders into the very front rank of "Do It Yourself" enthusiasts. SRP's home builders sometimes do all of the work on their homes, enlisting the whole family in the effort. Others leave the difficult parts to professional craftsmen. In some instances, neighbors or friends get together to help each other build a home, pooling their time and their skills. But all agree that the natural pride of home ownership is greatly increased by the feeling that "We Did It Ourselves."



JOHN LEMAIRE, Maintenance, designed and is building his home in the Millbrook section of Aiken. John is shown above working on the fireplace.

"The Jewel," and others like it could be purchased with FHA or VA financing. Kundinger, a Michigan firm, also built a hotel-type housing unit in Williston and a trailer camp for plant workers.[20]

Barnwell's residential building stock swelled with programmed housing, including the Kilkenny Acres development that included 130 single homes, and expansions of Barnwell Heights, Peachtree Gardens, and Hagood Heights. A total of 291 homes were built under federal programs in Barnwell.[21]

Local Subdivisions Associated with SRP Development, 1951–1953

Subdivision	Lots	Date	Location	Architect/Developer
Crosland Park	575	1951	Aiken	Gross-Morton
Silver Bluff	72	nd	Aiken	Not noted
Governor Aiken Park		1951	Aiken	Robert B. Russell, Engineer
Colonial Village	104	1951	Aiken	Survey by Columbia Engineering
Virginia Acres	71	1951	Aiken	Wm. G. Lyles, Bisset, Carlisle & Wolff, A&E, R. Emory Holroyd, Jr Associates, Columbia, Eugene R. Martini, LA, Atlanta, Ga
Forest Heights	356	12/51	Aiken	Plat drawn by W.A. Sanders
Dartmoor Woods	64	10/53	Aiken	Combs-McDonald Construction Co.
Lynnhurst Annex	---	8/51	Aiken Co.	Not noted
Elmwood Park	66	nd	Aiken Co.	Robert E. Penland and Hamilton Dicks
Lawton Acres	77	3/52	Allendale	A.L. Ervin, Florence
Parkwood Terrace	112	1952	Allendale	Parkwood Company
Richmond Hills	135	11/51	Augusta	E. Eugene Tovell, Reg. Engineer
Walker Villa	128	nd	Augusta	Not noted
Kendon Park	111	1/1950	Augusta	Approved by Augusta City Planning Commission
Forest Hills	---	2/52	Augusta	Not noted
Marion Homes	160	1/52	Augusta	Eugene R. Martini, LA, Owner Marion Homes Corporation
Glendale	73	7/52	Richmond Co.	Eugene R. Martini, LA and Surveyor
Thomas Woods	123	6/52	Richmond Co	Wm. G. Lyles, Bissett, Carlisle & Wolff, A&E, R. Emory Holroyd, Jr. Associates, Columbia
Kilkenny Acres	216	nd	Barnwell	Not noted
Peachtree Gardens	46	nd		"Proposed Re-Subdivision-Peachtree Gardens for Barnwell Peanut Co." Knox Corp, Thomson
Barnwell Heights	---	1951	Barnwell	Wm. G. Lyles, Bissett Carlisle & Wolff, A&E
Blackville Gardens	---	nd	Blackville	Bernard B. Saigal, AIA
Green Acres	---	nd	N. Augusta	John McDonald
Summerfield	---	nd	N. Augusta	Knox Corp, Thomson, Ga
Williston Homes		1/52	Williston	Wm. G. Lyles Bissett Carlisle & Wolff, A&E
Sherwood Acres	184	10/51	Williston	Owners-Craig Roberson Construction Co
Kenland Acres	---	11/51	Williston	Kenneth B. Simmons, ASLA, Columbia, William Stork Jr. AIA, Columbia

Source: Binder Containing Plats of Subdivisions in Aiken, SC; Allendale, SC; and Augusta, Ga, SRP Personnel-Employment Division. Courtesy of SRS Archives.

All of the subdivisions appear to be typical of 1950s subdivisions in their layout with large elongated blocks and curving streets. There were two exceptions, both designed by architects and landscape architects: Kenland Acres in Williston situated on S.C. 39, which was more formal in its design, and Blackville Gardens in Blackville, which was laid out around a central circle and featured cul-de-sacs.

HOUSING THE CONSTRUCTION FORCE



Barracks constructed for single men housing in Barnwell by Lyles & Lang Construction of Columbia, 1951. Courtesy of SRS Archives, negative M-422.

Public Law 139 also had provisions for government-provided temporary housing, but the act's passage in September 1951 came too late. The Atomic Energy Commission had moved ahead to obtain immediate housing for the construction force, authorizing Du Pont to enter into contracts with private firms to supply temporary housing. Two types of housing were offered to construction workers—trailer villages for families and barracks for single men.

H-shaped barracks with homosite siding were built by Lyles & Lang Construction of Columbia, South Carolina, in groups that would accommodate up to 1500 individuals. They were situated in Barnwell, Williston, and Allendale. The original contract also called for barracks at Beech Island, but this location was dropped from Lyles and Lang's scope. For $8.50 per man or $16.50 per room a week, each 12 x 12 feet room came with two linen changes and maid service. On March 28, 1952, the Office of Rent Stabilization rolled back the weekly rents to $6.00 per week per room for a single occupancy or $10 per week if a room was shared. The rollback was a disaster for the AEC who had fixed the rents in their contract with the builder. The AEC was forced to pay the difference in rent between the contract rental price and the ceilings set by the Office of Rent Stabilization.

To make matters worse, the barracks were unpopular with the construction force. They were Spartan in their accommodations. Individual rooms were furnished with two single beds, two dressers, two mirrors, shelves, a writing desk, two chairs, and a space for hanging clothes. While each barracks area had a canteen, barber shop, and cafeteria, the small number of amenities and their locations in the small towns surrounding the plant worked against them.



Some construction men lived in tents. This view showing two men, wearing hardhats, seated in front of a canvas tent appeared in a period banking magazine. Source: *Burroughs Clearing House for Bank and Financial Officers*, "Augusta, Georgia: The H-Bomb Brought a Boom," February 1952.

> It would seem also that the location of the barracks in small towns, two of these towns being more than an hour's drive from a large city, was a factor militating against full occupancy. A small town with already overtaxed recreation facilities would seem to hold little attraction for large groups of single men.
>
> One had only to drive up Green Street, or other downtown residential streets in Augusta, during the late afternoon in the summer or fall of 1952 to see where great numbers of these men lived. Often, there were some 10 to 15 plant workers sitting on one porch, and this scene was true to some extent in Aiken where several old, former winter colony houses were turned into boarding houses, some housing as many as 40 or 50 men.[22]

Trailer Court Life

"There are nearly 3000 trailer families in the bomb-plant area now, huddled in 100-odd parks and courts around the 315 square miles of the H-bomb reservation.

They are, perhaps, a new breed upon the earth - a growing tribe of willing migrants who by their own choice have arranged their lives so that they will be free to travel where ever there are atomic plants to build, or great dams, or power stations, or pipe lines, or massive factories to construct. In the sense that they call no place home, they are vagabonds, but in their skills they are the aristocrats of the construction trades - the workers on the high steel, the earth movers, the electricians, the insulators, the millwrights and the steam fitters and the boss carpenters. Proud of spirit, tough of body and hungry for money, when there is work to be done they don't care whether the job is in Carolina, Kentucky, or California, Michigan, or Mississippi, so long the road leads to it. Their security is not in the roots they might put down in any particular spot on earth, but in their craftsmanship and mobility.



They don't envy the stay-at-home worker his house and lot and his home-town job. Most of them have had these things and have swapped them for a way of life that to them is far more satisfying. They are, in spirit, gypsies, but they take great pride in the fact that in their rolling caravans they surround themselves with comforts and conveniences that few householders can afford. They are rolling stones, but the moss they gather in a year, the statisticians have learned with some surprise adds up to about $1000 more per family than the income of a sedentary worker with the same skills as theirs.

They have, they feel, one great advantage over the man who lives out his life in one place. They can go where the money is, carrying with them, as they move, all the comforts of home and all the soft pleasures of a normal family life. Before the days of the trailer coach, the construction man was a rough, red necked hombre with no more home life than a goat. When he went off on a job he left his family, if he had one, and lived in a tent or a barracks or a boardinghouse, and his folks never saw him for months at a time. If he took them with him, they had to live in whatever shabby, high-priced housing was at hand, and half his wages might go for rent. The women didn't like that, and it broke up families. Now it's different. Where he goes, mamma and the young'uns go. He sleeps in a good bed at night, eats his wife's cooking, and when he comes home in the evening, he reads his paper and smokes his pipe and listens to the radio or watches the television in his own living room, like any settled family man.

"From job to job," one trailer housewife said, "the only thing that changes is the view out the window."

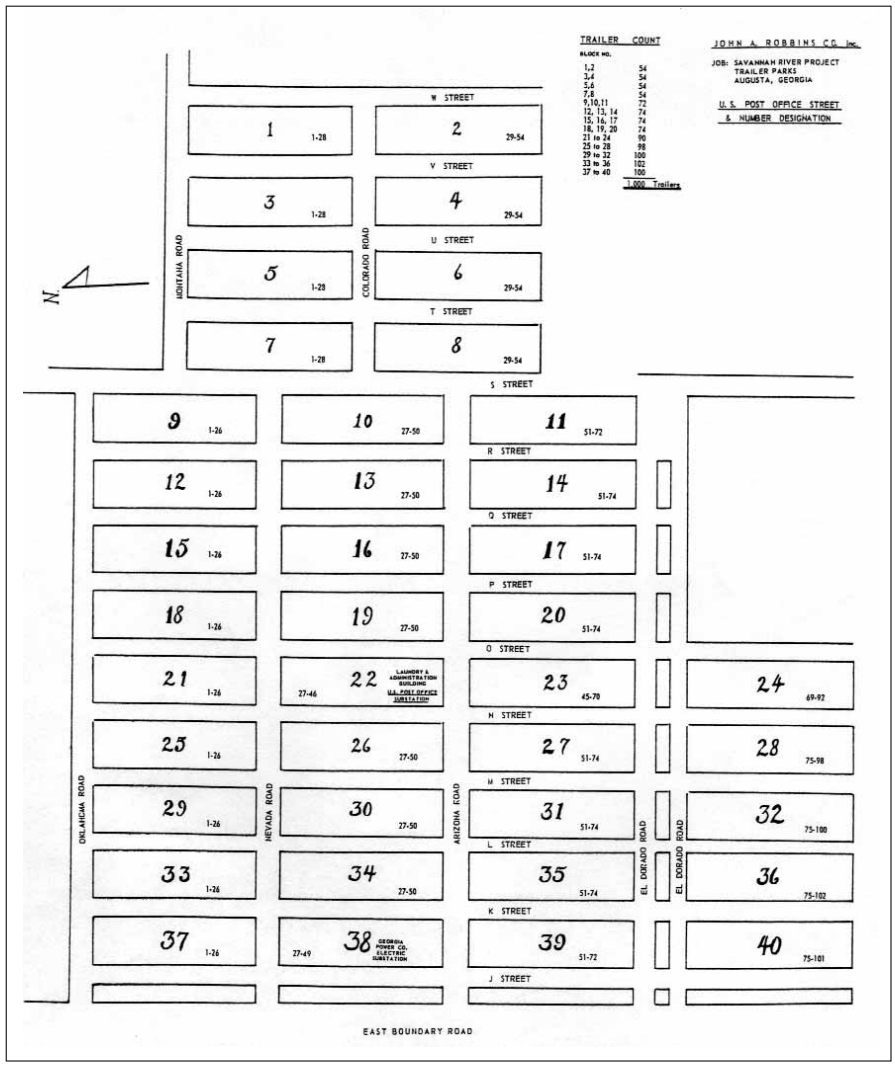
When the family is looking for a place to roost, they are as choosy as any city dweller picking out a suburban lot. They look first for shade and grass, and for neat, well-kept trailers with flower gardens and grass plots around them - an indication that their neighbors will be settled, quiet folk. They avoid like the pestilence trailer parks in the neighborhood of beer joints or honky-tonks, where the sound of revelry by night might disturb their rest, and they like parks where the trailers in which children live are segregated from the rest.

Once they have come to rest, the process of settling in requires even less time than the routine of getting ready to move. The neighbors rally around to help the newcomers tie on to the water, the sewer, and the electric lines. They jack up the frame end, set the blocks on which the coach is to rest, while the owner, inside, checks the tilt of the floors with a spirit level. Within an hour they will have the radio going, the potted plants back in the window, the coffee perking on the stove, and the new arrivals will be swapping the latest news of the road with old friends they have not seen since last they parked together a year ago and 1000 miles away.

Once settled, the trailer folk immediately begin to put down their shallow roots. Car pools are organized to take the kids to school. The boys start carrying paper routes, the teen age girls pick up change baby-sitting for the neighbors. The mothers form little clubs that meet, usually in the trailer-court washhouse on Wednesday afternoons, to play cards, knit, gossip and contribute to small funds from which they buy layettes for new babies or fresh flowers for neighbors who fall sick."

Source: Photograph and text from Harold H. Martin, "Don't Call Them Trailer Trash," *The Saturday Evening Post*, August 2, 1952.

At the peak of their occupancy in July 1952, there were only 1,092 men and 3,408 vacancies in the barracks. Given these numbers, the barracks closed down. The Barnwell group was open from January 14, 1952 through January 11, 1953, the Williston and Allendale barracks operated only for an eight-month period in 1952. The barracks debacle would prove costly for the AEC financially and from a public relations standpoint. Lyles & Lang filed suit against Du Pont over differing interpretations of the cancellation clauses. In May 1954, the U.S. District Court found in favor of Lyles & Lang, awarding the firm $854,614.



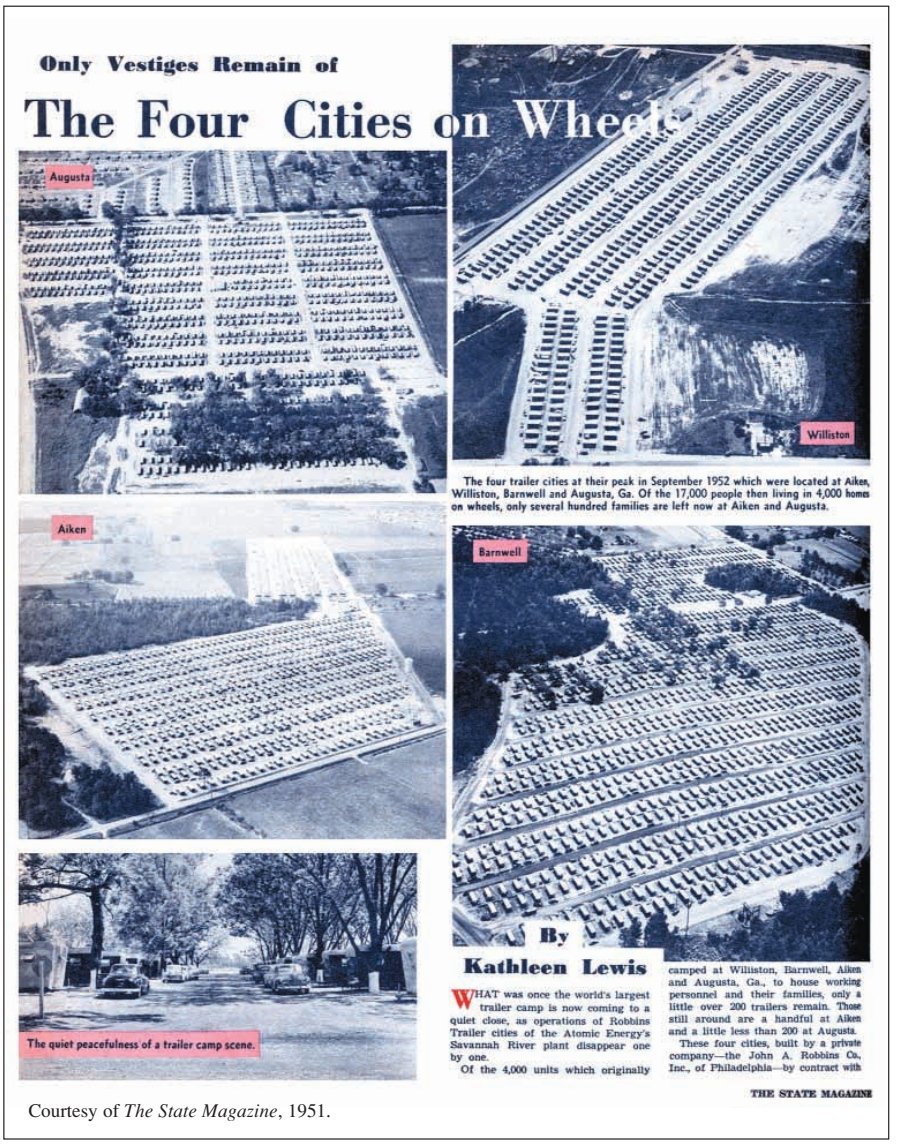
Trailer park layout designed by John A. Robbins Company of Philadelphia for 1,000 trailers for park on East Boundary Road, Augusta, Georgia. Courtesy of Duluth Prather.

The fact that the AEC had to make up the difference in terms of barracks rental also found its way to the press, setting off another round of investigations into AEC housing. An article written by local author George McMillan and published in the November 1953 issue of *Harper's Magazine* added to the investigative fervor. The McMillan article charged the project with wasting public funds, brought up the optioning of land by

Barnwell's political and economic leaders prior to the announcement, and stated that the tracts upon which the barracks and trailer cities were located were acquired or leased from men of influence.

The trailer parks, in contrast to the barracks, were an unmitigated success. Mobile homes were crucial to the success of the construction-era housing problem. The trailer offered construction families the mobility needed for construction work but stability in their family life. They allowed a new era of construction workers and their families to live under one roof, gave them some control over their future housing needs as they moved from one construction site to another, and no furniture-moving was needed.

Trailer parks that allowed for family accommodations were established at four locations, in Augusta, Aiken, Williston, and Barnwell. John A. Robbins Co. of Philadelphia, under contract with Du Pont, supplied a total of 4,000 metal trailers, 1,000 to each "city."



Only Vestiges Remain of

The Four Cities on Wheels

Augusta

Williston

The four trailer cities at their peak in September 1952 which were located at Aiken, Williston, Barnwell and Augusta, Ga. Of the 17,000 people then living in 4,000 homes on wheels, only several hundred families are left now at Aiken and Augusta.

Aiken

Barnwell

The quiet peacefulness of a trailer camp scene.

By

Kathleen Lewis

WHAT was once the world's largest trailer camp is now coming to a quiet close, as operations of Robbins Trailer cities of the Atomic Energy's Savannah River plant disappear one by one.

Of the 4,000 units which originally camped at Williston, Barnwell, Aiken and Augusta, Ga., to house working personnel and their families, only a little over 200 trailers remain. Those still around are a handful at Aiken and a little less than 200 at Augusta.

These four cities, built by a private company—the John A. Robbins Co., Inc., of Philadelphia—by contract with

THE STATE MAGAZINE

Courtesy of *The State Magazine*, 1951.

Each trailer was about 26 feet long and included a living room, kitchen, bedroom, and bath. A "divan" offered extra sleeping space in the living room. The trailers were successful in sheltering families with two to four family members. The Robbins' trailer cities were described in *The State Magazine*:

> These four cities, built by a private company—the John A. Robbins Co. Inc. of Philadelphia—by contract with E. I. du Pont de Nemours & Co. were unique in many respects, chief of which was the fact that no where in the world before had anything of a comparable nature been attempted.
>
> To accomplish such a feat of setting up so much housing so quickly for so many people, Robbins borrowed ten million dollars to start with and then poured in nearly an additional two million dollars of his own. That was the early beginning back in January of 1952. As soon as a trailer was moved into position and hooked up, it was occupied. All of the trailer cities were finished completely and 100% occupied within an average length of time of six months.
>
> To a casual passerby, it looked as if over-night that 400 acres of cotton fields had been transformed into four thriving communities, with every comfort provided for human habitation. Postal service, shopping areas, places for worship and recreation, laundry facilities, almost everything a permanent town could boast was to be found in Robbins' cities.
>
> To make the grounds attractive for those willing to take care of them, the firm furnished, grass seed, tools, and planted evergreens. Two hundred homemakers in one area alone took part in the planting program, and added additional shrubs and flowers.[23]

Occupancy was guaranteed for 90 percent for 52 months from date of availability. The trailer parks were successful and occupancy was 100 percent between 1952 and their closure in 1954. Augusta and Aiken's trailer cities appear to have been the most popular, given occupancy rates. The Augusta park was located on a lot off Gwinnett Street (now Laney-Walker) at East Boundary.[24] The Aiken park was located on Highway 19 north of the plant. Each trailer was initially rented for $82.50 a month including utilities. After the rollback, the rental rate for trailers was lowered to $60, and the AEC paid the difference of $22.50 per month.

Under his contract, Robbins was required to sell each unit after a set date and to credit the proceeds to the government. The Williston Trailer Park closed in July 1953, the Barnwell Park in December. In June 1954, all the Robbins trailers were purchased by the Continental Supply Company of Birmingham, Alabama, which sold each for $1,000 beginning in June. By November all were sold.[25]

Private trailer parks played a significant role in construction-era housing. While only a few were in existence prior to the plant, their numbers expanded quickly. About 18,000 persons would be housed in trailers. There were approximately 130 parks on the South Carolina side and 13 on the Georgia side. The heaviest concentrations were located on

Unlimited Hot Water

"The winter resident who has undoubtedly made the happiest adjustment to the presence of construction workers, is Mr. Fitch Gilbert, an extremely affable Whiskey Road man of sixty-eight who owns a large tract of farmland adjoining the government site. Mr. Gilbert has opened a trailer camp on his property that will accommodate four hundred families. 'My family is horsy, but I'm not,' he told me. 'I've tried a lot of things on that farm, winters, to keep busy—corn, wood, peanuts, cheese, cotton, cattle, and whatnot—but this trailer camp is the best thing yet. Four hundred families at eight dollars a week—why, that'll be more money than I've made in a long time. Some of my competitors are charging six dollars, but I am not making my customers pay for electricity and I'm letting them have unlimited hot water. A plumber was telling me the other day that the one thing women want in a trailer camp is hot water. I may even throw in a few washing machines. I've named my camp Pine–Shade, to get over the idea that it doesn't sit out in the broiling sun, the way the others do. It's a grove three hundred yards back from the road and only a mile from an artificial lake. My farmer put me on to the idea. I'm letting him run the camp's food store. He's been wanting to get ahead for a long time. Well now he's getting ahead!'"

Source: Daniel Lang, *The New Yorker*, "Camellias to Bombs," July 7, 1951.

access roads near the plant and in Jackson and New Ellenton. The privately-owned parks ranged in the amenities they offered. Only about 15 could be considered first-class while many could easily have been characterized as substandard. Many owners of trailers, on hearing of a vacancy at a better park, would move to the better location, and these moves were more frequent as the construction period began to wind down.[26]

The housing shortage, considered critical in 1952, became less so as the Savannah River Project began to wind down. The construction force's preferences for urban living locations and the popularity of the trailers were part of the AEC and Du Pont's learning curve. Aiken was the focus of much of the new housing, and much of that occurred with private financing rather than government aid. Smaller towns such as Barnwell, Blackville, and Williston needed Federal dollars to make their housing developments work.



(Above) Augusta afternoon scene. Courtesy of SRS Archives, negative 4254-22.

(Right) Georgia Avenue, North Augusta, circa 1956. Courtesy of SRS Archives, negative 4254-12.

(Opposite) Kelly Edwards School in Williston, built partly in response to SRP and Governor Jimmy Byrnes' three percent sales tax. Courtesy of SRS Archives, negative 3389-23.

IMPACT ASSESSED BY 1953

By 1953, the original estimates of "impact" were history. The communities of Augusta, North Augusta, and Aiken received the greatest number of newcomers, and the amount of Federal monies appropriated to handle the impact of the population increases, both short-term and long-term, were divided up accordingly. Under Public Law 139, water works, sewers, sewage, garbage and refuse disposal facilities, water treatment and purification plants, libraries, hospitals, recreational facilities, streets and roads, and daycare centers could be funded. Monies expended in the CSRA included grants for the construction or expansion of water purification and sewage treatment, sewers, water storage and distribution facilities, police and fire protection equipment, and one hospital addition.[27]

For schools, each affected county school board worked with their state board of education and the U.S. Office of Education to apply for financial assistance based on estimates of incoming workers supplied by the Savannah River Operations Office. The Office of Education under Public Law 815 (School Construction), Public Law 874 (Operations and Maintenance), and a third supplemental appropriation set aside in 1951 had the experience and financial wherewithal to act. Four school boards were affected: Richmond County, which had a consolidated school dis-



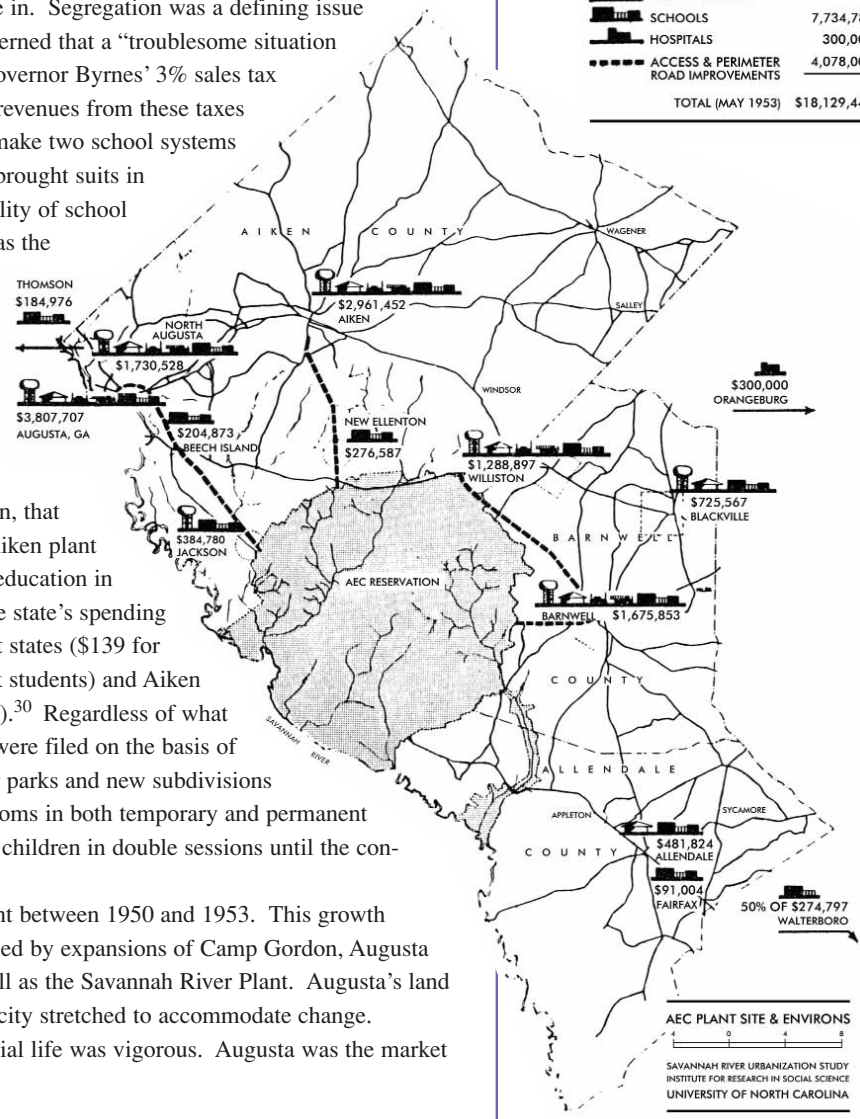


trict, Aiken County, Barnwell County, and Allendale County. Each South Carolina county had reorganized its districts, substantially reducing them in number at this date.

The school issue was as fraught with problems as the housing. Foremost, although the job of estimating was imprecise, adequate funding depended on good estimates of how many school-age children would arrive in the CSRA, their ages, and what districts they would live in. Segregation was a defining issue for public education, and the AEC was concerned that a "troublesome situation may arise."[28] The project coincided with Governor Byrnes' 3% sales tax and a similar measure in Georgia, in which revenues from these taxes would be used for school improvements to make two school systems separate but equal. African Americans had brought suits in Federal courts to challenge the constitutionality of school segregation. The AEC was aware that "it was the announced policy of both South Carolina and Georgia to withdraw entirely from the field of public education if a court order against segregation is obtained."[29] As the permanent operations staff was forecasted to be mostly white, the segregation problem was considered negligible. However, if the state were to withdraw from public education, that would greatly affect the desirability of the Aiken plant for a young engineer with a family. Public education in South Carolina was already a concern, as the state's spending level for public schools was lower than most states ($139 for each white student per annum, $77 for black students) and Aiken County's was lower than that ($124 and $61).[30] Regardless of what the future held, applications for federal aid were filed on the basis of the AEC estimates, and children from trailer parks and new subdivisions joined the children of area natives in classrooms in both temporary and permanent buildings. Some schools would educate the children in double sessions until the construction era was over.[31]

Augusta's population grew by 30 percent between 1950 and 1953. This growth stemmed from the population increases caused by expansions of Camp Gordon, Augusta Arsenal, and Oliver General Hospital, as well as the Savannah River Plant. Augusta's land in urban use also grew by 30 percent as the city stretched to accommodate change. Property values rose and the city's commercial life was vigorous. Augusta was the market town for the CSRA.[32]

Map showing the breakdown and distribution of Federal grants provided to Savannah River Plant communities. Source: Chapin *et. al.*, *In the Shadow of a Defense Plant A Study of Urbanization in Rural South Carolina*. (Chapel Hill, NC: Institute for Research in Social Studies, University of North Carolina, 1954).



Fifty new service-related businesses started during the first half of 1951. Houses were hastily erected in new sub-divisions. Richmond Apartments near Fleming Heights by Knox Homes of Thomson, Myrtle Court by Sherman and Hemstreet, Golf Court by Blanchard and Calhoun, Green Acres in North Augusta by John McDonald. Massive federal aid enabled the cities of Augusta and North Augusta to expand sewers, waterworks, streets and housing.[33]

Augusta received $3,807,707 in federal aid. Under Public Law 815, enacted by the 81st Congress, Augusta's schools were expanded by 18 classrooms housed within temporary buildings. A federal grant of $286,731 covered their purchase or construction. A second grant for $1,465,815 was also given to cover the construction of 58 permanent classrooms. Under Public Law 139, a total of $1,613, 061 was granted to the city to expand its water and sewage systems. Augusta matched the federal funds with over $3 million to make the necessary improvements. Additional police and fire protection were also needed, and Augusta was given almost $250,000 to help bring these services in line with the city's new needs.[34]

North Augusta in Aiken County, South Carolina, was essentially a bedroom community for Augusta. Its population grew from 3,659 individuals to 8,937 between 1950 and 1953. The Savannah River project was a factor in this growth, but as in Augusta's expansion, Camp Gordon, Oliver General Hospital, the Augusta Arsenal, and the Clarks Hill Dam also affected growth. The schools in this district received grants for permanent and temporary construction totaling $882,828. North Augusta's schools were increased by 18 temporary classrooms and 34 permanent classrooms.

Approaching North Augusta, circa 1955. Courtesy of SRS Archives, negative 4254-20.



Over 15 miles of new streets were laid out in North Augusta by 1953. The city annexed the many subdivisions that were newly constructed around it, causing a substantial change in needed municipal services that ranged from water systems to police and fire protection. Federal grants paid for most of the sewer upgrades ($339,200) and almost half of the water system improvements ($453,600). Expansion of their fire and police protection was funded by a $54,900 grant that was matched by $6,100 in local funds.[35]

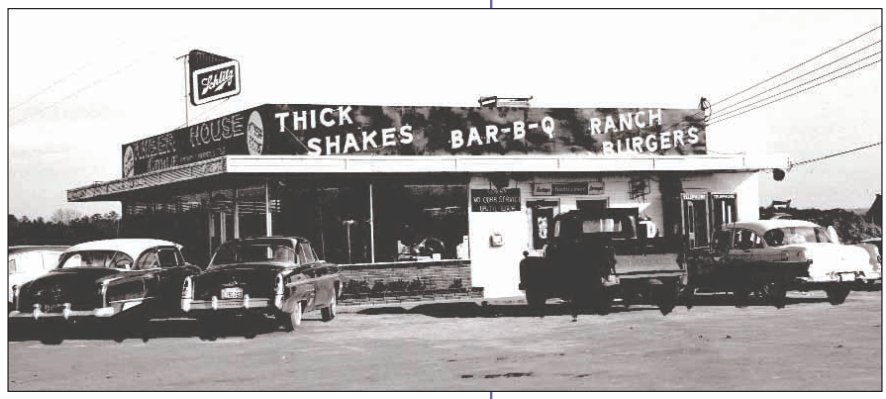
Aiken's population and land area also increased dramatically. Known as a winter colony for wealthy northerners and as an equestrian center, Aiken drew about two-thirds of the scientists, engineers, and managers to its city limits. Of the nearly 4,000 employees at the plant in the spring of 1953, about 1,300 were Aiken residents. This number had surpassed 2,000 by the following November.[36] The census listed Aiken's population at 7,083 in 1950; in 1953, its population was 9,100. In land area, Aiken grew 139 percent between 1950 and 1953 through annexation and development as about 21 miles of new streets were added to the city. Thirty-six temporary classrooms and 40 permanent classrooms were added to the city schools. The school population had grown from 13,400 pupils in November 1950 to 15,000 the next school year. Federal grants funded the majority of school expansions. Eighty additional teachers were hired in 1952, and more would be needed the next year.

The new housing developments were constructed faster than were community services in Aiken. In May 1953, residents in the northwestern section of the city were experiencing serious water problems that stemmed from inadequate pressure. Some homes were unable to get water during the day. The city received substantial grants to improve water and sewer systems; the grants covered about two-thirds of the cost of each. Aiken sold $85,000 in water revenue certificates for its local contribution. A new filter system and a 50,000-gallon water storage tank were constructed. The expansion of fire and police protection within the city had to be handled by city funding. The installation of 1,000 parking meters helped with those costs.[37]



Aiken's commercial or business development was described as conservative, with few new businesses established.[38] White's of Augusta, a department store, was the largest new business established between the announcement and September 1952. A shopping center on the south side of Aiken included a supermarket, dry cleaner, drug store, and a 5 & 10. Otherwise, Aiken's historic downtown commercial strip handled the city's businesses, while specialty items could be purchased in Augusta. The UNC study observed, "With North Augusta, Aiken appeared to be the preferred location for many of the in-migrant Du Pont and AEC personnel. The town was receiving a sizable number of well-educated, middle-income new residents who were building and buying housing in the $10,000 to $30,000 class, and who exhibited many of the status symbols in behavior and dress which made them accepted associates of local 'society' people." [39]

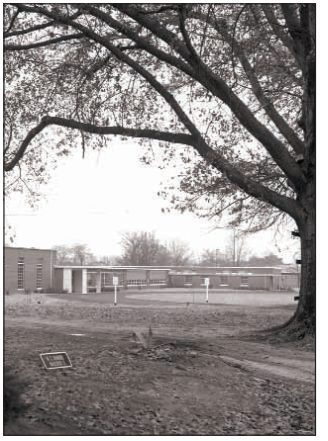
(Left) Southside commercial development, Aiken, circa 1955. Courtesy of SRS Archives, negative 1508-20. (Below) Fast food comes to town, Amber House, Aiken, circa 1955. Courtesy of SRS Archives, negative 738-5.



Smaller towns experienced growth as well. Williston, located six miles northeast of the plant in Barnwell County, was originally a small rural trade center. The city registered a 76 percent increase in population between 1950 and 1953 and almost doubled its built-up land area, adding over 8 miles of new streets. This overall increase in land area was due in part to the location of trailer parks and the Du Pont trailer city within its limits. School facilities were enlarged by 22 temporary and 16 permanent classrooms. Williston's commercial sector increased 30 percent by 1953, and its water and sewer facilities were improved with federal grants and loans supplemented by local funds. The water system cost in its entirety $277,500, the sewer system improvements $500,000. Prior to 1950 the city's sewage had been a long-term problem, most residents were served by individual septic tanks.



Barnwell County's seat, Barnwell, saw similar growth. Located about seven miles east of the plant, the town in 1950 had 2,005 residents. It was a commercial center within a rural county with some light industry. The town's land area increased by 95 percent through annexation, and over 10 miles of new streets were added. After annexation of a large amount of land in 1952, the town's population was estimated at 10,000. Barnwell contained the largest of the Du Pont trailer cities (4,400 persons) and its population change reflects that. To handle the needs of its new residents, the city's commercial base expanded, increasing about 50 percent from its pre-announcement size. The number of classrooms added to handle the new growth was considerable: 30 temporary and 33 permanent. Federal grants underwrote the temporary buildings and the majority of costs involved with the permanent construction. Water and sewer improvements were completed, mostly underwritten by federal grants.





(Above) Williston's railroad depot and business district, 1955. Courtesy of SRS Archives, negative 3389-1. (Inset) Barnwell School. Courtesy of SRS Archives, negative 3080-6. (Below) Commercial section, Barnwell, 1950. Courtesy of SRS Archives, negative 6950-1.

Allendale, nineteen miles from the plant, also saw change that emanated from the plant. Its population increased from 2,474 to 3,400 in late 1952.[40]

New Ellenton on the plant's perimeter on SC Highway 19 was essentially a new town directly attributable to SRP. The site of the town was a series of rolling sandhills on either side of Highway 19 between Aiken and Ellenton. The vicinity, a portion of the Talatha settlement, was acquired and promoted as a relocation site for Ellenton residents and others who lost their home places and as a place where newcomers could park their trailers. The chief promoters, some of the old business leaders from Ellenton, met with HHFA and AEC officials to plan their efforts.

The site chosen was less than desirable from a water-supply perspective. First forecasts suggested that there was little potential for an adequate water supply for a town and that bringing water in from another source would be an expensive venture.

> Nevertheless, the group pushed the development of the town, calling it New Ellenton, probably in the hopes that the name would exert an attracting power for residents of the old town. Some New Ellenton leaders often expressed the feeling that the town was a planned community because the streets had been laid out on a gridiron pattern, the hilly topography notwithstanding. With no experience or no advice on civic design and site planning, the promoters were intent on using a gridiron pattern to simplify deed descriptions in the sale of land parcels. The gridiron pattern was bulldozed into the hills and the street pattern took shape without regard to grades, drainage, soil erosion, or aesthetics.[41]

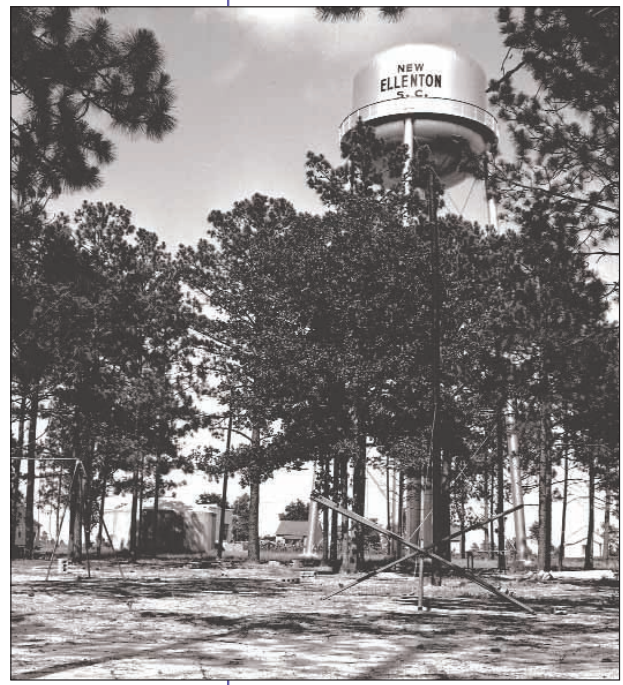


This farmstead was located in what would become the New Ellenton townsite. Courtesy of SRS Archives, negative 2713-10.

Some homes were moved there and others were built there. Houses moved from the plant area were placed on the East Side of Highway 19. These buildings with no indoor plumbing became rental properties for African Americans displaced from the Federal reservation. New homes intermixed with moved homes were placed on the West Side of the highway, laid out in a similar fashion to the African American neighborhoods. Single trailers and trailer parks were also part of New Ellenton's residential building stock. Drainage problems were profound on both sides of the highway.

In response to the many cars that filed through the new town site on their way to the plant, stores, filling stations, trailer parks, trailer sales lots and other service-related properties began to line Highway 19 within the new city. In December 1951, there were 25 businesses, 52 in June 1952, and 79 in February of 1953. Some of the businesses and homes that were placed along the highway were lost when Highway 19 was widened in 1952. With the incorporation of New Ellenton in mid-1952, the problems worsened. There was no funding available for municipal services, let alone to solve the water supply problem. The latter would finally be solved when a special congressional authorization in 1953 brought relief.

New Ellenton Water Tower and Buildings. Courtesy of SRS Archives, negative 2722-12.



The UNC study states that the town was home to 583 African Americans housed in permanent houses, 499 whites in permanent houses, 1,722 whites in trailers in parks, and 962 whites in temporary houses and single trailers. The total estimated population was estimated at 3,777 in 1952.[42] A census taken in January 1953 counted 4,011 individuals, half of whom were temporary residents associated with plant construction. The housing inventory included 161 homes occupied by African Americans, of which 140 to 150 had been moved to the new town. A total of 254 homes were occupied by whites, of which 50 to 60 had been moved. In addition, 205 single trailers, 550 to 600 trailers in parks, 12 tents, 14 expandable trailer units, and 35 hotels or barracks were inventoried. Of all of these only nine houses predated "New Ellenton," and these were individual farmsteads. None

of the programmed subdivisions were located at New Ellenton. This may have been due to the lack of a central water system that made the town vulnerable to fire and made banks reluctant to lend money for homes or other capitol improvements there. The city's first tax assessment was underway in 1953.



(Above) City of Jackson depot, 1950. Courtesy of SRS Archives, negative 2837-23. (Right) City of Jackson Fire Hall and Chief of Police, 1950. Courtesy of SRS Archives, negative 2837-3.

Jackson, on the plant's northwestern periphery, was a town of 200 in 1950, growing to 2,580 in 1953. Jackson's growth stemmed from both the relocation of plant families and newcomers coming to the area. It had 72 dwellings prior to the AEC announcement, and its commercial and institutional buildings were limited to two stores, some filling stations, a church, and a post office located in a store. Within a year, much change occurred. A new post office, a dry cleaning plant, a telephone exchange building, and a doctor's office were either built or under way. The Mack Foreman supermarket with a new soda shop was a source of community pride, and a theater was under consideration to replace a makeshift movie outlet housed in a tent.[43]

One hundred and thirty-two homes were moved to Jackson from the plant area, 60 new homes were built, and almost 400 trailers were located within the city. Only 15 temporary classrooms were added, all funded by Federal grants. The town had a sprawling layout through which new development was scattered. Jackson also received grants and loans in the amount of $235,000 for a water system to handle the needs of its new population.[44]



The federal acquisition program also created two small communities or settlements. The Hollow Creek section on Highway 781, about six miles west of New Ellenton, and Zion's Fair, a settlement north and west of New Ellenton, became home to concentrations of African-Americans households.[45] The majority of homes in these new settlements had been moved from the plant area. The Zion's Fair community included the church of that name described as an "old church on new foundations" that had been moved to the area along White Pond Road off Highway 19.[46] No Federal funding was mentioned in conjunction with these communities.

Finally, health services were considered insufficient to handle the influx of newcomers. There were so few doctors that patients waited from two to four hours for medical

treatment at office calls. Barnwell County had no hospitals, causing patients to travel to Orangeburg's 134-bed facility where overcrowding was an issue. Allendale had a 28-bed facility, and Bamberg County opened a 33-bed facility in 1952. Aiken's hospital had 115 beds, but was not as well staffed as Orangeburg's hospital and the patient care was found



Jonas Floyd in front of homes moved from plant area to the new African-American community called "Zion's Fair" on White Pond Road, north of SRS, 1952. Courtesy of SRS Archives, negative 1319003.

wanting. Serious cases were referred to Augusta's 479-bed University Hospital, which was a teaching facility for the Medical College of Georgia. The opening of St. Joseph's Hospital in 1952 provided some relief. However, the dependence of South Carolina's population on the Georgia health facilities continually caused overcrowding. Three federal grants helped area hospitals. Orangeburg Regional received a $300,000 grant under Public Law 139 to fund an additional 33 beds. Barnwell County received a $416,000 grant to establish a 40-bed hospital; the entire project would cost $650,000. And Augusta's University Hospital received $898,000 toward its $1,300,000 renovation program. The Barnwell County and Augusta grants were made under the Hill-Burton Act.

With the newcomers and the many expansions came the concomitant problems of sanitation and refuse disposal. Barnwell continued to have serious problems through the summer of 1952, and Aiken had not adopted modern landfill disposal plans by the spring of 1953. The UNC study notes that Aiken's open dumps and rat population were well publicized and that progress was slow in changing the situation. New Ellenton had similar problems through 1953 as it struggled to get its municipal services moving.[47]

NEON SIGNS ON BROAD STREET

SRP construction workers' preference for Augusta as a place to live was discussed above. Between the thousands of SRP construction workers and the military personnel stationed at Camp Gordon, Augusta had not only a vigorous commercial life but a lively nightlife as well. When Albert Howell, an editor of the *Aiken Standard & Review*, was interviewed on the impact of construction workers on his hometown, he predicted confidently, "They'll go to Augusta, This town's too dull for them. No night clubs, no roadhouses. You can get liquor in South Carolina only between sunrise and sunset, and you have to buy it by the bottle and drink it in somebody's home. No bars. Their big Saturday

Reaction from the Winter Colony

Terence Preece, one of the country's best polo players said of the construction men. "Those I've seen so far are rabid polo fans. We have sold more dollar admissions this year than ever before."

Gracefields, a seven thousand-acre hunting preserve near Ellenton that was formerly leased by Mrs. W.R. Grace, of the shipping family, for shooting parties, has been acquired by the government as part of its site. " Oh, well, there's no point on crying," Mrs. Grace assured me philosophically. "I've had a good time. The hydrogen bomb hasn't been the only surprise. This past winter, we had one of the coldest snaps and the camellias went. And, of course, in New York, the Ritz-Carlton's coming down. I lived there for eight years."

The feeling along Whiskey Road is that the hibernating grounds of the winter people will be left alone. "Or take it from a New York angle: Does anyone at the Racquet Club care what happens on the West Side?"

night would be dismal. All they could do would be sit in a restaurant and drink beer until midnight when the blue laws take over. But Augusta is wide open."[48] The data presented by the UNC study suggests that Howell was correct, as many construction men preferred living in an urban environment that had cultural amenities as well as a nightlife.

Historian Edward Cashin observed that sometimes an outsider can draw a more accurate picture of a place than one who is its familiar.[49] This was the case with an article written by Dorothy Kilgallen, a newspaper columnist and television personality, about Augusta. Kilgallen drew a portrait of the city's nightlife that captured how wide open Augusta was, and described a city that was a curious mix of the past and the future.

> It has white mansions and magnolias, honky-tonks and the H-bomb. It swarms with casual G.I.s from Camp Gordon, and it shelters proud D.A.R.s from the best families. It is beautiful with gambrel roofs and lacy ironwork, creeping vines and colonial porticoes; it is brash with jazz brasses and roulette wheels and chuck-a-luck and slot machines and strip-teasers and a sweet talkin' disregard for laws that people don't like. It is a town named for a princess, but early in 1951, in a swift, almost transvestite, metamorphosis, it became a virile, booming young giant…. the [Savannah River] project brought with it - the hordes of strangers, the new little saloons with their neon signs on Broad Street, the flashy floor shows, the new money, the new tempo allegro.[50]

Kilgallen was treated to a taste of Augusta's nightlife that began at the sedate Bon Air, moved to the Colonial Club, then a lobster dinner at the Town Tavern, followed by the Zoom Club on Broad Street that featured a singer like Sarah Vaughan, drove by Jack Dempsey's bar, then into "The Terry." The Territory was the African-American part of town. Charlie's Paramount in the Terry featured a jazz band, the Club Rio a society-dance band, and the Sand Bar put on a "rather standard strip act." Then Kilgallen accompanied by Louis Harris, the managing editor for the *Augusta Chronicle,* crossed the Savannah to visit the Club Royal in Hamburg, South Carolina. At three in the morning, Kilgallen and Harris returned to the Bon Air, but as she pointed out, they left quite a few Augustans behind who gave no indications of being ready to go to bed. She reported that despite the law that liquor could be purchased only at package stores, there were between 40 and 50 places where mixed drinks were served in Augusta, and that number did not include the many clubs where drinking and gambling were tolerated. Kilgallen's portrait was not appreciated in Augusta after it was published, but she had left a lasting impression of a city in change: "Since the H-bomb, more citizens are making history than recalling it."[51]

CONTINUED GROWTH

The economic impact of the plant continued after the construction period. The base construction, land acquisition, improvements to the facilities, and purchased equipment alone was figured at $1,546,435,000. Between 1951 and 1973, salaries and wages earned by Savannah River Plant employees in Construction, Operations, and the AEC reached

$1,652,307,000, an average of close to 72 million dollars annually. By 1970, the plant's annual operating budget averaged 117 million per year. The 1972 payroll, which reached $77.5 million ($74.3 for Du Pont including construction, and $3.2 million for the AEC), was the largest single payroll in the State of South Carolina. The total work force at the plant was counted at 5,902 with 5,265 or 89 percent in Du Pont Operations, 472 or 8 percent in Du Pont Construction, and 165 or three percent in the AEC. These figures on federal expenditures at Savannah River were prepared by the Savannah River Operations Office for use in compiling the President's proposed 1975 budget.[52] Appendix E contains the plant's annual operating budgets from 1950 - 1994. Census figures show the changes in occupational profiles that occurred between 1940 and 1960 in the plant area, particularly in the South Carolina counties adjacent to the plant. Emphasis has been placed on the South Carolina counties rather than the Augusta-Richmond County area. While Augusta, as the major economic hub and cosmopolitan center of the CSRA, reaped the economic benefits of the wages and salaries discussed above, its growth was shaped by a number of factors that included the military presence of Ft. Gordon and ancillary facilities. Its cosmopolitan character was already established and its workforce varied given its industrial history and its age. Given this, occupational statistics from the 1950 and 1960 Federal census were consulted for Aiken, Allendale, and Barnwell counties to better identify occupational change that could be attributed to the establishment of Savannah River.[53]

Comparison between statistics for Aiken, Allendale, and Barnwell counties show that Aiken showed the most change, then Barnwell. Professional and technical workers for Aiken, Allendale, and Barnwell counties were enumerated in 1950 respectively at 991, 202, and 283. A decade later, the same category of employment almost tripled in Aiken County (2,976) and showed healthy increases in Allendale (306) and Barnwell (482) counties. Notably, "Engineers Technical" first occurs as an employment category in the 1960 census tables that show occupations of county residents. 584 engineers were counted as Aiken County residents; 8 in Allendale County and 41 in Barnwell County in 1960. Growth occurred in other occupational groups related to SRP. Aiken County's clerical work force grew from 1,120 in 1950 to 2,845 in 1960. Barnwell's clerical workers grew to 494 from the 1950 number of 156. The number of clerical workers in Allendale doubled, increasing from 141 to 276 within ten years. The number of craftsmen and foremen also grew from 2,243 in 1950 to 4,213 in 1960 in Aiken County.

In 1950 agriculture and textile manufacturing were the principal industries in Aiken County. By 1960, the number of men and women employed in non-agricultural industries swelled to 26,230 or 93 percent of the county's total work force. The establishment of the plant played a role in this change as well as a regional decline in farming. The textile industry, however, held its own; approximately 6,367 "operatives" were employed in Aiken County. While agriculture was the main industry for Allendale and Barnwell counties, non-agricultural industries took the lead in 1960 for both counties. Again, such changes were probably the result of larger regional changes in economic pattern, but the coming of the Savannah River Plant may also have been a factor. Occupational census figures also show changes in the number of women in the workforce and the types of occupation they were engaged in. Again, Aiken County statistics show a different pattern than Allendale and

More Reactions:

"I think the heads of departments would make interesting additions," she said. "There's a beautiful forty-four acre section of my property on which I'm ready to let twenty-five of them build houses, provided the character of the property is preserved." — Mrs. C. Oliver Iselin (She was in exuberant spirits, her trainer having just phoned her from the Jamaican track that one of her horses had won a race)."

Source: Daniel Lang, *The New Yorker*, "Camellias to Bombs," July 7, 1951.



Women at SRP. A view of the plant's employment waiting room in 1956 shows that women were well represented among prospective applicants. Jobs were available in clerical positions, food preparation, and maintenance for the majority of the first generation of Savannah River women. Courtesy of SRS Archives, negative 2150.

"Different Kind of Growth"

Growth occurred in more abstract ways as well. Ken Kilbourne, executive secretary of the Aiken Chamber of Commerce in 1957, said that Aiken noted the population and economic growth, but also saw "a very worthwhile broadening of our cultural advantages. . . . . Our schools and recreational facilities have been improved and enlarged. So have our civic and professional organizations. And here's something that seems significant to me: just the other day the *Encyclopedia Britannica* folks told me that they received more inquiries per family from Aiken than any other city in the country"

Source: *SRP News and Views*, February 15, 1957, "Towns Surrounding Plant Grew With Us," V(1):7.

Barnwell counties. In 1950, 5,837 Aiken County women were employed. Thirty-four percent were operatives, 19 percent were private household workers, 12 percent were clerical workers, eight percent were considered professionals, .09 percent were laborers (non-agricultural and agricultural), .05 percent were service workers, and .05 percent were in sales. The remainder worked as farm managers (96) and managers (175). In 1960, a total of 9,299 women were employed in Aiken County, an increase of 62 percent since 1950. The breakdown of occupations listed in 1960 also show shifting trends in employment as clerical workers increased in number, as did the number of professional women. The number of operatives and private household workers decreased. The majority of Aiken County women were operatives (22 percent), clerical workers (21 percent), and private household workers (16 percent) and professional women (medical personnel, teachers, and other professional) counted for 12 percent of the workforce, .07 percent were involved with retail sales and .03 percent were managers. Other occupations represented were: laborers, craftsmen, and foremen service workers. The shift to clerical occupations and professional jobs probably shows the impact of SRP on the female workforce and the beginnings of the movement toward two income families.

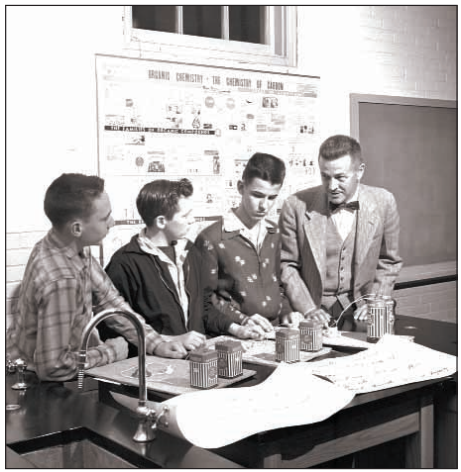
In comparison to Aiken County, employment for women in Allendale and Barnwell counties remained fairly static. Agricultural jobs, domestic work, and service work remained strong occupations for Allendale women in 1950 and 1960. The female Allendale workforce grew slightly, occupations for 1,309 women were given in 1950, and occupations were given for 1,680 in 1960. The census reported 1,886 women were employed in Barnwell County in 1950, 2,129 in 1960. Unlike Allendale County, private household workers were in the majority in Barnwell County in 1960 (20 percent), followed by operatives (18 percent), clerical (15 percent), professional women (10 percent), and farm laborers and foremen (10 percent). Farm managers, service workers, and non-farm laborers were also represented.

Occupational statistics for the closest South Carolina counties to the SRP indicate that Aiken County appears to have been the most affected in terms of the increase in jobholders between 1950 and 1960. Shifts appear to have occurred in occupational categories as agriculture becomes less important to all three county economies between 1950 and 1960 and as non-agricultural industries become a part of the CSRA scene on the South Carolina side. SRP was a pivotal factor in Aiken County's growing diversification and although textile manufacturing remained a fundamental part of the Aiken economy, technological professional jobholders begin to encroach on that dominance. The movement of women into the job market is also apparent as women in clerical and professional positions were recruited for work at the plant. The economies of Allendale and Barnwell counties share in the regional decrease in importance of agriculture, but show less impact in terms of occupations for both men and women. Aiken County was the preferred place to reside and the occupational statistics reflect this preference.

SETTING DOWN ROOTS

SRP brought to the CSRA a plant involved in not only production, but also in research and development in one of the most advanced technologies of the day, nuclear physics. These were times when the general public viewed atomic weaponry more as a promise of

peace than a threat, and associated developments in nuclear physics and atomic energy with a promise of at least cheap energy, if not of an entirely new age of civilization. The CSRA had been chosen as a one of the main points where that new civilization would begin. The influx of thousands of people to build the new plant and to conduct the research there made a great impact on the residents, both the new arrivals and those that had known the region before the change. Even children, or perhaps especially children, were infected with the excitement of the new endeavor in the CSRA region. In 1954, Heavy Water Technology employee Mac Latimer heard a child digging in the sand tell another, "Don't tear it down. That's my research project!"[54]



SRP scientist and Graniteville students work on laboratory experiment. Courtesy of SRS Archives, negative 4296-5.

Relationships with local and regional universities were cemented early in 1951 when the AEC entered into five-year contracts with The University of Georgia and the University of South Carolina to perform ecological studies at the plant. The University of South Carolina was asked to perform a taxonomic study of the plant area's plants and animals. The University of Georgia was to look at the larger picture and chart ecological change within the preserve.[55] The Georgia group had more staying power. Their efforts moved beyond inventory and they eventually established a program on the plant under Dr. Eugene Odum.

Tour of SRP laboratory by African American high school students, 1956. Courtesy of SRS Archives, negative 4998-6.



The University of South Carolina, however, developed another supporting role to the plant. In 1952, it began extension classes in Aiken at the high school in distillation in chemical engineering, pre-stressed concrete in civil engineering, and nuclear physics for graduate credit. Undergraduate credits were offered for courses in radiation physics, advanced calculus, and industrial organization and management.[56] The need for these classes and community growth spurred the establishment of the future USC–Aiken in 1961. In Columbia, USC further offered Saturday morning classes in nuclear physics and instrumental methods of analysis for graduate credit.[57] Augusta's higher education system would also grow. An August 1952 article in the *SRP News and Views* advertised for registration for night classes at the Richmond Academy and the Junior College of Augusta for credit toward college degrees and vocational training under the University of Georgia's extension classes program.[58] UGA's extension program later focused its efforts at Camp Gordon where it offered 45 courses. Tuition was $4.00 per credit hour for each quarter.[59] Finally, 21 students were enrolled in a field course in CPA Review given by USC at the plant, also as an extension course.[60] Aiken Chamber of Commerce secretary Ken Kilbourne commented in 1957,

"Even the curriculum of our schools have been affected as both children of Plant employees and others have taken on a great interest in scientific and technical courses. At the present time a movement, which I am convinced will eventually be successful, is under way to establish a four-year college in Augusta. Much of the strength of this movement can be traced directly to the influence of the Savannah River Plant and its highly trained employees."[61]



High Schoolers Explain Atomic Energy to Elders

No long-haired physicists but youthful students from Aiken High School, among them children of Savannah River Project employes, had the job of explaining atomic energy to the 8,000 persons who visited the American Museum of Atomic Energy exhibit when it set up shop, appropriately, at the city's futuristic new high school building. Carefully trained for their jobs, the student demonstrators reeled off information on nuclear fission, isotopes and other subjects to the amazement of their elders.

Explaining a reactor model to Curtis A. Nelson, right, top photo, the Atomic Energy Commission's manager for the Savannah River Plant, came easy for Jimmy Payne, left, son of Dunn Electric Line Foreman Leonard F. Payne of 200-H, and Jimmy Miller, son of B.F. Shaw Steamfitter Foreman Edward R. Miller, 100-K. Both boys are 10th grade students at Aiken High School.

Sally Herrmann, holding Geiger counter, tells how atomic energy combats disease to a group of visitors that includes her dad, Roy W. Herrmann, general superintendent, Carpentry and Paint, and his six-months-old grandson, Peter Roy Herrmann. (Photos by Salter)

MUSEUM OF ATOMIC ENERGY

FPM's Safety Achievement Award

Area	Craft
Week Ending March 9	
Miscellaneous Area Construction -- E. A. Rachal, division engineer.	Labor and Masonry -- Joe Kirkpatrick, general superintendent.
Week Ending March 16	
Miscellaneous Area Construction--J. F. Eppes, assistant field superintendent.	Labor and Masonry -- Joe Kirkpatrick, general superintendent.

When Oak Ridge's American Museum of Atomic Energy traveling exhibit was installed at Aiken High School's new gymnasium in 1955, all of Aiken turned out. The Van de Graff electrostatic generator and an exhibit "reactor" that irradiated exhibit goers' dimes were the main draws. Children of plant employees helped to interpret the exhibits, holding forth on nuclear fission, isotopes, and "other subjects to the amazement of their elders." Source: *SRP News and Views*, 1955.

Informal lectures were also held to benefit the general public. The YWCA sponsored a set of six lectures on atomic energy by SRP's Joseph Finke that ranged in subject material from the nature of matter to SRP's reactors.[62] An all-day seminar held for 620 of the CSRA's teachers, who wanted to learn more about atomic energy and how to include it and its development in their curriculum, was a success. The seminar, held at Aiken's Schofield High School, brought two AEC officials from Washington, one a specialist in education and the second, a classification expert. John Gray, Winston Davis, and Arthur Tackman represented the plant. A reporter observed at the close of the seminar, "the inter-

est of the teachers in learning more about atomic energy was apparent by the large turn out and the attentiveness of the group during the lectures."[63]

The interest by area educators was further expressed a year later when an exhibit put together by Oak Ridge's American Museum of Atomic Energy came to Aiken's new high school gymnasium in March. The main draw for the mobile exhibit was the Van De Graff electrostatic generator that was invented by Dr. Robert J. Van De Graff at MIT and also the exhibit "reactor" that could irradiate exhibit goers' dimes. Teaser articles were published on the important role atomic energy promised for future medicine. More than 830,000 individuals had seen the exhibit before it came to Aiken, and these numbers so impressed the Chamber of Commerce that they made the securing of an "Atomic Museum" a goal for the city in 1955.[64]



(Above) New chapters of national professional organizations were established. In this view, the Savannah River Chapter of the Engineering Association hold a meeting at the plant. Courtesy of SRS Archives, negative M-479b.

Regional chapters of national professional organizations were newly created as the plant's technical staff sought to establish regional networks and to maintain ties with the national communities. The Savannah River Chapter of the South Carolina Society of Engineers was created in 1952 and promptly claimed as members one-third of the project's engineers, with membership expected to reach 500.[65] The Savannah River Chapter of the American Society for Metals, chartered in 1954, began to hold meetings and invite speakers with national reputations to the plant area. Presentations at venues such as the Old Heidelburg Inn were well-publicized and the CSRA public was invited to attend. The Savannah River Chemical Engineers Club of Aiken and Augusta, organized in 1953, was equally energetic, inviting members of the government's national laboratories' staff to town for presentations.[66]

Social clubs were formed such as Du Pont's Supervisory Club, which had a membership of 230 supervisors from across the plant. No shop talk was allowed; the idea was to foster friendship among the new staff and to acquaint them with their new home community. Accordingly, a meeting, held at Kaps' Plantation Room, brought together the new Du Ponters with Captain Gaylard, Aiken's polo referee and riding master, and Kenneth Dresner, an authority on polo and ponies.[67] The Atomic Energy Club was open to AEC personnel.[68] Social clubs were established for women that catered to the working woman as well as the homemaker. The Newcomers Career Club in Augusta invited all career women new to the Savannah River Area into its folds.[69]



(Below) An explosion and fire in downtown Aiken on January 27, 1953 claimed 10 lives. Personnel and equipment from the Savannah River Site's Fire, Patrol and Medical assisted at the scene for 20 hours and recovered the bodies. Courtesy of SRS Archives, negative DPESF 463-6.

Community ties developed as plant families volunteered and performed community service. As examples, in 1954 two employees were elected as presidents of the Aiken Estates Civic Association and the Dunbarton Oaks Association.[70] A swimming pool was completed in 1956 in Williston, built by volunteers, many of whom were SRP employees. SRP employees also organized and staffed the Richmond County Suburban Fire Department.[71] Frank Adams, general superintendent of General Services arrived to work at SRP in 1951. By the time he had been

in the area ten years, he had served as president of the Augusta-North Augusta United Fund, had served as chairman of the Augusta chapter of the American Red Cross, and became president of the Augusta Rotary Club.[72] Kris Gimmy, who worked in Reactor Technology, conducted the Aiken Concert Band, which included a number of SRP employees.[73] Inside the plant fence, the Community Chest Program was chosen by the plant management as a way for workers to show their community support. Each year, money was energetically collected in support of this program, and contributors would indicate which community should receive their donation. In 1952, $50,908 was contributed; a year later, the total soared to $74,015. Local leadership for the area communities posed with plant management as the checks were presented.



(Above) Presentation of check by the officials of the Savannah River Plant to Aiken County Community Chest on November 24,1952. (Left to Right) Curtis Nelson, Manager, Strom Thurmond, Chairman of Aiken County Community Chest, Don A. Miller, Manager of Operations, and R.K. Mason, Field Project Manager. and Bob Mason watch. Strom Thurmond Collection, photograph 1034. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

The newcomers contributed to larger social and political change as Augusta's Lester Moody had predicted. The AEC and Du Pont joined forces in putting pressure on the FCC to allow television broadcasting in Augusta because it would be of "inestimable value as a source of recreation" for project employees. Augusta was assigned channels six and twelve.[74]

In race relations, the plant's presence brought slow but steady change as the distance between Federal law and South Carolina law and custom narrowed over time. Notably, Clemson University would reject a sizable AEC grant in 1957 to fund a nuclear program because the grant contract stipulated that the program would have to be open for enrollment by all students. While such a nuclear program was considered highly desirable—" almost essential"—by Edgar Brown, it would come at too high a cost. Clemson refused the grant while Georgia Tech and the University of North Carolina went forward with their plans with the AEC funding.[75]



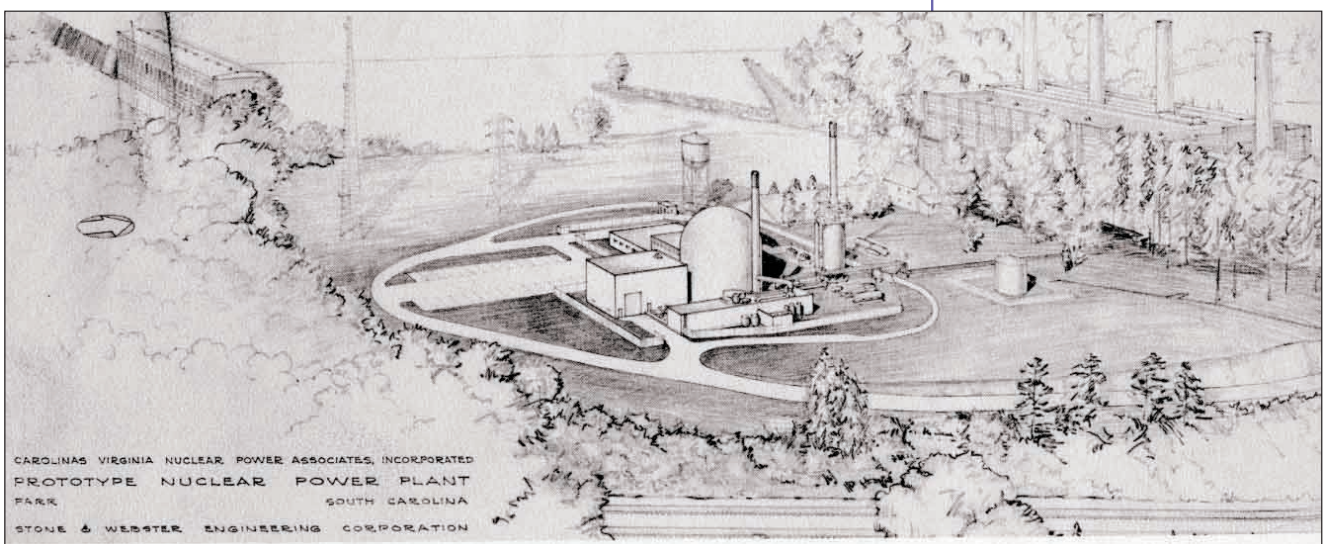
(Right) Eisenhower inauguration, 1953. Former President Harry S. Truman, President Dwight D. Eisenhower, Vice President Richard M. Nixon and former President Herbert Hoover. Strom Thurmond Collection, photograph 10380. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

Plant employees played an instrumental role in establishing the Republican Party in Aiken County and surrounds. Traditionally, there had been only one party in South Carolina, the Democratic Party. Historian Walter Edgar quotes Governor Olin D. Johnston who in 1936, provided Democrats with a depiction of how his fellow statesmen would regard a Republican: "There are some grown children down in my state who have never seen a Republican in their lives, and would perhaps run from one if such a strange being wandered too close to their homes."[76] The growth of industry in the state brought different viewpoints into the state's political arena and the inclusion of a strong civil rights agenda within the Democratic Party platform dissatisfied some South Carolinians. Those dissatisfied formed the Dixiecrats or States Rights Party and nominated Governor Strom Thurmond for president. Governor Thurmond successfully carried his home state and gar-

nered more than a million popular votes, but the party disappeared after the election. The formation of the Dixiecrats marked the beginning of South Carolina's two party politics however. In 1952, Governor James F. Byrnes, an opponent of Truman, formed "Democrats for Eisenhower" and campaigned for Eisenhower across the state, garnering more dissatisfied Democrats. Increasing dissatisfaction with the Democratic platform triggered many to change their affiliation, and the young Republican Party in South Carolina was strengthened when Senator Thurmond switched parties in 1964 to begin campaigning for Barry Goldwater, who carried South Carolina in the presidential election. Historian Walter Edgar notes that the success of the state Republican politicians was not fully realized until the election of 1966 when statewide offices were carried by Republican party members.[77]

Many of SRP's operations staff who were Republicans prior to their move to Aiken wished to vote accordingly and joined forces with others to establish the Republican Party in South Carolina and in their local communities. Aiken was a case in point. A slate of three site employees, Tallie Crocker, Gene England, and Ed Sampson ran repeatedly for Aiken City Council on the Republican ticket in the late 1950s. By 1964, the local Republicans captured three seats.[78] Efforts to organize the party on the county level occurred in the early 1960s. SRP employee Walt Joseph remembers the first convention. "The law required political conventions to be held in public buildings so the group reserved the courthouse for the designated evening. When the small band of party faithful arrived for the convention, they discovered the courthouse dark and locked. Repeated

Southeast's First Atomic Power Plant, Parr Shoals, SC. Conceptual drawing of Carolinas Virginia Nuclear Power Plant to be built at Parr Shoals. Drawing by Stone & Webster Engineering Corporation. Source: Cover Illustration on brochure, *"Carolinas Virginia Nuclear Power Associates,"* not dated. Stetson Collection, SRS History Project.



ARTIST'S CONCEPTION of the Southeast's first atomic electric power plant now under construction at Parr, South Carolina.

CAROLINAS VIRGINIA NUCLEAR POWER ASSOCIATES

Formed in 1956 by four privately owned utilities.

Carolina Power & Light Company
South Carolina Electric & Gas Company
Duke Power Company
Virginia Electric and Power Company

attempts to phone the building custodian and other political figures were unsuccessful. Finally, in desperation, but within the letter of the law, the convention was held in the courthouse parking lot. Aiken County Republicans held the first countywide primary in the state of South Carolina in 1967. In some isolated precincts, parked cars with American flags served as makeshift polling places." Change was also imminent in Georgia when the Crackers on the Georgia side of the Savannah, who had held onto the reins of Augusta's city government, were brought up short by a wave of change that the newcomers helped to realize in the 1950s.



Conference on Atomic Energy held in Aiken, June 14, 1956. (Left to Right) R. M. Cooper, State Development Board, South Carolina Governor George Bell Timmerman, and Strom Thurmond, U.S. Senate Nominee from South Carolina. Strom Thurmond Collection, photograph 1255. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

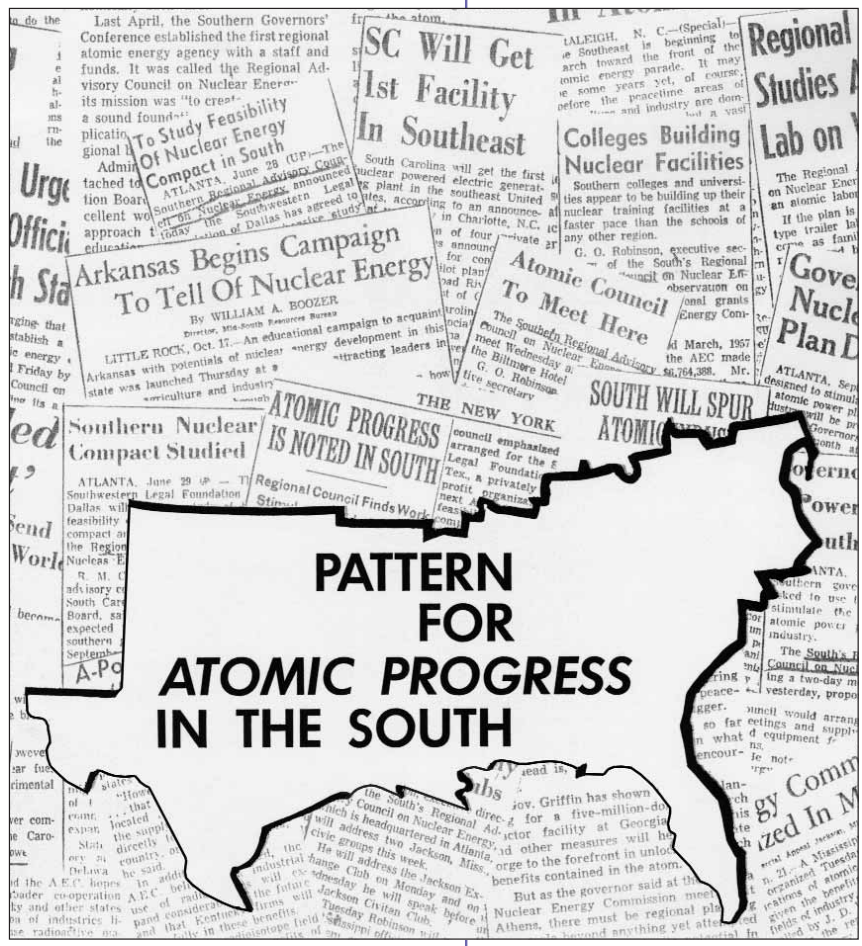
The creation of the Savannah River Plant was watched closely by the political leadership who saw nuclear energy as a path to regional economic growth. As new members of the growing nuclear community, Senator Edgar Brown and Governor Timmerman were invited to attend the tests at the Nevada Proving Grounds in April 1955. Another new member of the nuclear community, J. Strom Thurmond, would join with his colleagues in watching how the AEC spent monies in the future to make sure that South Carolina got its fair share. A proposal by South Carolina Electric & Gas for a test reactor at Parr, South Carolina, in 1955 was eagerly endorsed. Rumors that the AEC was going to build more reactors in early 1956 was watched closely by Thurmond, who would prefer them to be located at Savannah River rather than Hanford.[79] From new reactors to NASA installations, South Carolina was now a player with experience, and the fact that Senator Strom Thurmond was a native son didn't hurt. Edgar Brown was also a staunch supporter. The papers of Senators Thurmond and Brown show they both maintained an acute interest in the plant and the development of atomic energy for their home state, and both let decision-makers know what South Carolina had to offer.

While many of the first overtures at garnering additional nuclear projects were not successful, a proposal by the Carolinas-Virginia Nuclear Power Associates for the AEC's Power Demonstration Reactor Program in 1958 was successful. The Carolinas-Virginia Nuclear Power Associates was a collaboration of four utilities, Duke Power Company, Carolina Power and Light Company, South Carolina Electric and Gas Company, and Virginia Electric and Power Company. Stone and Webster Engineering Corporation and Westinghouse Electric Corporation built the $17 million reactor complex at Parr Shoals, South Carolina. The 17,000-kilowatt nuclear power plant at Parr Shoals featured a pressure-tube reactor, heavy-water-cooled and heavy-water-moderated, fueled with slightly enriched uranium. It is notable that it used heavy-water technology, as did the Savannah River Plant reactors.

While South Carolina's political leadership and Aiken's planning board were vigilant in protecting the plant and its future, other Southern states also watched the progress of the plant and its impact. The Southern Governor's Conference in 1955 took note and recommended that an exploratory study of the nuclear field and its applications be initiated within a southern context. In 1956, representatives of the Southern Governor's Association met for a "Work Conference on Atomic Energy" in Aiken to survey nuclear energy development in relationship to industry, agriculture, medicine, public health, manpower, and education. Between 75 and 100 delegates attended the Aiken conference led by the Southern Regional Education Board.[80] A tour of the plant was included for attendees.

The Regional Advisory Council on Nuclear Energy was formed in 1957, and a program was adopted to implement recommendations for state and regional actions in atomic energy. Foremost, the council began a study on the advisability of a nuclear energy compact among the 16 southern states "for the development and regulation of the atom." From the 1956 work sessions came several recommendations that would be the basis for the Council's program: to establish a central clearinghouse for public information on atomic developments on the south; to expand training programs in the South for technicians and skilled manpower; to encourage nuclear education at Oak Ridge Institute of Nuclear Studies; to hold regional conferences and seminars and expand regional facilities that dealt with agricultural research and radiation; to assist universities to plan nuclear research and educational programs; and to provide information on nuclear medical developments.

This far-reaching agenda involved the Savannah River Plant on two objectives. First an agreement was reached with the Southern Regional Education Board, and the AEC for the use of plant facilities to train students from southern universities and colleges. By 1958, students from the University of Florida, Georgia Institute of Technology, Alabama Polytechnic Institute, University of Georgia, University of Tennessee, and the University of Miami were in the program. No South Carolina universities were participants due to the funding proviso that enrollment should be open to all students. The plant was also considered for agricultural research, particularly, the use of radiation for forest research.[81]

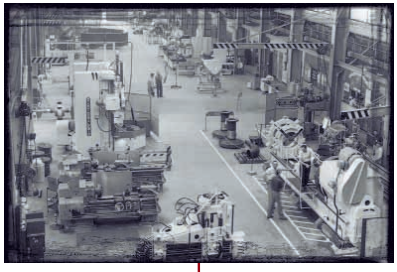


Cover illustration for *Pattern For Atomic Progress in the South.* This pamphlet was prepared by the Regional Advisory Council on Nuclear Energy for the Southern Governor's Conference held in Lexington, Kentucky on September 22, 1958. Strom Thurmond Collection, Mss 100, Subject Correspondence, "Atomic Energy," 1958. Courtesy of Special Collections, Clemson University Libraries, Clemson, South Carolina.

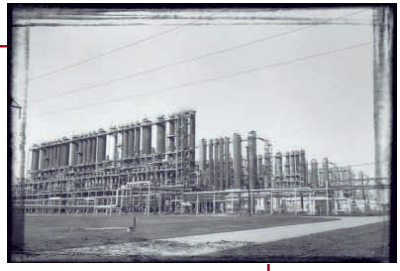
The work sessions of 1956, which produced the Regional Advisory Council on Nuclear Energy and the ambitious program outlined above, were aimed at jolting the South into a leadership position in exploiting the benign uses of the atom. The Council was subsumed under the Southern Interstate Nuclear Board (SINB) in 1961.[82] The jolt worked. Within a six-year period, all seventeen possible states signed the Southern Interstate Nuclear Compact, which was described as a nationally recognized nonfederal, public-supported program developed for services in nuclear energy, space, and related technologies. The compact was a model of interstate cooperation. The South may have lost out on the nineteenth-century industrial revolution, but Southern leaders had no intention of not being in the forefront of the revolution atomic energy had the potential to bring in the twentieth century.

We don't dig Uranium out of the ground, and we don't make bombs, but we do nearly everything in between.

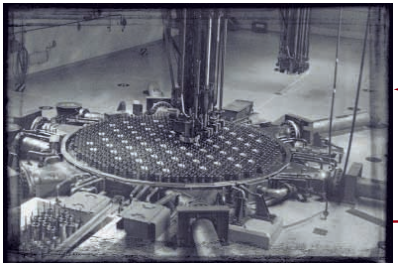
Plant Processes



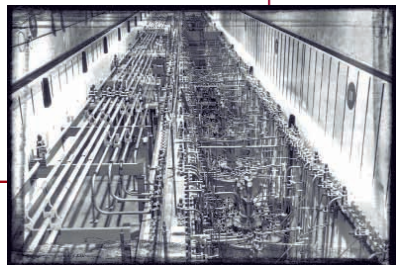
Fuel and Target Fabrication



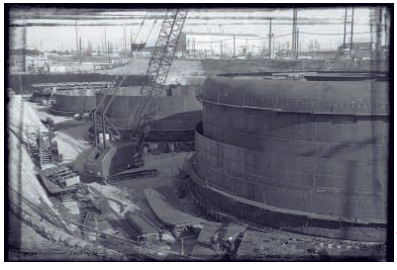
Heavy Water Extraction



Reactor Irradiation



Separations



Waste Management

Products

Plutonium-238

Produced by neutron irradiation of neptunium-237, a byproduct of uranium irradiation. Valuable for its heat generating capacity.

Curium-244

Properties and applications similar to plutonium-238.

Plutonium-239

Used as a nuclear explosive, a breeder reactor fuel, or as the starting target material for production of heavier radioisotopes.

Tritium *(Hydrogen-3)*

A radioactive isotope of hydrogen, component of thermonuclear explosives, and a potential fuel for thermonuclear fusion power generation.

Cobalt-60

Known radiation source and has long been used for radiotherapy.

Californium-252

One of the rarest man-made isotopes, has great potential value in medicine, industry, research, and education.

Heavy Water *(D_2O)*

Important nonradioactive product of the Savannah River Plant. It occurs at a concentration of 0.015% in natural water and must be concentrated to 99+% to be useful in reactors as a neutron moderator.

And Other Radioactive Isotopes

PART 3

Savannah River Plant (1953–1979)

Operations, Construction, and AEC personnel celebrated the first shipment of plutonium from Savannah River Plant on December 28, 1954. All three groups shared in the success of bringing the plant and its complex facilities into reality, training the new work force, and creating a safe, secure, and self-sufficient workplace. Once in operation, perfecting plant processes to increase efficient and safe production became the driving force of the plant. Savannah River Laboratory was established to advance operational know-how and to further develop plant processes. Support organizations such as Works Technical, Instruments and Engineering, Power, Traffic and Transportation and others underpinned the work in the process areas. Health Physics monitored the workplace and the environment. And the 700 Area became home to administrative personnel, both AEC and Du Pont. Each area had its identity and mission within the larger plant-wide goal to produce nuclear weapons materials.

AEC Commissioner Glenn Seaborg's mandate in the 1960s to explore the peaceful uses of atomic energy generated diversification within the Plant's products. The excitement of this growth is in marked contrast to the impacts of shutdowns in heavy-water production and two reactor areas at SRP compelled by a decrease in product need. Part Three describes SRP's main production processes during their heyday, the plant's efforts toward diversification during the Seaborg years, and the impact of the area and facility shutdowns caused by the growing size of the nation's atomic stockpile.

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Chapter Eleven
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Chapter Fifteen
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The Middle Years (1964–1979)

(Opposite) Source: Savannah River Laboratory, *Nucleonics of Tomorrow in the Making Here Today* (Aiken, South Carolina: E. I. du Pont de Nemours and Company, not dated).

11 Startup and First Years in Operation (1953–1963)

INTRODUCTION

Savannah River grew out of a web of national and international events in science, politics, and business development, as well as relationships developing among these toward common goals of national defense and an increased understanding and development of nuclear physics. Interaction with the local community and local residents' responses to the plant helped to shape its emerging identity. Although the primary goal of the site was to produce tritium and plutonium for the national nuclear weapons complex, the tenor of the times during the early years of operation pushed production at Savannah River into diverse missions. These first simply used the available versatility of the reactors, but by the 1960s began to make that versatility a key factor in the image projected of the plant by both Du Pont and the Atomic Energy Commission.



Operations, Construction, and AEC personnel pose in photograph taken in 221-F on December 28, 1954, commemorating the first shipment of plutonium from Savannah River. The photograph was first published in 1972 in the *Savannah River Plant News*. Its caption identifies the individuals as well as their 1972 job titles. "From left, Julian D. Ellett, general superintendent of Production and now manager of Du Pont Atomic Energy Division; Henry Greene, assistant plant manager; Sam Smiley, Separations; Don Miller, first plant manager; James J. Urban, Separations; Curtis A. Nelson, manager of AEC Savannah River Operations Office; Lowry Danser, Separations; Robert K. Mason, Construction field project manager; James K. Lower, Separations, now assistant plant manager; and Ralph Rosette, Julius Rubin, Goff Giboney and Dave Low, all of SROO." Source: *Savannah River Plant News*, Vol. XX, No. 1, February 18, 1972. Courtesy of SRS Archives, negative 1511007.

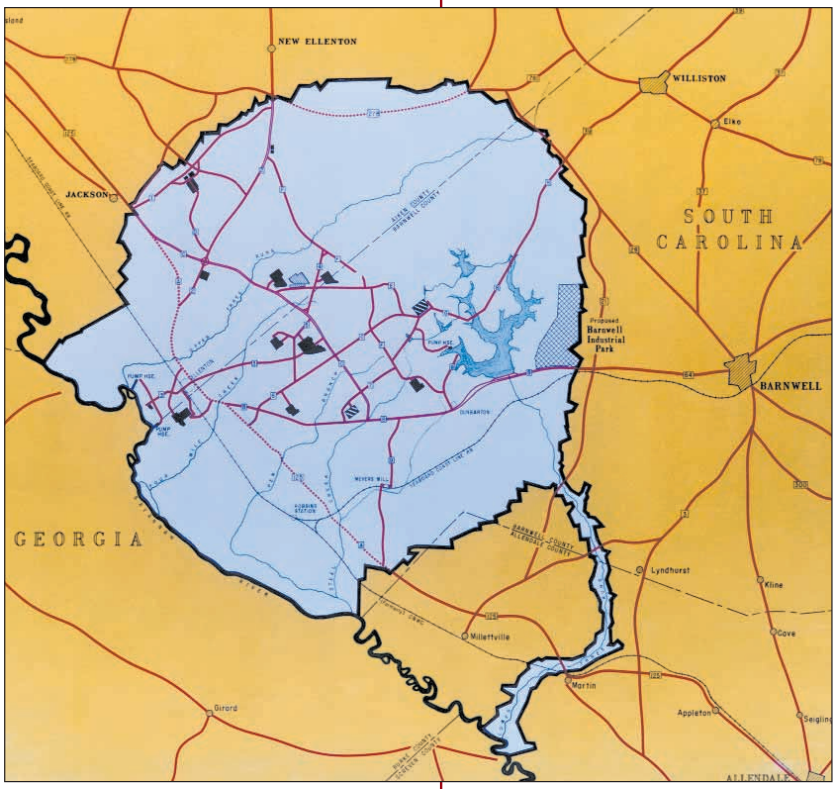
The approach to the administration of the operations at Savannah River developed in the political environment of the years that followed World War II. This was combined with the expertise Du Pont had gained during World War II and since the beginning of the twentieth century. The combination of business and government experience created a system of operations that governed in the individual areas and at the site as a whole, and that reached out to integrate Savannah River into the Atomic Energy Commission's national nuclear complex. Overarching and intertwined with site administration were concerns for security and safety. At Savannah River, as elsewhere, the former was necessary due to the military missions, and the latter due to the nature of the work at the site and the commitment of the Du Pont company.

The common threads that wove the site and its major processes into a system of operations are the focus of this chapter.

THE SAVANNAH RIVER SYSTEM

Du Pont organized its management of Savannah River in a way that allowed for input from a variety of administrative and functional divisions and departments to be considered in determining the means to achieve missions. Savannah River was part of an atomic energy infrastructure whose overall mission was production of weapons and non-weapons material to meet a variety of goals, and which also aimed to establish the groundwork for new atomic energy-related industries in the United States. Savannah River was not a single factory guided by a single administrative organization, but was nine factories under an administration that was, at times, a collaboration and at times a duel between government and contractor management.

In the broad view, the Atomic Energy Commission held the responsibility to establish the goals for the burgeoning nuclear industry in the nation, and to orchestrate the overtures played out across the continent in efforts to achieve its goals. Hand in hand with that responsibility was the necessity of relinquishing the authority and providing the support for the contractors of individual facilities to make their contributions. Du Pont was adamant in contract negotiations that it have the liberty to operate Savannah River in the way it saw best fit within the legal framework of the Atomic Energy Act, and that the Atomic Energy Commission help coordinate Du Pont's efforts with the other components within the national system. Without this coordination and attention to defined—even if evolving—goals, the effort would be shoddy if not ineffective. And Du Pont had little reason in the postwar era to deviate from its commercial endeavors and become involved in an effort that did not shine.



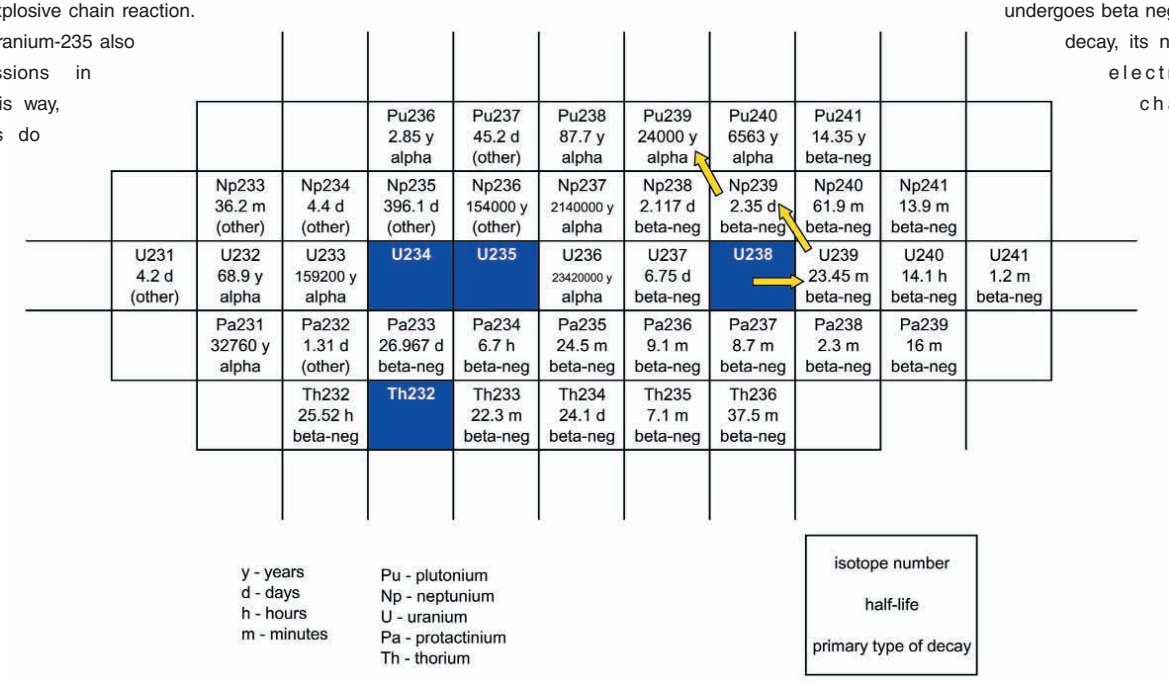
Savannah River Plant Site Map showing process areas in operation and site layout, circa 1970. Par Pond (center right) is shown. Hatching in Building Areas indicate that that process area is shut down. Source: SRS History Project.

Plutonium-239 and Tritium—The Weapons Mission

Plutonium is a chemical element that does not exist on earth, although it would be present in some exotic environments in space. Scientists at the University of California first produced the element in 1940. The first isotope produced was plutonium-238; the same group produced plutonium-239 the following year.

Plutonium has the atomic number 94, which means it has 94 protons in its nucleus. Add a proton or take away a proton, and the element will no longer be plutonium—it will become americium if a proton is added, neptunium if one is taken away. To put it another way, the chemical element with 94 protons is called plutonium. This 94-proton element can, however, exist in several different forms, called isotopes. Just as the element changes with a change in the number of protons, the isotope changes with the addition or loss of neutrons. Plutonium that has 100 neutrons would be the isotope plutonium-194, the isotopic number being arrived at by adding the number of protons and neutrons in the nucleus. Weapons-grade plutonium is the isotope plutonium-239, meaning it is an atom with 94 protons and 145 neutrons in its nucleus. The special characteristic that makes plutonium-239 important for weapons applications is that it fissions easily when it absorbs a highly energetic neutron. When a plutonium atom fissions, it breaks apart into smaller atoms and releases neutrons and energy. These neutrons cause other plutonium atoms to fission, releasing more neutrons and energy in an explosive chain reaction. Uranium-235 also fissions in this way, as do some other isotopes, but supplies of these are limited, and plutonium-239 is relatively easy to manufacture.

Since natural plutonium is not available to us on earth, it must be created from elements that are readily available. The element that comes closest to having the 94 protons of a plutonium atom and does exist with relative abundance in nature is uranium, with 92 protons, so naturally it would seem easiest to use that as the building block for plutonium. Which in fact is what is done. Plutonium-239 is created from uranium-238, which has 92 protons and 146 neutrons. The uranium-238 is bombarded with free neutrons in a reactor, some of which are captured by the uranium nuclei. When a uranium-238 atom captures a neutron, it is then the isotope uranium-239. The nucleus of a uranium-239 atom is unstable, so it cannot remain in this form for long before undergoing some sort of alteration. The change that usually occurs in the nucleus of uranium-239 to increase stability is the loss of one unit of negative charge, and this change is called beta negative decay. One way of describing this would be that a neutron (neutrons have a neutral electrical charge; protons have a positive electrical charge, and electrons have a negative charge) gives off—or radiates—the equivalent of an electron. The particle emitted in this way is called a beta negative particle, and this type of radioactive decay is called beta negative decay, or sometimes just beta decay (beta positive decay rarely occurs). When a neutron undergoes beta negative decay, its neutral electrical charge



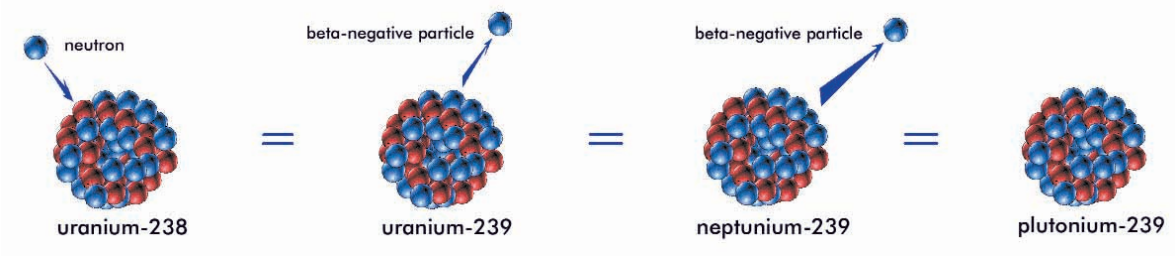
How Plutonium and Tritium are Produced

becomes positive by the loss of the negatively charge particle, thus the neutron becomes a proton. The same atom now has 93 protons, which means it is no longer uranium but has transmuted into neptunium, or more precisely neptunium-239, the total number of neutrons and protons being still the same. Uranium-239 has a very short half-life of about 23 minutes, so one out of every two uranium-239 atoms will become neptunium-239 every 23 minutes. The neptunium-239, also unstable, has a slightly longer half-life of about 56 hours. This element goes through the same process of change to further increase its stability, beta negative decay, to become the relatively stable plutonium-239, which has a half-life of over 24,000 years.

The Place of Plutonium Among the Isotopes, and How it is Produced

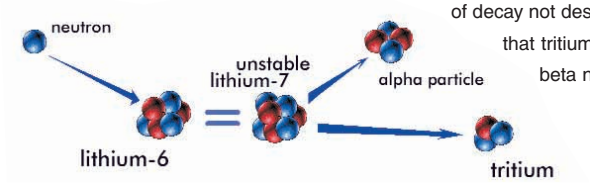
The numerous protons and neutrons in the nucleus of a plutonium atom make it a heavy material, slightly heavier than lead, which is usually found in nature with between 206 and 208 protons and neutrons. Tritium is at the opposite extreme, among the lightest elements. Tritium is also known as hydrogen-3. Most hydrogen is found in nature as hydrogen-1, having only a single proton in its nucleus, but a small amount of hydrogen-2, also known as deuterium, occurs in nature. Tritium has one proton and two neutrons, and does not generally occur in nature.

The type of reaction that is used to produce tritium is slightly different than what is used to produce plutonium-239. Tritium production begins with lithium-6, one of the two naturally occurring isotopes of lithium, this one containing three protons and three neutrons. As in plutonium production, the lithium is bombarded with neutrons, and when one is absorbed the nucleus becomes unstable. Instead of emitting a beta particle, this unstable lithium-7 atom emits an alpha particle. Alpha particles are comprised of two neutrons and two protons (in other words, they are helium atoms without any electrons), so subtracting the two neutrons and two protons from the lithium atom leaves two neutrons and one proton—tritium.



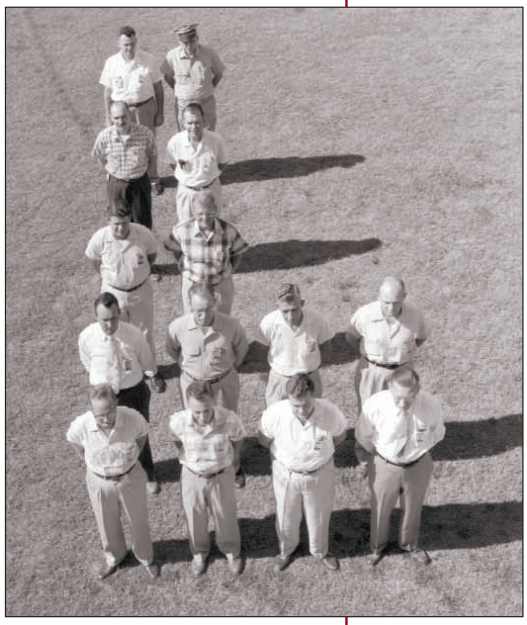
The Place of Hydrogen Among the Isotopes, and How Tritium is Produced

As we can see from the chart of isotopes, for the uranium-239 to neptunium-239 to plutonium-239 decay chain, beta negative decay caused each isotope to become the isotope identified in the square one row above and one column to the left of the isotope that underwent decay. Alpha decay, on the other hand, can be followed by moving two rows down (the loss of two protons) and two rows to the left (the loss of two neutrons). The decay of any isotope for which the type of decay is known can be traced in this manner (there are other types of decay not described here, which can also be traced on isotope charts). Thus it can be seen that tritium, which has a half-life of slightly more than 12 years, will decay by emitting a beta negative particle to become helium-3.



Source: Adapted from charts developed by Richard B. Firestone, Lawrence Berkeley National Laboratory, used with permission. Charts available at http://ie.lbl.gov/decay.html and http://ie.lbl.gov/astro/astronuclear.html.

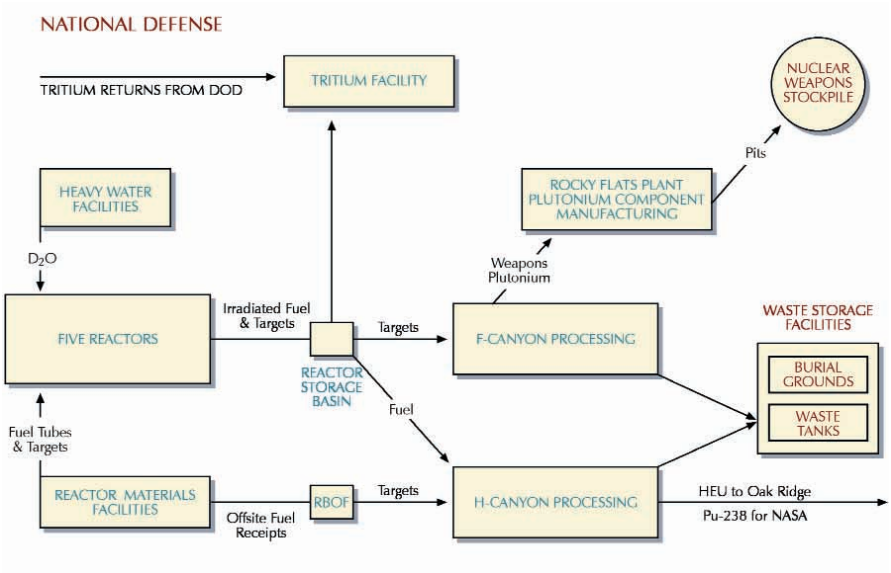
Experience with the development of products like nylon and Duco had taught Du Pont that progress could come from unexpected sources, and that broad-based communications between departments could benefit research and manufacturing efforts. The company's involvement would be likely to be more valuable if it were fully integrated into the government's atomic energy infrastructure through effective communications channels. Also, broad access to information was more likely to generate ideas for commercial atomic energy endeavors. Du Pont sought assurance of expanded communications in its Atomic Energy Commission project along two paths. From its headquarters, it reached out to other installations that had research and operations experience of value to the Savannah River Project by requesting that the Atomic Energy Commission establish initial links with the other contractors.[1] Requiring this to be done through the commission lent greater authority to the relations with the other contractors than such efforts would have if initiated by Du Pont. The company then extended those links down through its own Atomic Energy Division by setting up a network of cross-communication and avenues of cooperation within the various division sections at Wilmington and Savannah River. Although the organization charts for the division and its plant and laboratory sections appear to be a simple and straightforward hierarchy, the links between the various departments were complex and helped ensure a broad experience base that would better encourage input from diverse sources.



For instance, Technical Standards—the basic documents that determined the limits on plant operations—were developed by the Wilmington Technical Division and incorporated operations experience as documented by the appropriate Works Technical departments at Savannah River. Liaison between the Technical Division and the Atomic Energy Commission helped bring outside experience to the creation of Technical Standards when needed. Technical Standards had to be approved by representatives in Works Technical, the Savannah River Laboratory, the Process Section Manager in the Wilmington Manufacturing Division, and the director of the Manufacturing Division, thus ensuring that all four of the main Atomic Energy Division administrative units had an opportunity to comment on the development of the standards. Operating Procedures—generally step-by-step guides to production-related work—were developed by the Savannah River Plant production departments. These required more limited approval, but review by the section and general superintendents of the Works Technical Department, which maintained liaison relations with the Wilmington Technical Division, helped to incorporate the expertise of that division and by extension of the laboratories and other facilities associated with the Atomic Energy Commission. Test Authorizations were the means of deviating from operations procedures and operating outside limits established by technical and mechanical standards. These were a necessary step in process improvement, and were one means by which operations procedures were altered. Test Authorizations required a similar approval process, as did Technical Standards, again giving all major divisions opportunity for input.[2]



As part of its company philosophy, Du Pont wanted to keep its employees satisfied with their work, which meant the company provided them with opportunities to contribute to operations—to stand out and make themselves known so they could advance through the company hierarchy. Part of employee contentment is attributable to the general workplace environment Du Pont established, but the management structure was also a factor. Production improvement is one of the most obvious ways an individual or group can have an obvious impact on operations of a production facility—when production improves, management notices. Du Pont made attention to continual improvement a philosophy of site management. In contract negotiations, Du Pont insisted that there be a laboratory established specifically to support Savannah River, and this was a key to the company's intention of giving employees opportunities to show how they could be of value to the company. Shortly after assuming the directorship of the Atomic Energy Division, Milton Wahl stated that one of the basic responsibilities of the division in directing the work at Savannah River was to improve products and processes.[3]



Savannah River has been a cooperative organization of nine fairly autonomous production areas coordinated under a central administration led by the contractor to meet broad mission criteria established by the government. The physical products of those broad goals have been introduced in the preceding section. The following is an introduction to the processes that created those products and the site management under which initial operations took place.

INTRODUCTION TO THE PROCESSES

Heavy Water Moderator

Most hydrogen in nature has one proton and no neutrons, an isotope of hydrogen called protium, but about 0.015 percent of naturally occurring hydrogen exists as the iso-

(Opposite Page) Each area had a committee that represented the various departments that staffed the area. This committee allowed for input from all area workers into operations and the creation of a safe work environment. Each department contributed to the area's successful operation by maintaining machinery, supplying power, providing health protection, calibrating instruments, and other support functions.

L Area Committee, 1956. G. E. McMillan, Production; F. R. Bucko, Maintenance; D. D. Stubbs, M & S; O.A. Kraehenbuehl, Works Technical; C. F. Baxley, Service; W. A. Carrick, Traffic & Transportation; J. M. Tufft, Power; G. R. Reese, Patrol; D. G. Price, H.P.; V. O. Beam, Instrument; E. H. Hamilton, Project; A. D. Williams, Security; M. C. Milkerit, Electrical; D. E. Arnold, Safety; Dr. D. Clark, Jr., Medical. Source: *Savannah River Plant News*, October 12, 1956.

H Area Committee, 1957. Ray Larson, Wendell Beane, Walt Egan and Carl Wagner, Production; Don Laffoday, Safety; Gene Blakely, Security; Pat Patterson, Power; Tom Ridge, Traffic and Transportation; John Roop, Electrical; Bob Caldwell, Health Physics; John Elliott, Separations Technology; Milt Kirkpatrick, Project; Bob Girdler, Separations Technology; Al Rothwell, Instrument; Zane Kofford, Patrol; Perc Hennessey, Methods and Standards; and Dr. Charles Whitaker, Medical. Source: *Savannah River Plant News*, January 18, 1957.

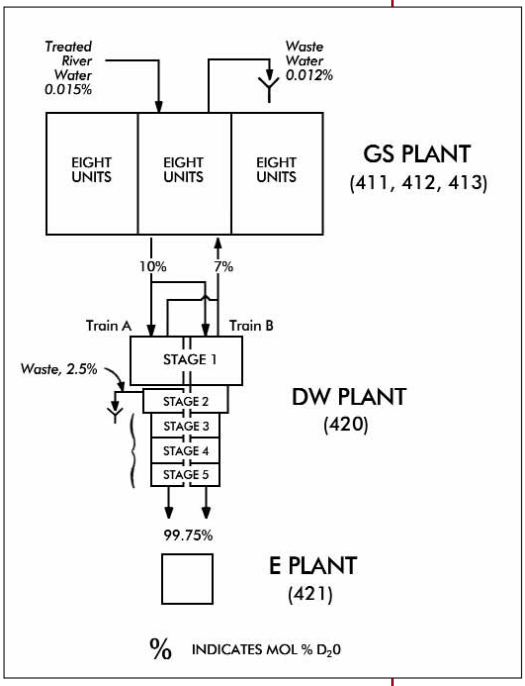
(Left) This simplified view of materials flow through Savannah River covers only the major lines of movement. More detailed descriptions of material flow are given in later chapters.

tope deuterium, which has one proton and one neutron. Water, a chemical compound of oxygen and hydrogen, can be comprised of any isotope of these chemical elements; water molecules that contain the heavier deuterium isotope of hydrogen are called heavy water. Because of its special properties, the reactors at Savannah River were designed to use heavy water as the moderator (a moderator in a reactor slows neutrons so they are more likely to be captured by other atoms). Heavy water is also a source of deuterium, which is used in thermonuclear weapons.[4]

Several methods have been used to increase the percentage of heavy water in natural water, among them fractional distillation, electrolysis, hydrogen sulfide–water exchange processes and various combinations thereof. To fill the immediate need for massive amounts of heavy-water as moderator for the Savannah River reactors, a heavy water production facility was built by Du Pont at Dana, Indiana. Additional and more permanent production capacity was provided in the 400 Area at Savannah River itself, and the Dana facility was closed in 1957. At the Savannah River heavy water plant, all three methods mentioned above were used to produce heavy water. In the columns that defined much of the appearance of the 400 Area, the hydrogen sulfide–water exchange process was used to provide a first stage enrichment of the heavy-water content of water from the nearby Savannah River. Fractional distillation, then electrolysis, were used to further enrich the water.[5]

The type of hydrogen sulfide–water exchange process incorporated in the heavy-water plant at Savannah River is called the Girdler Sulfide process. The process uses different concentrations of the heavier isotope in hydrogen sulfide and water at different temperatures to concentrate the heavy water. By repeatedly passing hydrogen sulfide gas through water in alternately heated and cooled columns, the amount of deuterium can be concentrated in the water.[6]

Fractional distillation involves boiling the water to remove the lighter isotope. Since molecules of heavy water vaporize at a higher temperature than those of water containing the more common protium isotope (also called light water), boiling water and removing the vapors will leave water with a slightly higher concentration of the heavier deuterium



Materials flow through Savannah River's 400-D Area. The hydrogen-sulfide water exchange process occurred in the GS Plant. Fractional distillation took place in the DW Plant and electrolysis occurred in the E Plant. The buildings associated with each step are shown in parenthesis. Adapted from flow chart in W. P. Bebbington, J. F. Proctor, W. C. Scotten, and V. R. Thayer, "Production of Heavy Water in the United States" in *Proc. Third International Conference on the Peaceful Uses of Atomic Energy, Vol. 12 Nuclear Fuels–III Raw Materials* (New York: United Nations, 1965).



Heavy water was produced at D Area at Savannah River. After enough moderator was produced to supply the reactors, D Area was used to produce heavy water for offsite sales and leases, to purify moderator used in the reactors, and to produce deuterium for use in weapons components. The tall process columns used to produce heavy water, known by some as the Iron Forest, defined D Area. Courtesy of SRS Archives, negative 3391-3.

isotope. Water enriched by this method must go through many stages of controlled boiling. Final purification at Savannah River was provided by electrolysis, a process whereby electric current is used to separate the hydrogen and oxygen atoms in water—light water molecules more readily disassociate into their component gaseous elements than do those of heavy water, thus the light water tends to turn to a gas more quickly, leaving behind water slightly enriched in deuterium.[7]

INTO THE CORE

Two basic forms of materials for irradiation in reactors were fabricated during the Cold War era— solid slugs (usually rods, but a few plates were also used), and tubes. These were combined into assemblies for insertion into the reactors; slugs were situated side by side, and tubes nested inside each other. The assemblies included an outer aluminum housing that contained the slugs or tubes, and that outer housing is what is seen being inserted into reactor cores in photographs. The slugs and tubes were produced by foundry and machine shop procedures that converted uranium and other elements and alloys to metal then produced the shape desired for the assemblies. The production processes involved first casting the raw material into ingots, then shaping the ingots by extrusion, drawing, swaging, and straightening to produce rods or plates. These were often heated so they would release any gases trapped within the metal (called "outgassing"), then they were machined, cleaned, coated, and assembled into finished components. One of the last steps in the fabrication process was called "canning." The slugs and tubes had to be canned, or encased, in aluminum to prevent chemical interaction of the core material with heavy water used to cool the assemblies and moderate the nuclear reaction. Canning also hindered the leakage of radioactive material that could contaminate the moderator. When needed, the uranium would be bonded to the aluminum to optimize heat transfer by minimizing irregularities along the contact surfaces. Irregularities could cause "hot spots" and lead to the failure of the assembly components.[8]

The earliest natural uranium slugs contained both uranium-235 and -238; the former used to supply neutrons for the chain reaction and the latter used to absorb neutrons for the production of plutonium. The rods were produced in pieces five to six feet long and about one and one-half inches in diameter, then machined to units about eight inches long by 1.36 inches in diameter. As the understanding of reactor physics progressed and greater amounts of enriched uranium became available during the early years of the Cold War, reactor operators began placing the two isotopes of uranium in separate positions within the reactor tank. The manufacture of tubes provided even greater flexibility in arrangements of the uranium and other isotopes. Further advances included making

Attention to Improved Production Procedures was Evident from the Beginning of Operations

Even during the first years of operation, the slug canning process was improved and quickly made much more efficient. In June 1953, 10,000 slugs were produced at a cost of $13.04 each; by the following month, production had been increased to 39,000 slugs, which was 110 percent of the rated capacity for the 300 Area canning facilities. The cost of the procedure had also been cut nearly in half, to $7.13 per slug. These improvements were made possible by coordinated efforts that involved Du Pont technical groups (the Technical Division in Wilmington and Works Technical at Savannah River) and collaboration with the National Lead Company of Ohio through the Wilmington Manufacturing Division. National Lead was at that time operating the Feed Materials Production Center at Fernald, Ohio.

Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 46–47.

assembly components from uranium containing a higher than normal percentage of uranium-235 for use as the reactor fuel, and making components containing less than the normal percentage of uranium-235 for use as targets for the production of plutonium.[9] Assembly components with slightly more than the normal amount of uranium-235 could be manufactured using the same techniques as were used with natural uranium, but highly enriched uranium had to be worked with special techniques that safeguarded against accidental criticality. Components made of natural, depleted, and low enriched uranium were produced at other facilities in the nuclear complex, then shipped to the Savannah River 300 Area for canning. Highly enriched uranium components were manufactured at the Savannah River 300 Area facilities. The lithium components, used in the production of tritium, were also manufactured in the 300 Area.[10]

Other materials have also been manufactured in the 300 Area for use in reactor assemblies to meet the various missions handed to Savannah River during its operation. Targets of thorium-232 were used to produce uranium-233; neptunium-237 components were used to produce plutonium-238; and bismuth-209 components were fabricated for irradiation into polonium-210. Small amounts of a number of other target materials have been irradiated to produce special isotopes such as thulium-170, iridium-192, plutonium-242, and various isotopes of lanthanum, americium, curium, and californium.[11]

Although the physics of nuclear reactions can be highly complex, as can be the design of reactor assemblies, their constituent parts, and the design of reactor loadings (the organization of the different assemblies in the reactor vessel to achieve specific goals), the actual operation of a reactor is not terribly complicated. The reactor assemblies are built up from the components manufactured or otherwise machined in the 300 Area, then placed in storage. The assemblies are taken from storage to be inserted into the reactor by a charge and discharge machine, control and safety rods are removed from the reactor vessel by overhead cables, and the materials are allowed to react (sometimes informally described as "to cook") while being monitored for problems. Some reactor campaigns went on for years, the process being stopped periodically to replace assemblies and deal with problems.

Once the reaction was complete, the assemblies would be removed from the reactor vessel and placed in a holding tank and allowed to cool for typically no less than 90 days (later 180 days). This allowed some of the more dangerous fission byproducts to decay into less harmful or more controllable isotopes; too short cooling times resulted in some releases from the separations areas during early operations. After spending time in storage, the assemblies were disassembled and placed in casks for movement by rail to the separations areas.[12]

The five production reactors operating at Savannah River during the Cold War were identified as C, K, L, P, and R reactors. The first Savannah River reactor to go online was the R reactor, which was tested for integrity and operability during the fall of 1953 and brought to criticality in December. P reactor was the second to go critical, the event occurring on February 20, 1954. The first irradiated fuel was discharged from R reactor the following June, and all five reactors were operating by the end of March 1955. Changes were soon made to both how the reactors operated, and to the reactors themselves. Improvements to instrumentation and signal systems mitigated the emergency shutdowns, or "scrams," that plagued the first months of operation. And increased tritium requirements from the Atomic Energy Commission required that the reactors be loaded in

configurations specifically meant to produce tritium—during the first two years of operation tritium had been produced as essentially a byproduct of plutonium production, in spite of the initial intent of the construction of Savannah River as a tritium production facility. As operators found they could increase the power levels at which the reactors operated, they began adding heat exchangers so that the greater heat generated at the higher power levels could be carried away. C reactor was constructed with 12 heat exchangers, but the other four reactors initially only had six, a necessary shortcoming due to limited supplies of heavy water and vender production capabilities during the construction period. The number of heat exchangers was increased to 12 on all reactors in 1956, and the original power output of 378 megawatts was increased to 2250 megawatts.[13]



Startup of R Reactor

SRS retiree, Dexter C. (Skeet) Lee, remembers that December day in 1953 very well. He was reactor console operator on duty when startup occurred. In a newspaper interview on the 25th anniversary of startup, Lee, a man of average height, confesses that he felt, "I was 27 feet tall" that night.

He was one of three operators on the 4-12 am shift. The others were Earl Williams, who later transferred to Seaford, and Jim Huskey, who eventually became Lee's Sunday School teacher at Millbrook Baptist Church in Aiken.

Lee remembers that he came in to work at 4 and found chairs set up in the control room. Senior Supervisor Hank Kiser approached him and said, "Skeet, we want you to take this thing up."

"Taking it up" involved raising the safety rods and then performing the tedious job of pulling the control rods. A pistol-like grip was used to apply pressure slowly and at intervals, while others kept their eyes glued to instruments.

Gradually, the instruments started to record the flow of neutrons as the pile became critical. There was a sigh of relief, some hand-shaking and a sort of "whoopee," Lee recalls, on the part of those who had been working day and night to bring about startup.

Still, Lee states the overall mood was somber and "there was no horsing around." The control room decorum established in the earliest days and continued through 35 years of reactor operation by Du Pont was preserved.

Source: SRS History Project.

To further increase the capabilities of the cooling system, a large retention lake was created. Heavy water was used to remove heat from the reactors, and light water from the Savannah River was used to remove heat from the heavy water. The increase in the amount of heat being removed via the heavy water meant a concurrent increase needed to be made in the amount of heat being removed by the light water. But unlike the heavy water, the light water was returned to the river, so a means of dissipating its heat before returning the light water to the environment was necessary. The 2600-acre P and R Pond (generally known by its acronym as Par Pond) was constructed for this purpose, and was integrated into the cooling system in 1958. All the cooling water from R reactor then was routed to Par Pond, and a portion of P reactor water was sent out via Par Pond. The new

reservoir not only served as a means of cooling water, it also created an additional source of cooling water for P and R reactors, which produced savings in pumping costs. Since they would then be drawing less water from the Savannah River, more would be available for the other three reactors. These and further improvements in the light water circulating system allowed C reactor to be brought to a power level of 2575 megawatts in 1960, and to eventually reach its all-time peak of 2915 in 1967.[14]

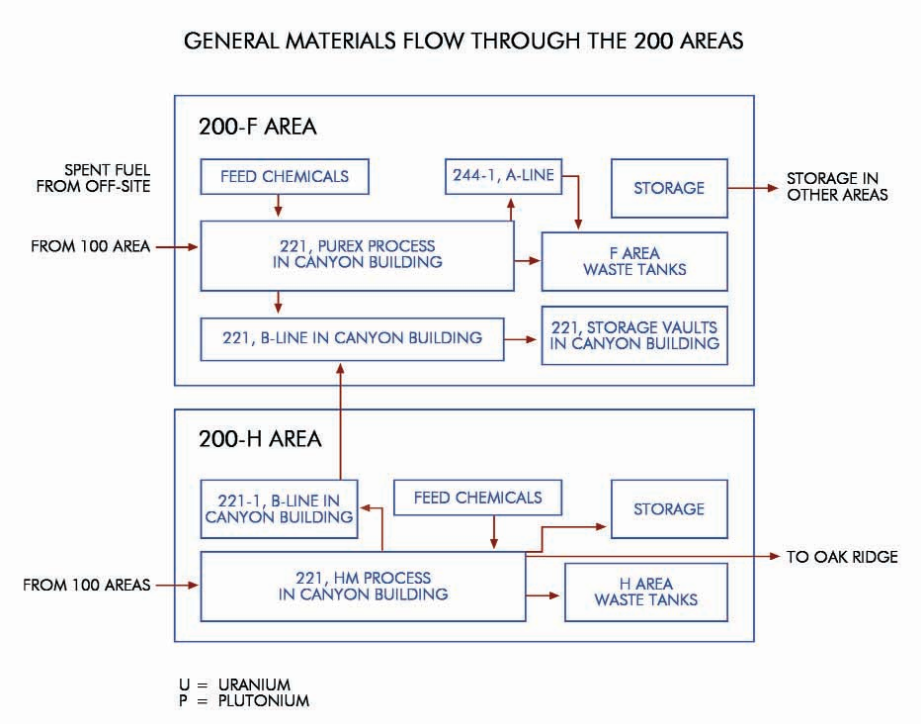


Aerial view of 105-P. Each reactor building is a concrete envelope covering the three major process areas: the reactor under the high hat and the two wings; the assembly area and disassembly area. Fuels arrived in the 100 Areas by truck and were placed in the Assembly Area where they were readied for irradiation. Once irradiated, they were cooled in the Disassembly Area from which they were transported to the 200 Areas by railroad. Courtesy of SRS Archives, negative 30141-10.

PURIFYING THE PRODUCTS

What is generally called "separations" at Savannah River, the purification steps that follow irradiation in the reactors, involves some of the most complex operations at the site. As the name implies, these operations involve the separation of chemical elements from each other, in this case desired products from contaminants, waste, and other reactor byproducts. After material has been irradiated in a reactor, the products must be separated from waste so that they can be used.[15] By chemically dissolving or melting the irradiated fuel and target elements, then reacting the irradiated atoms in liquid or gas form to various chemical elements, the desired products can be separated from the fission wastes and byproducts. The term separations as used here also includes not only the separation of the desired product from the undesirable fission byproducts, but also the dissolution or melting of reactor assembly components prior to actual separation, and the conversion of liquid product streams into solid metal or other stable form. In the case of tritium, the process includes the packaging of the gas into containers for storage or use in weapons.[16]

Savannah River has primarily employed two types of separations—wet processes and gaseous processes. Wet processes involve dissolving reactor assemblies, then treating the resulting solution with chemicals and actions that separate unwanted material from wanted material. Gaseous separation has been used primarily for tritium extraction. The separations steps take place in the 200-F and 200-H Areas at Savannah River, and much of the wet chemistry process equipment is installed in the enormous canyon buildings in the F and H Areas. The two canyons were originally designed to be run by remote operation

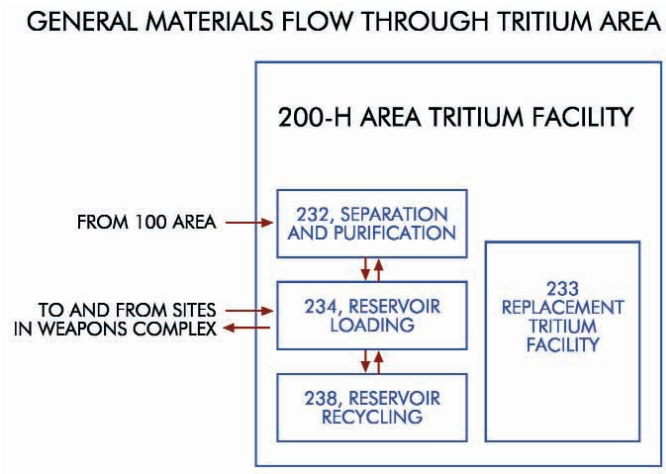


The movement of materials through the F and H areas is complex because of the number of products being separated and the variety of locations and special facilities for dealing with the different products. To further generalize from the figure, all wet chemical separations were accomplished in the canyon portion of the canyon building. Final products were solidified for shipment elsewhere in the B-Lines, and uranium was solidified for reuse or storage in the A-Lines.

and maintenance—which meant that the process areas were not designed to be entered by personnel on a routine basis. A chemical process was developed for use at Savannah River as the facilities were being constructed, and that process, called Purex, has become the standard for plutonium and uranium separation around the world.[17] Scientists at the Knolls Atomic Power Laboratory and at Oak Ridge developed Purex during the late 1940s and early 1950s. The Savannah River F Area was the first full-scale Purex separations plant to go into operation in the world. That process has always been used in F Area to purify plutonium, and H Area employed a variation called the HM process to recover enriched uranium during most of its history. Other variations on the Purex process have been used to extract additional products in both areas.[18]

The initial gas separations process for the purification of tritium took place in F Area, but the plant there was more of a pilot plant than full-scale production facility. F Area tritium separations began in 1955, where the first irradiated lithium–aluminum reactor assemblies were melted in furnaces, then separated by various means that relied on heat to make lighter elements rise and the ability of certain hydrides to absorb and release specific gases. A tritium facility originally planned for H Area was left unfinished during the orig-

inal construction project due to diminished need for tritium in the weapons program at that time. Evolving requirements soon reactivated construction of the H Area tritium facility, where many improvements were developed and installed based on the experience gained in F Area. In 1958, all tritium production was shifted to H Area.



Shown in this diagram is the material movement through the H Area tritium facility during the majority of its operational history. Most tritium separation and purification now takes place in the Replacement Tritium Facility.

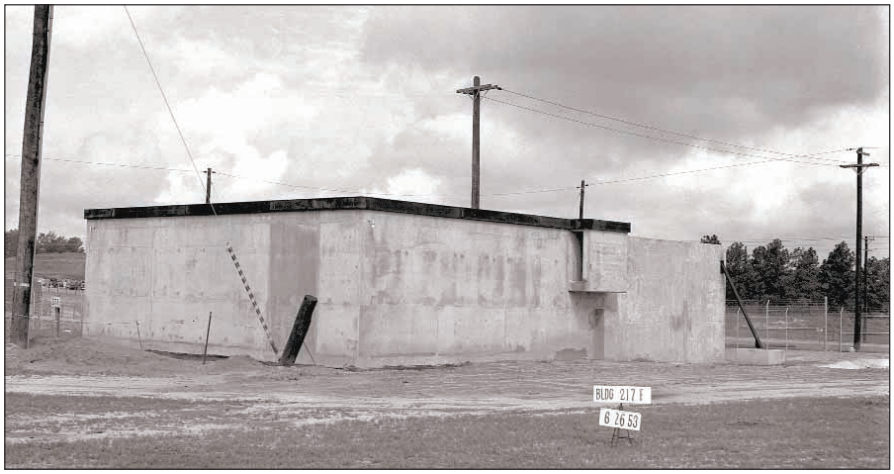
The F Area canyon went into operation in November 1954, and the H Area canyon was online the following July. In these two buildings, the assemblies that came from the reactors were dissolved in acid to separate the uranium and plutonium from waste fission products by chemical extraction in solution.[19] The major steps of the separations process involved dissolving the reactor assemblies in nitric acid, then adding chemicals to cause select molecules in the solution to rise or fall, enabling the desired products to be separated from contaminants. Once separated, plutonium or other elements in solution could be concentrated and further treated by conversion to metal or other forms suitable to shipment or storage. The conversion generally took place in the A-Line or B-Line. The heart of the Purex process is the chemical compound tributyl phosphate (commonly known as TBP), which has the ability to carry or release various metallic elements in the actinide series of elements (uranium, plutonium, and neptunium are all actinides). Making only minor chemical adjustments to the solution in which they are dissolved can alter TBP's affinity for these various elements.

During the first year of operation, the F Area canyon attained its designed throughput level of three metric tons of uranium per day. Modifications to the H Area canyon by applying lessons from early operations in F Area allowed H Area operations to see a throughput of seven tons per day. In early 1957, the F Area canyon was closed down so that substantially larger equipment could be installed to increase throughput, and so that a new, enlarged facility to convert the plutonium to metal (the B-Line) could be built on the canyon roof. This would more than double the capacity of the canyon. The modifications took two years to complete, and the F Area canyon went back into operations in March 1959, with a capacity to process 14 tons of uranium each day. As soon as F Area was back in operation, H Area was shut down for conversion to a modified Purex process designed to safely recover enriched uranium from target elements then beginning to be used in the Savannah River reactors, a change that took only three months. The H Area canyon was back in operation by June. After the Savannah River reactors began using highly enriched uranium in 1968, the H Area canyon B-line facilities recovered this uranium from spent fuel rods and some offsite research reactor fuels. The enriched uranium recovered in H Area was sent to the Oak Ridge Site Y-12 plant for conversion to metal and reuse.[20] Many more minor modifications of the canyons followed over the years to allow products other than uranium and plutonium to be recovered, but the fundamental processes for extracting plutonium and uranium remained essentially the same throughout the operational history of the 200 Areas.



Plutonium-239 button. As plutonium-239 only emits alpha radiation, the plastic covering and gloves offer the holder sufficient protection from exposure. Courtesy of SRS Archives.

Tritium separations took place in two much smaller portions of the F and H Areas. Slugs irradiated to produce tritium were initially sent to Building 232-F, which started operating in October 1955. There, the slugs were melted, instead of dissolved, to release the gaseous tritium. After melting, the tritium was purified by a process known as thermal



Vault, 217-F, on completion in 1953. 217-F was the only facility on the site that was solely controlled by the AEC. Once the product entered its separately gated area, the AEC officials accepted responsibility for its storage and shipment. Visual barrier walls extended from the nondescript but important building that had an integrated loading dock providing access to two vault areas. Courtesy of SRS Archives, negative 2-481-11.

diffusion. The H Area tritium building was outfitted for production in 1956, and by the end of the year two lines were operating. The process was similar to that employed in the F Area tritium facility, but the equipment and process steps were much improved, greatly increasing throughput. The tritium-containing assemblies were melted in furnaces, then purified by thermal diffusion and other methods developed and improved during the ensuing years. These additional processes have included low-temperature distillation and thermally cycled sorption and desorption in hydride beds. In 1958, all tritium separation and purification was moved to the H Area, and Building 232-F was closed. Tritium was originally shipped elsewhere for placement in reservoirs—the canisters that hold the tritium in thermonuclear weapons—but by 1957 this was being done at Savannah River in Building 234-H. In August of the following year, tritium began being removed from reservoirs, purified, and placed again in reservoirs in this facility as well.

DEALING WITH THE REMAINS

The process of chemically separating uranium and plutonium from byproducts produces great amounts of highly radioactive waste, called high-level waste. Less radioactive wastes are divided into low-level waste and mixed low-level waste. Another category of waste is called transuranic waste. This latter category of waste has relatively low levels of radioactivity, is composed of materials contaminated with uranium-233 and heavier-than-uranium (transuranium) elements, and has been segregated to make future handling of the transuranium elements easier.[21]

High-level waste is stored at Savannah River in 51 underground carbon steel tanks set in concrete vaults; most of this waste comes from wet separations processes. Of these tanks, 24 are single-wall tanks with catch pans to contain leaks; the remainder is composed of double-wall units. The waste facilities at Savannah River were modeled on those

at Hanford, modified somewhat since the radioactivity of the high-level wastes would be greater than those at Hanford. The original tanks each had a capacity of 750,000 gallons, were supported by internal columns, set on top of a steel pan to catch any leaks, and encased in concrete. Separate tanks were provided for high- and low-level wastes, and the high-level units were provided with cooling coils to remove heat generated during the decay of the wastes (cooling coils were added to all these tanks in 1955). Waste evaporation facilities were also provided as a means of reducing waste volume.[22]



Eight such tanks were originally built in the F Area, and four in the H Area (with space for four additional tanks set aside), each buried under at least 9 feet of soil. Four more tanks were approved for H Area in 1954, due to expected increases in the throughput of H Canyon. These four tanks were larger, each having a capacity of 1.07 million gallons, but other details of design were essentially the same as those of the original 12 tanks. They were constructed in 1955 and 1956. By June 1955, the first high-level waste tank was already full, prompting efforts to reduce the volume of waste sent to storage.[23]

Four single-wall tanks for low-heat, high-level wastes were constructed in the F Area in 1958 and four in the H Area in 1962. These tanks have caused numerous problems due to leakage through fine cracks caused by the reactions of the solutions stored there with the materials in the tank walls. However, only

The separation of uranium, plutonium, and other materials from contaminants and unwanted fission byproducts was carried out in the F and H Areas. The largest building was known as the "canyon" building because of its unusual shape and interior—within are two, long, and open process corridors running the length of the building, each called a canyon. The buildings and structures surrounding the canyon all provide support or supplementary functions. Waste tanks both in use and under construction are shown.

(Top) F Area, 1978. Courtesy of SRS Archives, negative 28317-1.

(Right) H Area, 1978. Courtesy of SRS Archives, negative 28320-1.



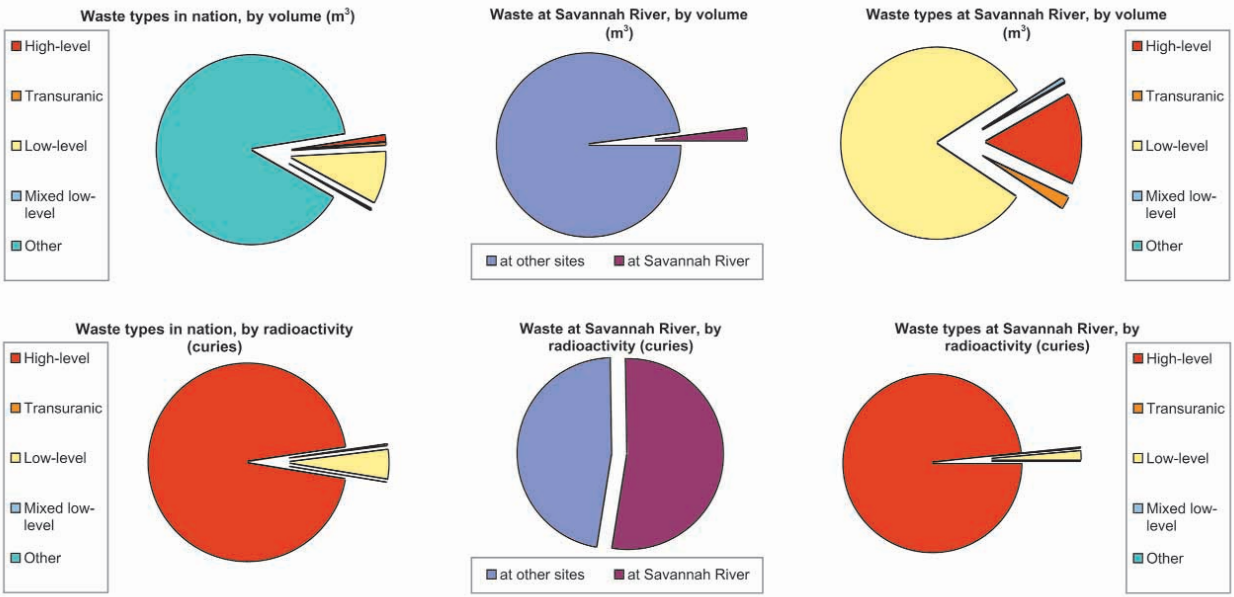
one of the original 12 tanks has leaked substantially. Four others have deposits on the outside of the tank walls that may indicate leakage, but no leaks have been found. An additional 27 tanks, each with a capacity of 1.3 million gallons, have been constructed since 1962. These are all similar in design to the initial tanks, except the catch pans extend the full height of the tanks, rather than only five feet, as with the initial design.[24]

Since 1960 in the F Area and 1963 in the H Area, evaporation has been used to reduce the volume of the Savannah River separations wastes. Solids in the high-level tanks are

allowed to settle, then the liquid is concentrated by evaporation. Condensate from the evaporator, containing only low levels of radioactivity, has been discharged to surface level seepage basins and, since 1990, mixed with concrete and stored in aboveground vaults. High-level wastes began being encased in glass in 1996 in the Defense Waste Processing Facility. From the beginning of operations until 1988, some of the low-level wastes from canyon processes were discharged to seepage basins, then to streams after evaporation. After 1988, these wastes were processed through the Effluent Treatment Facility prior to discharge. Solid wastes were generally sent to the E Area Radioactive Waste Burial Ground and the Mixed Waste Management Facility burial ground.[25]

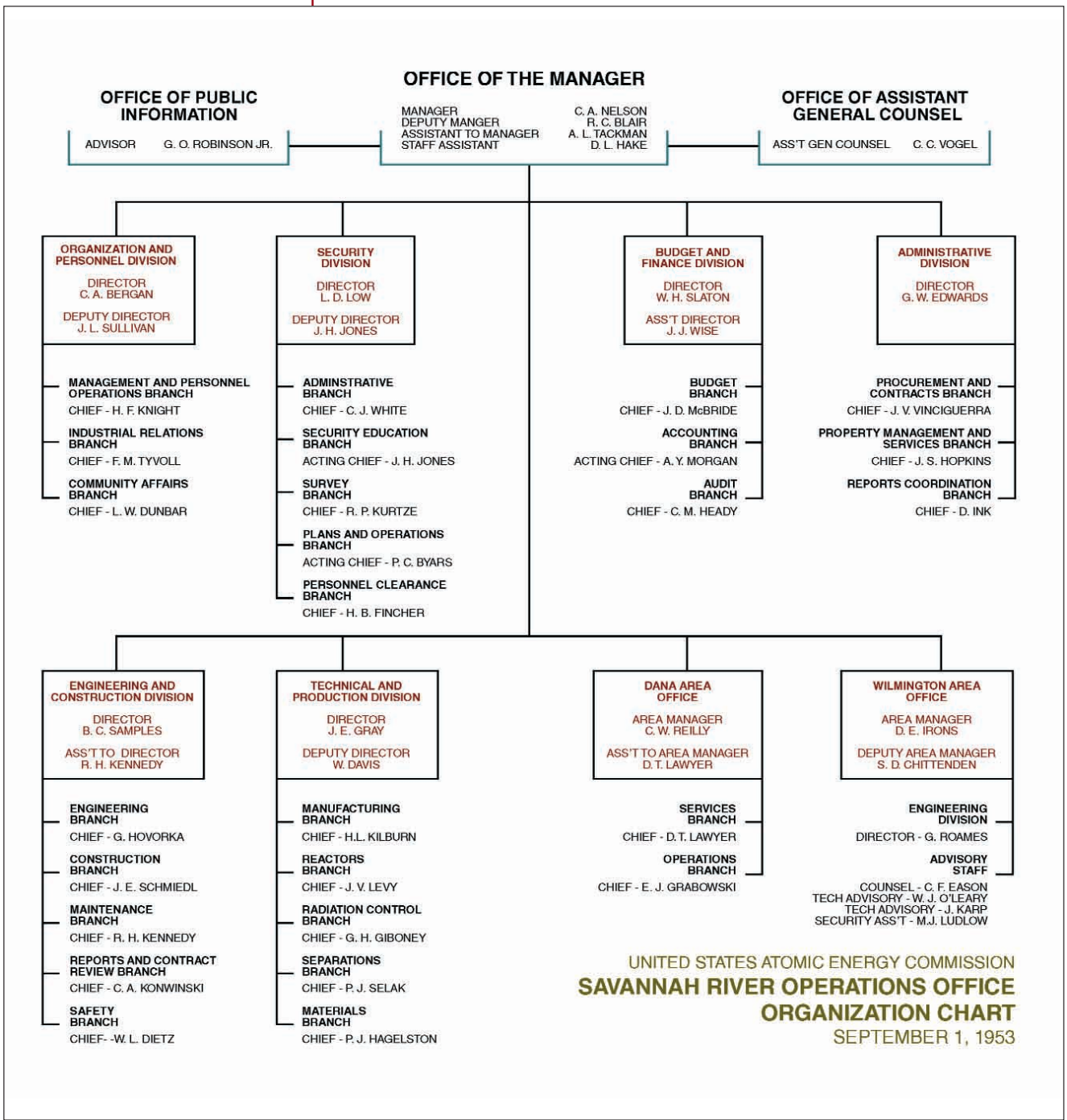
Two burial grounds serve as the disposal site for solid wastes. The original burial ground occupied about 76 acres and was used from 1953 until 1972. The second, larger burial ground has been used since 1972; it covers approximately 119 acres. Solid low-level waste from all plant areas has been buried there, with special areas set aside for items

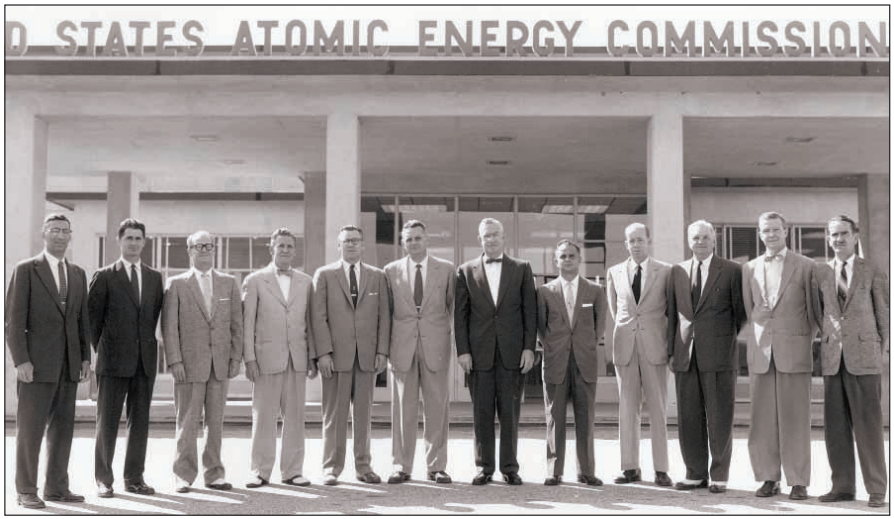
	Volume in cubic meters		Radioactivity in curies	
	Other Sites	Savannah River	Other Sites	Savannah River
High-level	380,000.00	130,000.00	960,000,000.00	532,000,000.00
Transuranic	220,000.00	19,900.00	3,800,000.00	591,000.00
Low-level	3,300,000.00	681,600.00	50,000,000.00	9,409,000.00
Mixed low-level	146,000.00	7,300.00	0.00	0.00
Other	32,079,000.00	140.00	0.00	0.00
	35,286,060.00	838,940.00	471,800,000.00	542,000,000.00



One of Savannah River's most important missions has been and continues to be the safeguarding of radioactive waste in storage at the site. As can be seen by theses charts, the volume of waste is only a small portion of that created by the nation's nuclear weapons production complex, a little over two percent. However, the waste at Savannah River accounts for nearly 55 percent of the radioactivity contained in nuclear waste across the nation. Savannah River is taking care of about 34 percent of the nation's high-level radioactivity generated by the government weapons and atomic energy programs. Although that high-level waste accounts for only about 15 percent of the waste stored at Savannah River, it produces nearly 98 percent of the radioactivity that the site manages. Source: Department of Energy, *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences* (Washington, DC: U.S. Department of Energy, 1997) 7, 36, 42, 47, 55, 59, and 62.

with higher levels of radiation or with plutonium fission products. The transuranium solid wastes have been in the past buried in designated sections of the burial ground, but by the early 1980s were being stored on concrete pads in containers that allowed for later retrieval.[26]





(Left) Savannah River Operations Office Photograph, 1957. Robert Blair succeeded Curtis Nelson as Manager and a cohort of Savannah River personnel was established. From left to right: Joel V. Levy, James J. Wise, John L. Sullivan, Bourke C. Samples, J. Howard Jones, Winston Davis, Robert C. Blair, John V. Vinciguerra, Howard L. Kilburn, C. A. Bergan, Allen M. Coker, and James S. Hopkins. Courtesy of SRS Archives, negative DPSPF 4601-3.

SITE MANAGEMENT

ATOMIC ENERGY COMMISSION

Savannah River grew out of the national organization that had as its primary purpose the development and production of nuclear and thermonuclear weapons, and as its secondary purpose the promotion of peaceful uses of atomic energy. The government arm of that effort was extended to Savannah River in the form of the Savannah River Operations Office, the Atomic Energy Commission operations office that had jurisdiction over Savannah River. Shortly after its creation, the commission determined that it would have a decentralized administration structure, which more broadly was to be "the touchstone of future Government practices."[27]

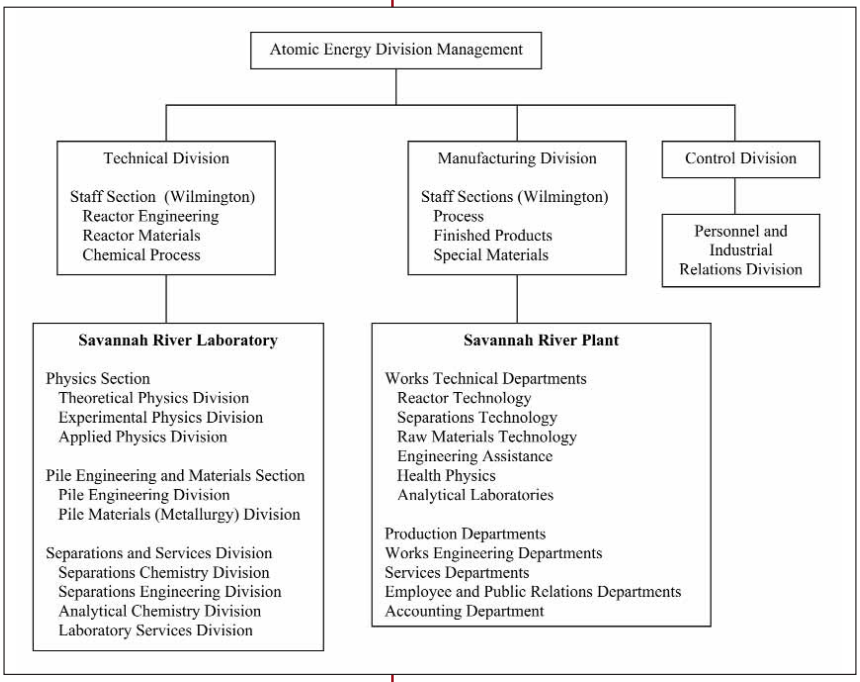
The overall goals of the Atomic Energy Commission and the weapons and peaceful programs related to nuclear energy in the United States were established in Washington at the Atomic Energy Commission headquarters. The Atomic Energy Commission headquarters staff could be divided into two groups: program directors in charge of the various commission projects and management directors in charge of administration. The general manager, through assistant general managers and the commission division directors, carried out policies. The major divisions within the commission were Production, Research, Reactor Development, Contracts, Construction, Safety, Raw Materials, Isotope Development, Nuclear Education and Training, Biology and Medicine, Licensing and Regulation, and International Affairs. The policies, programs, and oversight functions of the headquarters were carried out through the major field offices, called "operations offices." Each operations office was "a complete



(Below) SROO, US AEC and Du Pont Staff, 1959. **(First Row)** Left to right: Dr. J. Elton Cole, Director of Manufacturing, Du Pont; Robert Blair, Manager, SROO; Admiral Paul F. Foster, Deputy Manager, USAEC; Julian D. Ellett, Manager, Savannah River Plant, Du Pont; and Hood Worthington, Director of Technical Division of the Atomic Energy Division, Du Pont. **(Second Row)** Left to right: John V. Vinciguerra, Assistant Manager, SROO; A. D. Day, Field Project Manager, Du Pont; Dr. Milton H. Wahl, SRL Director and Assistant Director of the Technical Division of the Atomic Energy Division, Du Pont; and Nat Stetson, Director, Technical and Production Division, SROO.

organizational unit with almost entire responsibility for the business and technical aspects of the programs under its jurisdiction."[28] These operations offices—originally located at Los Alamos, Oak Ridge, New York, Chicago, and Hanford—were given authority to hire and fire their own personnel and to set their own means of meeting commission objectives.[29]

The Savannah River Operations Office was established in early 1951. The field office was ultimately under the authority of the Atomic Energy Commission director of production, the local focus of responsibility being the manager of operations. This operations manager was charged with seeing carried out the production of fissionable and special materials, as well as fabricated items (such as the plutonium warhead pits originally planned to be produced at Savannah River); oversight of engineering and construction program administration; supervision of the Dana Area Office; and the approval of purchases and contracts, with the further approval of the director of production for those valued over five million dollars. The operations office geographical area of responsibility included not only the Savannah River production facility, but also general assignments for Atomic Energy Commission programs in South Carolina, North Carolina, Georgia, Florida, Alabama, and in the Former Panama Canal Zone. These responsibilities primarily included monitoring and coordinating with off-plant persons and organizations in issues related to atomic energy and radiation control and research, and providing public information.[30]



Du Pont's Atomic Energy Division had two major operations-related subdivisions and an administrative subdivision. Wilmington's Technical Division headed research and development at Savannah River via its administration of the Savannah River Laboratory. The Manufacturing Division at Wilmington extended to South Carolina in the form of the Savannah River Plant, the production entity at Savannah River. Source: *Science and Engineering With Du Pont at Savannah River* (Aiken, South Carolina: Savannah River Plant, ca. 1960), 6.

DU PONT MANAGEMENT AND DEPARTMENTS

Initial Du Pont management of its operations at Savannah River was derived from its commercial operations and its recent wartime experiences. As stated in the contract covering Du Pont's involvement at Savannah River, the company had very nearly full control of site management. Du Pont took the stance that the functions of the Atomic Energy Commission, and its oversight arm of the Savannah River Operations Office, as far as the operation of the plant was concerned, were limited to setting production goals; coordinating efforts in the national complex; ensuring the quality, safety, and accountability of products and operations; and auditing expenditures.[31]

Du Pont management extended from the company headquarters in Wilmington, Delaware, through the Atomic Energy Division of the Explosives Department, established as soon as Du Pont agreed to take on the Savannah River project. Concurrent with this change, R. Monte Evans was made assistant general manager of the Explosives Department, and Bill H. Mackey became manager of the new division. H. F. Brown was at that time general manager of the Explosives Department.[32]

Construction was managed under two departments, the Explosives and the Engineering departments, with the assistance of auxiliary departments such as Legal and Purchasing. The Explosives Department had primary responsibility—it defined the scope of work and developed process specifications—and Engineering acted as the architect–engineer. The Design Division of the Engineering Department handled all in-house design work; all final designs had to be approved by the Explosives Department, whether those designs were developed in-house or subcontracted. Once plans were approved, Engineering's Construction Division took on the construction. Completed facilities were turned over to the Explosives Department for operation.



Savannah River Plant Staff, January 12, 1955. **(First Row)** Left to right: C. W. J. Wende, G. W. Coulson, A. J. Schwertfeger, W. A. Smith, M. H. Wahl, D. A. Miller, H. L. Greene, F. S. Adams, J. D. Ellett, W. P. Overbeck. **(Second Row)** Left to right: W. R. Tyson, J. W. Morris, C. M. Patterson, W. P. Bebbington, R. T. Cooke, H. J. Bowman, C. W. Setter, L. S. Danser, W. O. Christy, T. E. Dill, T. C. Evans, G. Dessauer, E. R. Riggin. **(Third Row)** Left to right: E. Symes, Jr., H. M. Fogel, C. R. Bradford, J. L. Gosnell, L. G. Ahrens, W. S. Church, K. W. Millet, R. B. Fenninger, F. H. Endorf, A. A. Johnson, J. W. Croah, Jr., H. A. Hansen, L. C. Peery. Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).

The Construction Division, under the direction of the Du Pont Engineering Department, was formed during operations. This division, based in Central Shops, was responsible for changes and improvements to the facilities and for new construction. Their ranks included field project managers, engineers, and superintendents for most of the major crafts groups such as ironworkers, pipefitters, layout, electrical, sheet metal, and carpentry. Employee relation's superintendents, such as T. E. Ewing and I. B. Lawton, Jr., were part of the force, as was a physician, cost and evaluation personnel and individuals with expertise in instrumentation. Construction also had resident subcontractors who were specialists in piping, electrical work, insulation and testing and inspection of completed works.[33] B. F. Shaw is a good example of a resident subcontractor.

The head of the Atomic Energy Division was ultimately responsible for the company's management of Savannah River. Under the division head were three managers over functionally divided Technical (originally Research), Manufacturing (originally Production), and Control divisions. The Technical Division during the design and construction phase was responsible for development of the operations facilities and their equipment; initial engineers who served important functions in the Technical Division included V. R. Thayer

(heavy water), J. C. Woodhouse (metallurgy), D. F. Babcock, and C. W. J. Wende (reactor physics and development). As Savannah River went into operation, the Manufacturing Division took on more responsibilities. William C. Kay was the original manager of that division.[34]



Savannah River Construction Staff (As of August 1, 1969) **(Front Row)** Left to Right: J. C. Spinks, Div. Eng.; W. F. Powell, Div. Eng.; J. W. Mercke, Control Supt.; G. A. H. Tice, Doctor; J. T. Chesser, Jr., Asst. Field Project Mgr.; R. K. Mason, Constr. Mgr.; A. M. Scherffius, Jr., Field Project Mgr.; R. L. Wootten, Field Supt.; I. B. Lawton, Jr., Asst. to Employee Relations Supt.; T. E. Ewing, Employee Relations Supt.; M. E. McDaniel, Sr., Mech. Supt. (transferred 7/13/69); P. J. Masciocchi, Eng. Office Supt. **(Second Row)** Left to Right: A. A Cornell, Area Eng.; G. A. Georgeson, Area Eng.; R. D. Cook, Gen. Supt.; A. S. Freeman, Asst. Control Supt.; D. A. Damewood, Div. Eng.; W. W. Whalen, Asst. Ironworker Supt.; H. J. Kennedy, Div. Eng.; T. H. Riner, Pipe Supt.; R. A. Sentelle, Layout Eng.; R. C. Brineman, PTL Supt.; J. C. Carter, Elec. Supt.; P. J. Codespoti, Sr., Sheet Metal Supt,; T. W. Carr, Area Eng. **(Third Row)** Left to Right: C. W. Barksdale, Area Eng.; P. J. Cotter, Insp. Leader; L. P. Lalonde, Sr., Div. Eng.; D. M. Butler, Sr., Area Eng.; A. D. Herndon, Instrumentation Supt.; A. W. Schoenfelder, Asst. Elec. Supt.; R. M. Garnto, Carp. Supt.; H. S. Mura, Jr., Div. Eng.; W. C. Welborn, Transportation Supt.; J. B. McPherson, Layout Eng.; J. C. Lovett, Jr. Mech. Supt.; J. E. Crawford, Cost and Evaluation Supvr.; W. G. Edmonds, Jr., Area Eng.; R. D. Brown, Area Eng. **(Supervision Absent at Time of Photograph)**: N. R. Salley, Safety Supervisor; W. H. Spangler, Resident Design Eng.

Wilmington's Manufacturing Division was responsible for the operation, maintenance, and security of Savannah River overall; for assuring that design, construction, and modifications were carried out effectively and as necessary; and for safety and quality in general. The most important section of the Manufacturing Division was Process. The Process Section coordinated work with Du Pont's Engineering Department, analyzed Technical Division information and prepared it for use in production, worked closely with the Works Technical and Works Engineering at Savannah River to overcome problems and make improvements, and helped with the budgeting and coordination of major activities. The Process Section also acted as liaison between South Carolina operations and the Atomic Energy Commission and its other contractors concerning engineering and process matters.

Works Technical's Steve Markette and Joel Livingston inspect equipment for corrosion and to evaluate the need for replacement, 1956. Courtesy of SRS Archives, negative 3051-21.



Under the Savannah River Plant organization, the Works Technical Department served very important functions assuring continued safe and efficient operations. There was a department for each major manufacturing activity at Savannah River, and departments for overall concerns such as the Health Physics, Analytical, and Equipment Engineering Divisions of the Works Technical Department. Works Technical provided guidance

for operations, initiated and followed facility improvement tests, evaluated results, and very importantly served as the channel through which production requested assistance from the laboratory and worked with the laboratory to translate research and development efforts there to plant operations. Works Technical also prepared Test Authorizations and Reactor Startup Authorizations, which were formal notifications granting permission to begin operations activities according to normal practices or deviating from normal practices. Of great importance to the site in all areas was the Health Physics Department, which was responsible for monitoring contamination and potential contamination both within the site boundaries and in the wider region.

"If It Can't Be Bought, EED Can Make It"

Equipment Engineering Department designed and made custom equipment, developed software, analyzed metals supplied by offsite vendors as raw materials, and furnished new techniques and technology where needed in support of the Plant's missions. Originally organized under Tom Evans in 1952 to provide process assistance to the plant's fuel and target fabrication program, the small team was located in Buildings 320-M and 8300-M. In 1954, their mission was expanded and nineteen individuals, within the new Engineering Assistance Section of Works Technical, participated in providing metallurgical, mechanical, and instrument assistance to the plant. The group was then housed in M and H areas. The M Area group split off, developing into the Raw Materials Technology Section, and would later become part of the Reactor and Raw Materials Technology Department in the 1980s. The remainder still worked as part of the Engineering Assistance Department, which was renamed the Equipment Engineering Department in 1975. Tom Evans stewarded the department through 1975. Bill Taylor, Ben New, John Stewart, Stan Goodman, and Bill Anderson followed in that capacity through 1982.

From a staff of 19 in 1954, the EED grew to 125 by 1962. This department employed 152 individuals in 1982 working with computer and instrument development, a mechanical group, a metallurgical assistance group, and a power technology group. The NIMs (nuclear incident monitors located on the plant), health protection badge readers, Automatic Incident Alarm (AIA), an emergency cooling back-up system for the reactors, and the plant perimeter gamma monitoring system were developed by the EED personnel. Also computer control applications first developed for 105-K were a "first of a kind."

Source: "If It Can't be Bought, EED Can Make It," *Savannah River Plant News*, April 29, 1982.

The Production Departments, as the name implies, were responsible for operations in the various plant areas in accordance with the technical standards developed by the Wilmington Technical Division. Production also wrote operations procedure manuals for normal and abnormal conditions. Each of these will be discussed at length in following chapters.

Works Engineering embraced five departments. The Power Department supplied water, steam, and electricity to the entire site. Its services could be likened to a public utility. The Power Department personnel were the first to occupy each building area as it was completed, allowing the power workforce time to check all power equipment and to inspect all domestic water and sanitary waste treatment facilities to assure they were ready for use. The first work force report showed 132 employees on the payroll and one source notes that over half had previous power-related work experience. Les Ahrens was power superintendent from start-up to 1955 after which he was transferred to the GS Department. He was followed by Art Kroll (1955–1961), E. P. Eckhardt (1961–1976), F. W. Kanne (1976–1977), Hal Smoland, and Joe Jiunnes in the 1980s.

The First Laboratory Managers, Milton H. Wahl and W. P. Overbeck

The Savannah River Laboratory's first director was Dr. Milton H. Wahl, an early pioneer in the field of nuclear physics. Wahl was born in Emden, Illinois, in 1908, and received his primary and secondary education in St. Louis public schools. Central Wesleyan College awarded Wahl a Bachelor of Arts degree with highest honors in 1928. Then two years later he earned his Master of Arts degree in chemistry from the University of Missouri. Wahl received his doctorate in physical chemistry from the University of Illinois in 1933. During the next two years, he worked with Nobel Prize winner Harold C. Urey in isotope separation research.

In 1935, Wahl joined the Du Pont Explosives Department, working at the Eastern Laboratory on new types of explosives and explosive hazards. In 1942, he was transferred to Wilmington to take up a position as an upper-level technical assistant in the Chemical Department. He was next transferred to the Technical Division of the TNX Department during the Hanford project, where he made significant contributions to equipment design. During his tenure with the TNX Department, he became the department's Process Manager.

Wahl returned to the Eastern Laboratory in July 1945 to head a development group, where he stayed until his 1950 appointment to Du Pont's new Atomic Energy Division. He first served as Liaison Office manager at Argonne National Laboratory, then became the director of the Savannah River Laboratory in August 1952. Wahl became the head of the entire Atomic Energy Division in 1961.



Physicist Milton H. Wahl served as the first director of the Savannah River Laboratory, holding the position from 1952 through 1960; Wahl became director of the Du Pont Atomic Energy Division in 1961. Dr. Wahl is seated to the left, C. W. J. Wende, laboratory assistant director, is seated to the right and J. W. Morris, director of Separations and Services Division, is standing.

When Milton Wahl became head of the Atomic Energy Division, W. P. Overbeck was appointed to take Wahl's place as laboratory manager. Overbeck was born in Glenwood Springs, Colorado, in 1911 and first attended college at the University of Denver. In 1934, he completed his Bachelor of Science degree in electrical engineering at Massachusetts Institute of Technology. He then worked for Raytheon for several years before becoming a research associate at the Massachusetts University and later at the University of Chicago, where Overbeck was one of the group of scientists that assisted with the first controlled nuclear chain reaction, in December 1942. Wahl was asked to supervise Du Pont instrument maintenance engineers working at Oak Ridge in 1943, then joined Du Pont in 1944 as an instrument superintendent at Hanford, staying on at that facility after General Electric became the operator. By this time, Wahl had authored or co-authored several patents related to early computer development and reactor operations.

In 1951, soon after Du Pont formed the Atomic Energy Division, Overbeck returned to Du Pont to help with the design and construction of the Savannah River facilities. He spent a year as director of Technical Division Instrument Development, then was transferred to Savannah River, where he served as general superintendent of the Works Technical Division until being named director of the laboratory in July 1961. He held the position until his retirement in October 1967.



The second director of the Savannah River Laboratory was W. P. Overbeck, a participant in the experiment at Chicago to initiate the first self-sustaining nuclear reaction. Overbeck served as laboratory director from 1961 through 1966. He is shown here (on the right) with LeConte Cathey (experimental physicist) discussing Cathey's home-made lithium-drifted germanium detector. This kind of detector was just being developed for high-resolution gamma ray spectrometry. Sources: “Introducing . . . Dr. Milton H. Wahl," 2; and "Savannah River 'A Vital Enterprise' In Organization of Du Pont Company," *Savannah River Plant News*, February 23, 1962. "Introducing . . . W. P. Overbeck," *Savannah River Plant News*, April 3, 1953, 2; "Overbeck Shares in Credit for Basic Reactor Patent," July 4, 1958, 2; "Major Reassignments & Promotions Announced," *Savannah River Plant News*, July 14, 1961; "Overbeck Retires, Kruesi to Head Laboratory," *Savannah River Plant News*, October 6, 1967, 1; and “Overbeck Attends Event Commemorating 'Landing in New World' of Atomic Energy," *Savannah River Plant News*, November 30, 1962, 1.

When designed, the power facilities at Savannah River were considered one of the largest industrial-types power facilities ever built. Nineteen coal-fired boilers were operated with a combined capacity of almost 2.5 million pounds of steam per hour at pressures ranging from 325 psig to 900 psig. About 450,000 tons of coal were burned annually to generate sufficient steam to operate the plant. The steam is used for process needs and for electrical generation. Steam driven turbogenerators in P, K, and D areas generated electricity and additional electricity was purchased from South Carolina Electric and Gas Company. In 1980, Savannah River was their largest customer. The electricity was distributed over 190 miles of transmission line; the load dispatcher's office in the control house (Building 751-A) coordinated the transmission of purchased power and the interchange of power between generating stations.

The Power Department also operated the Site's water systems. The department operated 52 water wells, 33 deep wells, and 19 shallow wells that were capable of providing almost 45 million gallons a day for domestic and process uses. The surface clarification water plant in D Area was under their administration as were the water-pumping stations that supplied approximately 510,000 gpm of cooling water to the 105 reactor buildings. That translated into pumping 533,000,000 gallons of water per day. The operation of seven large cooling towers and seventeen smaller towers was also part of their job, as was responsibility for the operation of the standby electrical generators. Finally, the department was responsible for the sanitary waste treatment facilities and the fulfillment of regulations later passed for meeting the discharge requirements of the site's NPDES permit.[35]

The Maintenance Department, under Works Engineering, played an equally important role. They were responsible for the care and maintenance of non-electrical stationary equipment in the areas. The canyon mockup facility in F Area was operated by Maintenance. Process equipment and interconnecting piping (known as jumpers) were readied for remote installation in the canyons in the mock-up building. The Electrical and Instrument Departments were tasked with the repair of motors, electrical distribution systems, process controls and instruments. Large repair shops were located in A Area, where difficult jobs were undertaken, while satellite repair shops were situated in the areas where smaller tasks could be completed. The two departments were joined in 1961 under the direction of Harold Bowman and Jack Gosnell.

The Project Department, the fifth department within Works Engineering, undertook smaller construction projects, providing specialized engineering assistance needed in maintaining specifications and standards, evaluating problem areas, and improving existing facilities through capital and cost projects. Initially, under first superintendent Bill Christy, vacated houses and the Ellenton School Building were renovated for use as temporary office space for Operations. By the 1970s, this department was responsible for the design, development and construction of equipment for processing high-level liquid waste, beginning with the sludge transfer process. Its staff included engineers, estimators, drafts persons, project assistants and clerical personnel. Other service departments performed the necessary support, administrative, and employee and public relations functions.

The Wilmington Technical Division was responsible for new products and processes, and for major improvement work, as well as for establishing technical standards. The division also maintained technical liaison with the Atomic Energy Commission and other sites under subcontract to the commission. The three technical sections in Wilmington worked with the Savannah River Laboratory by supporting and reviewing their efforts and

coordinating the exchange of information between the laboratory, other Atomic Energy Commission sites, and the sections in the Manufacturing Division. The Technical Division also served as a channel for communications between field operations and Du Pont's Wilmington auxiliary departments and the Executive Committee.

At Savannah River, the laboratory organization was initially divided into three broad functional divisions associated with general physics, the reactors, and separations. In general, the laboratory was responsible for most development work, the testing of process modifications, maintaining the plant's technical standards, and approving test authorizations. The Physics Section dealt with broad theoretical, experimental, and criticality data, including the assessment of new reactor loadings. The Engineering and Materials Section developed and evaluated designs and fabrication techniques for reactor assemblies and their constituent components. Separations and Services operated the laboratory facilities and made improvements to chemical separations processes and equipment.[36]

By directive of the Atomic Energy Division, tight control on technical standards was a must, but the system that was developed also left room for improvements:

> A formalized system is employed by [the Atomic Energy Division] consisting of manuals, standards, specifications, and procedures. The control point in the system is a set of Technical Standards which prescribe fixed limits for the basic variables within which the process must be operated. The operating manuals and procedures of varying degrees of detail are designed to insure that these limits are maintained during operation and they are usually written to allow some factor of safety between the operating limits and the limits specified in the Technical Standards. The necessary flexibility of the system is obtained by means of Test Authorizations or Test Permits which are temporary technical standards intended to set the basic controls for tests of process changes or other operations of a nonrepetitive nature. The Technical Standards are based upon Technical Manuals which record the technical background of the equipment and process in sufficient detail to serve as a reference for the preparation and approval of Technical Standards.[37]

HUMAN ELEMENTS: SECURITY AND SAFETY

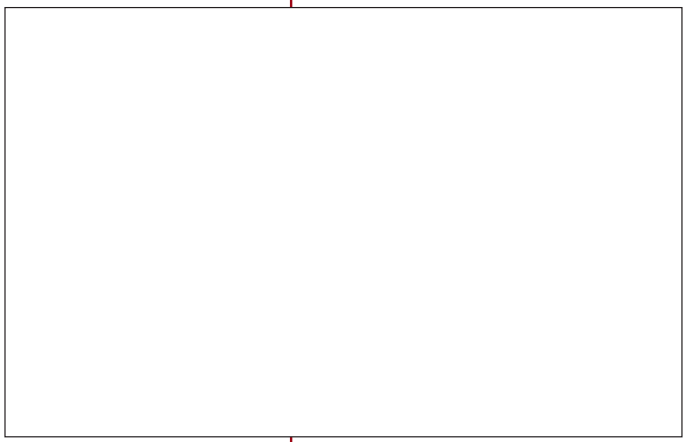
There are two aspects of work at Savannah River that have probably done more to define the work experience there than any other—security and safety. The extent to which these two items permeated the workplace did more than simply establish a framework within which the employees and managers would operate. They were two fundamental principles of operation that built a pervasive work environment which directed and even dictated many aspects of not only work life, but also of life at homes far beyond the plant fences. Security considerations could also be viewed as limiting the flow of information to the general populace that is necessary if the citizenry is to knowledgeably exercise its democratic rights of public governance. Safety had long been a hallmark of Du Pont oper-

ations. The company went to great lengths to establish safe working environments for employees, and to encourage the export of safe practices to the home. And security issues set limits to conversation both at work and at home.

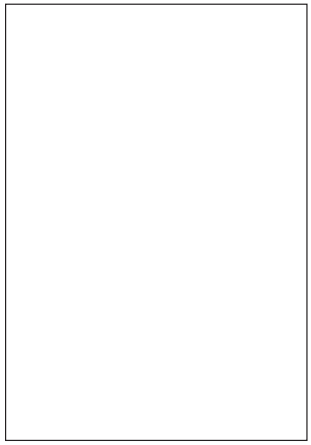
STAYING WITHIN THE FENCE

As discussed in Chapter 9, entry into the site and information leaving the site had been an issue of control from the earliest days of design; measures to keep information within the fence were well in place by the time operations began.

Physical barriers at the plant included a perimeter fence around the entire installation and additional fences around areas with restricted access. At least one area, surrounding Building 217-F, was from the beginning provided with a double fence, a separate alarm system, continuous lighting, and housing for the patrol force. This important building was where what was simply called "product"—plutonium-239 and tritium—was stored prior to transfer to the next point of manufacture in the nuclear weapons production complex. Entry to areas of restricted access was gained by way of the guardhouses. Some allowed vehicular passage, but many were designed for foot traffic only. Some were also designed with special protective features for the safety of the guards in case of an emergency. Entry to the site by air was for a short time guarded against by extensive anti-aircraft emplacements, constructed at several locations around the installation and operated by Army troops. In 1955, the 11th Antiaircraft Group provided this defense, with 90 officers and 1023 enlisted personnel, but the antiaircraft emplacements they manned were abandoned by 1960.[38]



Employees line up to pass into and out of the M Area gate in 1953. Courtesy of SRS Archives, negative 2-282-4.

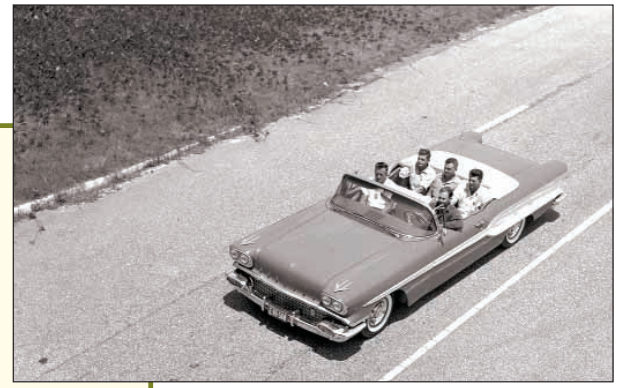


Like today, employees at Savannah River wore badges for identification and to indicate their level of clearance during the early years of operations. Here, Helen Yarborough of the Health Physics department shows off one of the newly designed badges issued in 1958. Courtesy of SRS Archives, negative DPSPF-5285-3.

To manage security, Du Pont set up a Security Department with two divisions: Security and Patrol. The former was to establish the rules and administrative procedures needed to comply with federal regulations and to educate employees about those rules and procedures, while the latter was to enforce the rules.[39] The patrol force, originally operated by Du Pont, was described as large enough to maintain "a city the size of Boston, San Francisco, or Washington, DC."[40] It was established in October 1952, and grew rapidly as construction was completed and operations began. By the end of 1952, after the 400 and the 300/700 Areas had been turned over to operations, the division had a total force of 261 persons. Patrol reached its peak in early 1954, with 854 patrolmen and 109 other persons. The force began to decrease as construction drew to a close, patrolmen transferred to operations positions, and the use of personnel was made more efficient. The gradual decrease continued through the years, reaching a low of 227 persons in June 1975. The number of persons in the division grew thereafter because of increased security concerns. Then, between November 1983 and February 1984, the Du Pont security force was disbanded and security of the plant was gradually turned over to Wackenhut Services, Inc., which continues to provide security at the site. Throughout Du Pont's operation of the patrol force at Savannah River, over three million rounds of ammunition were expended without an injury resulting in a lost workday.[41]

The broad requirements for security were established by federal legislation, then interpreted and applied by first Du Pont, then Wackenhut. The high level of security was nec-

The Carpool



For many plant employees, the workday began and ended with a ride in a car pool. In 1953, F Area clerk Deloris Fitts noted that her car pool companions would daily remind each other not to forget their badges. Evidently, the car pool buddies were commonly relied upon to be certain not to leave one's badge at home. During construction, information about forming car pools was made available to employees through the Personnel Division, and during operations through classified advertising in the plant newspaper. The Savannah River Plant News also ran a regular column called "Car Pool Comment," which as noted in its initial appearance took its text from the car pool conversations.

The car pool brought the plant to the employees' doors, but was not a complete extension of the plant boundaries. The prohibition against discussions of classified information at home was intended to include the car pool as well. Car-pooling was a family necessity, because many families had only one car, and a convenience because of limited parking space at plant lots. Some of the car pools were for-pay arrangements, where the driver would charge the riders a fee for the service, but most were offered on a shared basis. Typically employees carpooled with neighbor employees; companions were chosen on the basis of geography rather than common work departments or shared interests. Since employees did not always find rides with persons in their same departments or even in their management or labor grade, the ride to and from work sometimes offered cross-communication not otherwise available. Car-pooling was almost ubiquitous among plant employees, and as such was a defining element of Savannah River workers. Like a gatehouse that offered a defining point of entry to a controlled area, the car pool—with its reminders to not forget badges, its rules of timeliness ordained by the shift schedule, its attendant responsibility for the safety of other workers and for national defense—offered an extended, social point of entry to the work environment.

Photograph courtesy of SRS Archives, negative 5979-1.

essary because the Cold War was not just a battle of armaments and international positioning, but also one of technology, where gains on research or production fronts could be lost quickly with the transfer of vital information—inadvertent or purposeful.

THE PRIORITY OF SAFETY

"Whatever you do, on-plant or off, 'Fit Safety In First.'"[42]
—Savannah River safety theme for 1962

The Du Pont company had made safety a prerequisite for plants long before operations began at Savannah River. After 40 employees were killed in an explosion in 1818, company founder Eleuthère Irénée du Pont established basic safety practices that have become principles of company operation. Du Pont had also, in company literature, relinquished the primacy of operations to safety by stating that the company would produce only materials that could be made, shipped, and used safely.[43] The text of one company safety publication states this clearly:

> The technology of a process or an operation is considered to be incomplete until every possible element of danger has been mastered or eliminated. And no such project gets the go-ahead signal until the safety factor is satisfactory. The rule is inexorable, and applies equally to a plant costing millions or a stairway costing a few dollars. Chance cannot be ruled out of any man's work, in industry or elsewhere. But predictable chance can be reduced to a minimum . . . [, and it] continually shrinks in Du Pont plants toward the visionary irreducible.[44]

The most formidable safety hazard at Savannah River was radiation. To create a safe work environment, buildings and work areas within buildings were designed to limit worker exposure. Items and materials that emitted penetrating gamma rays and neutrons were kept behind thick shielding. Protection from the less energetic radiation sources was provided by shielding, as appropriate. That protection in some areas including full protective clothing and external breathing air. Areas where workers could be exposed were clearly marked by barriers, and various personal monitors were worn to ensure shielding and barriers were operating as

they should be. Workers also had to monitor themselves for radiation exposure when leaving designated areas. Monthly and annual exposure limits were set, and if employees approached these limits they would be reassigned to areas where they would be less likely to be exposed to radiation.[45]

Another safety hazard at Savannah River was hydrogen sulfide. This highly toxic gas can be harmful or fatal even in very small quantities. Large quantities were used in the 400 Area, where the use of the gas was made even more dangerous by the pressures in the processing equipment—up to 300 pounds per square inch—and the high corrosiveness of the gas. From the beginning of 400 Area operations, the atmosphere in the area was continuously sampled, each worker carried paper that would indicate the presence of the gas in air at concentrations less than can be smelled (it has a strong rotten egg smell that can be detected at far below lethal levels), all personnel were issued gas masks, and workers in the units carried cylinders of breathing air. All work was also conducted on the buddy system, which required most work to be done by a minimum of two persons. If one was overcome by hydrogen sulfide, the other could get help.[46]

Du Pont also set up a safety monitoring and oversight department within the plant operations structure called the Health Physics Department; the name was later changed to Health Protection Department, and it is currently organized under the Safety and Health Department. Inspectors in this department monitor radiological safety conditions in the various operations areas. Although they were assigned to work in operations areas, and their work was determined by production demands and schedules, the Health Physics inspectors were not ultimately accountable to production management but to the independent Health Physics management. Thus radiological safety was placed on a level roughly equivalent to operations in the plant management hierarchy. The Health Physics department had the authority to alter or halt operations that were not being conducted according to Health Physics procedures, that were being conducted in areas that had become contaminated beyond allowable limits, or were for some other reason deemed unsafe.[47]

Health Physics had its beginning in the health group of the Manhattan project. The group conducted frequent physical examinations of employees, set exposure standards, developed instruments to measure exposure, measured radiation levels, and monitored contamination of clothing, laboratory desks, waste water, and the atmosphere. K. Z. Morgan, who did much to define the profession in the beginning, directed the Health Physics Division at Oak Ridge during the postwar years and helped form the Health Physics Society. There were few academic programs producing health physicists at that time, so Savannah River drew from personnel at Oak Ridge and Hanford. Early health physicists included H. A. McClearen, who had worked under K. Z. Morgan at Oak Ridge; C. M. Patterson, who worked at Hanford and headed the Savannah River Health Physics department from its establishment until 1978, and W. C. Reinig, also a Hanford health physics alumnus and manager of the department at Savannah River after 1979.[48] In September 1952, the section was moved under the Works Technical Department to better integrate it with other technical groups at the plant and give the section greater access to personnel. The move was made because it was then felt doing so would not undermine Health Physics' ability to control its own functions.[49]



Safety sign at the entrance of K Area in July 1958. The bottom flag had just been awarded to the area for operating 1000 days without a lost work case. Courtesy of SRS Archives, negative DPSPF-5265-1.

Safety

1



Du Pont and other industries tallied workplace safety in terms of the number of hours worked without an injury serious enough that it required the employee to take off work. For instance, 100 employees, who worked an eight-hour day without an injury, would accumulate 800 injury-free person-hours. Figures like these were used to more dramatically illustrate the number of injury-free person-hours worked at Du Pont plants.

1. Courtesy of SRS Archives, negative M-307-5. 2. Courtesy of SRS Archives, negative M-2737. 3. Courtesy of SRS Archives, negative M-176. 4. Turtle Club members and their safety initiatives were noted in the Site newspaper. Courtesy of SRS Archives, negative 1941-12. 5. Courtesy of SRS Archives, negative PCD 0199-4. 6. Courtesy of SRS Archives, negative PCD 0199-5.

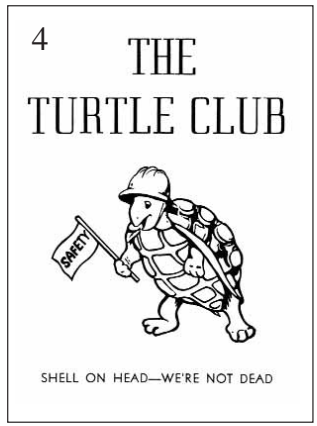
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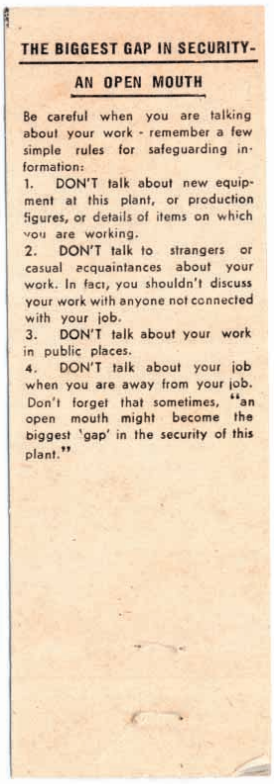


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Security

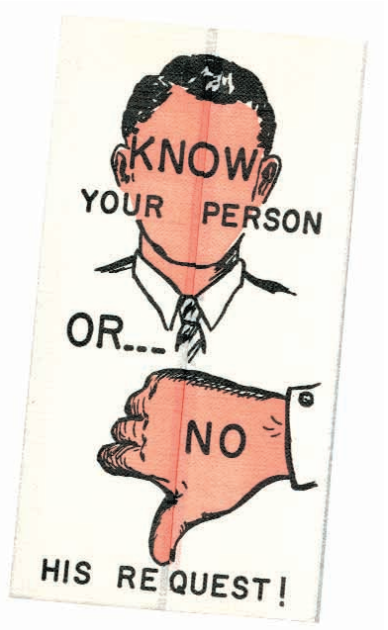






Security signs and slogans were found painted onto billboards and placed along the plant's roads or over entry doors, made into posters, and in some cases, printed onto cafeteria napkins and matchbook covers.

The Savannah River's Security department archived a collection of sample signage printed on postcards that were used as models for SRP's Sign Department in the 1950s and 1960s. Shown are samples of security slogans from this collection. Source: SRS History Project.









The Health Physics group's three initial engineers began a training program in mid-1953 and started following the construction in the reactor and separations areas so they would have an intimate understanding of the designs and hazards, and so they could suggest improvements from a radiation safety perspective. The staff grew during the following year; training sessions were held for startup operators, and radiation zones and danger areas were established in all process buildings. The zones were designated, from less to more radioactive, as clean areas, regulated areas, and radiation zones. The latter two con-

Radiation and its Biological Impacts

Radiation is energy emitted in the form of particles or waves. The term includes microwaves, radiowaves, and even visible light, but in relation to atomic energy radiation refers to energy emitted from an unstable nucleus when it decays or when it is broken apart by means other than decay. This type of radiation is more specifically called ionizing radiation, which means it is energetic enough to strip electrons from other molecules.

There are four types of radiation: alpha and beta particles, gamma rays, and neutrons. Alpha particles are heavy, slow moving, and can be stopped by shielding as lightweight as a sheet of paper. They are composed of two neutrons and two protons, and thus are a form of helium. Although alpha particles do not travel far, an alpha emitter lodged in living tissue can do substantial damage. Beta particles are free electrons (and occasionally protons), and travel much farther and faster than alpha particles. A thick piece of wood is required to stop beta particles. Their higher energy levels mean they are much more penetrating and can cause greater damage to living tissue than alpha particles. Gamma rays are highly energetic and are similar to X-rays. They can pass through several inches of lead and several feet of concrete, and gamma rays can be extremely damaging to living tissue. Neutrons are emitted at a variety of energy levels and can also be very damaging.

Radiation is measured by two main yardsticks: curies and rems. A curie is a measure of the rate of decay of a radioactive source, and thus is a measure of its rate of emission of radiation. One curie is equivalent to 37 billion decays per second. A rem is a measure of the approximate effect of radiation on living tissue. The term "rem" is an acronym for roentgen-equivalent-man, a measure of effect based on the roentgen. A roentgen is a measure of radiation required to produce ions (that is, to strip electrons from molecules) in a specific quantity of air, and a rem is a measure of radiation exposure (expressed in rads) multiplied by various factors that take into account the damage caused by different types of radiation. Thus a rem expresses the amount of ionization in living tissue caused by exposure to various types of radiation. The ionization of molecules in living tissue can cause cell damage or death; if extensive enough, ionization can cause entire organs or organisms to die.

High doses of radiation can cause the burning of living tissue, while low doses can alter DNA and cause cancerous tumors and genetic mutations by the ionization of molecules. However, all of us are exposed to radiation every day. On average, about 82 percent of our daily radiation exposure comes from natural sources such as radon on earth, cosmic rays from space, and sources within our own bodies. External sources include medical X-rays and a small amount from fallout caused by nuclear explosions. On average, our exposure to radiation from manufactured non-medicinal sources is less than about five percent of our total exposure.

Sources: *Closing the Circle on the Splitting of the Atom*, Document Number DOE/EM-0266, (Washington, DC: Government Printing Office, January 1996), 39; and *The Nuclear Waste Primer* (1985; revised ed., Government Printing Office, 1993), 11 and 18.

(Opposite Page) 1. Many different types of radiation monitors have been used to assess exposure of personnel. An employee checks hands and feet for contamination by using an early style hand and foot counter. This type of monitor was used in the 1960s. Courtesy of SRS Archives, negative DPSTF-1 –8902. 2. Walkover monitors were used to ensure that contamination did not leave an area on the soles of employees' shoes. Courtesy of SRS Archives, negative DPSTF-1-10229-8. 3. Mary Canuette, Ruth Edenfield and Louise Montgomery working in mobile unit change film in film badges, 1956. Health Physics personnel performed this task weekly, working two shifts. Courtesy of SRS Archives, negative 3109-30. 4. More precise measurements of exposure could be determined by analysis of the components in the criticality Neutron Dosimeter, also called a "pencil," and sometimes "pen" for short. These pencils were about four and one-half inches long and a half-inch in diameter. Neutron Dosimeters were worn so they would fit tightly against the body for a more accurate count of exposure to neutrons. Courtesy of SRS Archives, negative DPSTF-1-11757-5. Views 5 and 6. Film badges and dosimeters were used to measure beta and gamma radiation exposure. Film badges were worn by all persons in areas where they could be exposed to radiation during a criticality accident or other event resulting in possible radiation exposure. These badges allowed health physics personnel to quickly determine if and to what extent a person had been exposed to radiation. In this photograph, the badge has been disassembled to show its component parts—the complete badge is on the left. Courtesy of SRS Archives, negatives DPSTF-1-10310-16, DPSTF-1-11945.



Detecting Radiation

The instruments and equipment used by Health Physics personnel were important aspects of their jobs. World War II-era instrumentation included "Sneezy" and "Pluto" monitors, used to measure airborne radioactive dust and surface alpha contamination, respectively. An array of instruments and equipment had been developed by the mid-1950s. These had names like Juno, Fish Pole Probe (manufactured at Savannah River using Raychronix Cutie Pie monitors), Samson, A. C. Poppy Probe, Kanne Chamber, and the P. I. T. Source Monitor (manufactured by the Health Physics section).

During the Manhattan project, pocket detectors were developed to be worn by individuals as a means of roughly determining levels of exposure--the first dosimeters. These unreliable first models (employees wore two of the first pencil-style monitors for greater accuracy) were soon replaced by better film badges initially developed at Oak Ridge and improved there and at other locations; film badges were used at Savannah River to monitor beta, gamma, and neutron exposures. Special Neutron Dosimeters were also used to measure neutron exposures.

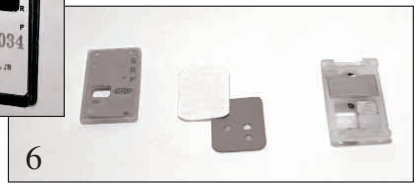
Improved personal monitors called Thermoluminescent Dosimeters (or TLDs; TLNDs in the case of the dosimeters for neutron measurement) replaced the older style film badges in 1970. The new monitors more accurately reflected the actual effect of radiation on biological tissue. This type of dosimeter was used for beta and gamma radiation exposure estimates until replaced by the current model in 1982. The neutron dosimeter was replaced by a new design in 1995.

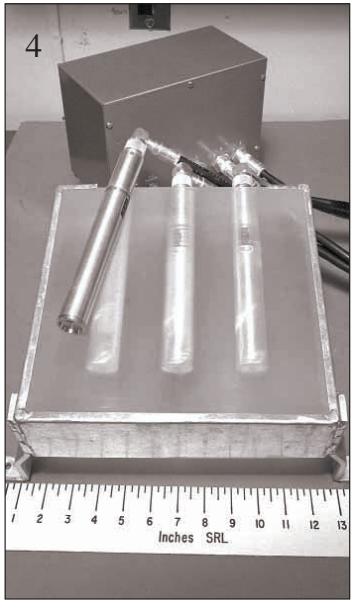
Sources: C. N. Wright, J. E. Hoy, and W. F. Splichal, Jr., *Savannah River Plant Criticality Dosimetry System* (Aiken, South Carolina: Savannah River Laboratory, November 1965),5; Smyth, *Atomic Energy for Military Purposes*, 149--151; Dante W. Wells, "Advances in External Dosimetry at the Savannah River Site," in *50 Years of Excellence in Science and Engineering at the Savannah River Site*, Document Number WSRC-MS-2000-00061, draft (Aiken, South Carolina: Savannah River Site, 2000), 219-222; and W. L. Marter to S. D. Smiley, "Health Physics Instrument Specifications, 200 Area Increased Productivity Program," with attached equipment and manufacturer list, February 16, 1956, 1-5, Acc. 1957, Series III, Box 8, Folder 3, Hagley.





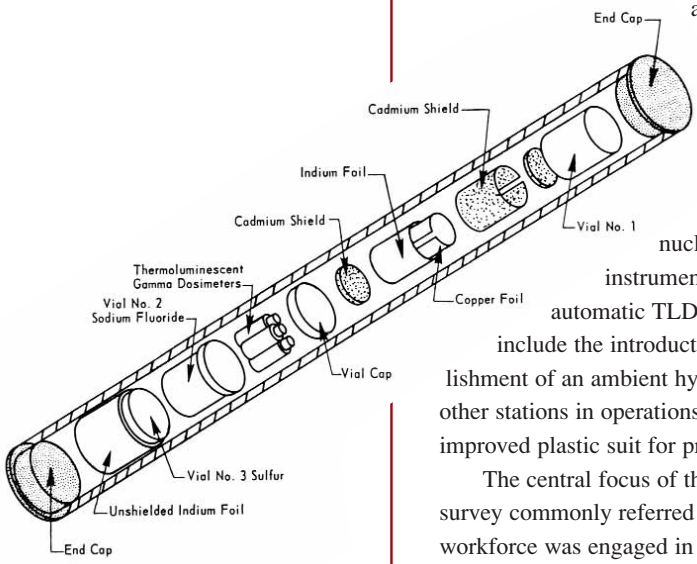






trolled zones, known as RAs and RZs, had guidelines for personal protective clothing and monitoring.[50] Health Physics also issued work permits for construction, maintenance, and service work in these areas after operations were underway. The work permits, which specified the type of protection and dosimeters required for the employees conducting the work, were means of incorporating Health Physics assessments into all modifications of the physical plant where radiation was a potential concern. Now generally known as Radiological Work Permits, similar permitting systems are the standard in the nation's nuclear industry.[51]

During the 1960s, health protection research and development expanded. An automated film badge system was introduced that allowed badges to be loaded and film numbered automatically. The whole body counter was completed in 1960 and calibrated for Savannah River radionuclides, and the process for counting employees was in place in 1961. The international limits for tritium protection were structured by data presented by Savannah River's Health Physics department. Also a new method for monitoring radiostrontium from fallout was devised by analyzing baby's teeth donated by employees and local dentists. In dosimetry, an advance was made with the introduction of a personnel dosimeter for measuring employee's exposure in the event of a criticality incident. This device was adopted for use at other nuclear plants. 1970 marked the replacement of film with thermoluminescent crystals in the personnel monitoring badges, and in 1971, the thermoluminescent neutron dosimeter (TLD) replaced the nuclear track film badge to determine neutron exposures. With instrument assistance provided by Engineering Assistance, now EED, an automatic TLD reader was created to read the new badges. Other advances include the introduction of a carcinogen handling policy and procedures, the establishment of an ambient hydrogen sulfide gas monitoring system in D Area that led to other stations in operations areas for other non-radioactive pollutants, and the design of an improved plastic suit for protective clothing.[52]



More precise measurements of exposure could be determined by analysis of the components in the criticality Neutron Dosimeter, also called a "pencil," and sometimes "pen" for short. These pencils were about four and one-half inches long and a half-inch in diameter. Neutron Dosimeters were worn so they would fit tightly against the body for a more accurate count of exposure to neutrons.

The central focus of the program, however, was the radiation and industrial hygiene survey commonly referred to as the "area survey." The majority of the Health Physics workforce was engaged in area survey, providing 24 hour assistance to all the departments in operations that ranged from surveillance of ongoing radiological and industrial hygiene conditions as well as providing input on preplanning work and job plans. Their objectives were the minimization of personnel exposure to radiation, toxic materials and other potentially damaging agents, such as noise; to minimize contamination of the site's facilities and environment; and to train its personnel to handle routine work and emergency situations safely. The Area survey personnel were also directly involved with the site's emergency response plan, providing training for all shift crews for the Emergency Operating Center.

The Health Physics Department was also responsible for monitoring the effects of radiation from Savannah River outside the plant boundaries. Its work supplemented that of another important organization from offsite. In May 1951, the Department of Limnology at the Academy of Natural Sciences in Philadelphia began a year long study of the plant and animal life in the region to ascertain normal biological conditions, to be used as a base from which to measure the impact of future industrial operations. Subsequent studies have been conducted every three to five years since the initial study.

The health of employees on the job was the domain of the Medical Department, which was responsible for pre-employment physicals, annual physicals, and emergency treatment. During construction, four first aid stations, one each in 3/700, D, R, and P areas, provided emergency care until a diagnosis could be made and a treatment plan defined. The first pre-employment physical occurred on February 1952. Du Pont experienced difficulties in hiring physicians the first two years of the project. The first Medical Superintendent was Dr. Cecil Bradford who transferred from Du Pont's Chattanooga Plant to Savannah River in 1952.

Dr. Bradford and Mary Hannah, the plant's first nurse, worked out of 704-D initially. With the completion of the main Medical Building (719-A), A Area became the central focus of the Medical Department with smaller medical stations established in each of the building areas. In June of 1955, the department employed 10 doctors, 38 nurses, 10 medical technicians, and 9 clerical employees. Training programs were undertaken to provide the medical staff with information about Du Pont Company medical health plans and policies and to train these individuals in the treatment of patients involved in hazards particular to Savannah River. Dr. Bradford retired in 1964; Dr. Donald Eckles was superintendent for the next two years. The plant's third medical superintendent, Dr. George A. Poda, promoted to the position in 1966 and active in that role for over two decades, became synonymous with health and wellness at Savannah River. Dr. Poda also strengthened community ties. He was appointed assistant clinical professor at the Medical College of Georgia where he taught industrial medicine in addition to his position at SRP. Also, a mutual assistance pact, hammered out by AEC's Karl E. Herde, was agreed upon between Fort Gordon and the Plant during his tenure.

As Operations got underway, physicians were assigned to each area where annual examinations and disability wage follow-ups were given. A nurse would rotate from area to area on a schedule, providing twenty-four hour coverage to all the outlying stations in the operating areas. Under Dr. Poda, health services were expanded to include audiometric testing, pulmonary function studies, and expanded laboratory tests that included blood chemistry and a blood count and hematology. All Savannah River nurses were trained as Emergency Medical Technicians, audiometric technicians, and pulmonary function technicians in order to carry out their expanded mission.

Overall, the department's responsibilities evolved into seven tasks: pre-employment physical examinations; continuing education about wellness; periodical physical examinations; the provision of emergency treatment for on/off jobs or injuries; practicing and educating employees about preventative medicine; providing some immunizations; referrals to private physicians; and providing physical examinations for retirees. The latter included the completion of a questionnaire, height, weight, and blood pressure checks, urinalysis, blood chemistry (13 parameters), complete blood count and hematology, eye examination, audiogram, chest x-ray and pulmonary function, and physician's examination.[53] Focus on health education programs increased over time.

Safety concerns extended to much broader areas beyond industrial medicine and radiological health onsite and off. Over $1.5 billion was budgeted for safety during the first 15 years of Savannah River operations. The first efforts to address broad operations safety issues were taken by the Central Safety Committee, established July 30, 1951, and comprised of upper management personnel. The committee held meetings twice a month and dealt with issues from operations safety to traffic accident prevention campaigns. The first

From Horse and Buggy to the Modern Jet

I just completed a residency in Philadelphia where I averaged two hours of sleep a night and decided that I wanted some place that I could work, and get eight hours of sleep a night. So, I answered an ad that led potentially to New York City. He [the interviewer] referred me to Du Pont for an interview and [I] was hired. Well, I went to Wilmington, Delaware…and they sent me to the Yerkes plant in Buffalo New York, where I started working as a facility physician. Arrived here [at Dana] January 31, 1951, with my administrative degree. Two years there, then I went to the Navy for two years, then to the Savannah River Site. When I was in the Navy, I got two phone calls, one - asking me to go back to the Dana plant, which I declined, and the next phone call offered me the Savannah River Site, which I gladly accepted.



[At Savannah River] I had a staff to coordinate, and I always felt that we were there for the employee… We wanted a prototype thing. I did not want them to say I'm medical, you're not. Therefore do what I tell you or else. I saw enough of that in the Navy. And I was bound and determined we were going to have an easy flow-family type thing. You come to me like a child, "Hey I'm hurt. What do I do?" That was the kind of attitude I tried to sell to my staff, and was able to do it. We had a good staff. We didn't have the employee-employer attitude. We were just one family. Medical and the Plant. And we ran it that way. Consequently people were not afraid to come to us. They came to us with all sorts of problems, and we were able to help them.

That was one of the things. The newness of the game, [we had] to look at the working conditions, which I did all the time. I made a lot of surveys while I was working there. For instance, in a hot gang valve corridor people were working at 140 degree temperatures. All right, I looked around and saw elbows in steam pipes that were not covered. I asked how come. They couldn't find any good insulating material that would take a bend like that. So I called Du Pont and wanted to know if their modular form could be casted, and they told me yes. So, our area supervision sent a foreman down to a plant in Georgia. I don't remember the name now. But he learned how to fabricate those things. We were able to manufacture all elbows and everything else to insulate these things and drop the temperature down to about 120 degrees. But it was still too high. So then I ran across a little tube sitting in the Health Physics office known as the vortex tube. Asked about it and was told that at one end you get red hot stuff that you can fry an egg [on] and at the other [end] it's about 45 degrees. I said that's exactly what we need in the hot gang valve corridor. So I went to Paul Moore who was then superintendent of F Area, and he assigned an engineer to get this adapted to Savannah River Plant, which we did. That…has been pretty much copied industry-wide for hot environments.

We had tritium. [As] a gas it's easier to maintain. If it's in water form, it'll go right through our polyvinyl suits. So Jim Corley of Industrial Hygiene and I worked together, and we found two key items that would keep it out: saran and silicone. I finally got two plant engineers to figure out a way of needling a saran to their tiegran and we were able to get somebody in Texas to manufacture plastic suits for tritium, and we were able to absolutely keep the tritium level down. These are some of the problems that we have. The big ones. And of course, how do you get rid of any radioactivity or radioactive materials that gets into the body? At that time very little was known about it. Very few people had any experience with it. So again, we kind of had to take the bull by the horns, and we developed two techniques down here of treating that, which was adapted throughout the whole world on the treatment of radioactive nuclides.

One, we had to develop a punch mechanism for cutting a finger and small puncture wounds. Just take a little punch and pull it out and instead of using surgery which made a lot nastier incision. This healed up over very quickly, and we were able to get it all out. We also developed a new technique we called chelation, which is the material that was given intravenously at one time to help the body get rid of everything. Well most of our uptakes were respiratory. Going back to basic high school chemistry if you want the quickest reaction you put two chemicals in one bottle. You don't put them in two bottles and put some permeable membrane between them. So if that was so, we could put the medicine in a bottle [to be inhaled], and I devised that, using what we use for asthma. Then we got more sophisticated. It was finally proven in England that that was a much more efficient technique than [was given] intravenously. It gave less drug more effectively, and that's been used world wide [since]. We also developed an ambulance service. We always had an ambulance service, but later on we developed EMTs specific for the ambulances.

All my doctors were required at least once a month to go out into the work place. Preferably some area that they hadn't been to before. So we all know somewhat [about] what a person [is] involved with. I mean it's awfully easy to sit back in an office and say hey. But you don't know what's going on. For instance in 400 Area, heavy-water area, we had the biggest power plant. Well when they shut down to clean it up. They went down into a great big type of thing which was 44 feet deep, but had only a 36-inch opening. If somebody got hurt down there how were we going to pull them out? Well, until I went down there and actually crawled through the 36-inch opening and went down to 44 feet and looked up and saw finally what was the problem, I didn't know what to do. But after going down there, yes. I was able to get what we call a restretcher which we could wrap around a person, and haul them up and get them through…And that same technique worked at the bottom of the storage tanks, and the separations divisions because they were deep and [we had] limited space to get them out. These are all the things that you have to work at in order to have a safe, helpful environment for people. Du Pont [supported us] very much that way. They tried awfully hard not to be the boss. Everyone worked together. Most of the

foremen there were previously mechanics or operators. So you can't work with people for five or ten or more years and then all of a sudden be a supervisor and sit up on the throne. You're still one of them, and that's the way the whole plant was run. Management applauded [doctors going out into the areas]. They wanted all of us doctors to know what was going on. Prevent stuff. We were on all safety committees, and they listened very closely to what we had to say about hazards that might be apparent out there. So we had no problem there, [we] had a lot of help from management.



Before I was promoted to Superintendent of the department [1966], we had minimal medical offerings to the employees. I did not like what we were doing. I didn't think it was enough. I went to management and told them that, and they said, "Hey, it's your baby go ahead." [As a consequence] …we went to the multi-blood tests, like you would get on the outside. It's the only way I could see of finding early changes that might possibly be job related. X-ray program was improved. I worked with Du Pont, and I worked with Kodak, and I worked with others to lower the dose of radiation to the point where we had absolutely the lowest amount of radiation to get darn good x-rays. And as a matter of fact, some of the hospitals around here followed suit, and we cut radiation because of that. We got electro cardiograms, soft reading electro cardiograms, so that if in the areas if somebody went in with chest pains there was just a nurse there at the time, she could run a cardiogram. It would say right there or something like that. And she knew enough back then to either get the person by ambulance into a hospital, or call one of the physicians to come down and evaluate. We did all of those things. We developed a hearing program. Pulmonary program, checking eye pressures, so that they got a real complete physical, and we were able to perceive any subtle changes. Then if we solve them, we evaluated them against their job and referred them to private physicians for followup if it was not job-related, and that way had what's called a healthy worker problem out there. Most of our people had less problems than the general populace because we picked up [symptoms] early. I don't know how many cancers we found early dealing with the lung. We referred on them. They were able to remove a portion of the lung. The person got a cure. Things like that.

Health Physics personnel were in the field. They monitored everybody. They did all the monitoring of chemicals, radiation, environment. All that sort of stuff. And without them, I would not have known what's going on. We had a wonderful HP department, probably the best in the country, and whenever anything cropped up they would come to me with it. My area at first, and then when I was superintendent, any area would come to me with it. We'd go over it and try to come up with a solution. People that had a problem health, I treated with health physics monitoring. If they didn't monitor, I wouldn't know if my treatment was good or not. And we were able to in all of the years out there. There was not a single person that had a deleterious body burden from anything they picked up on the plant. For instance, for a while we were working with californium out there. Nobody in the world ever worked with californium. Health Physics people picked up on the stuff, and actually we found two people that ingested some californium. Okay. They were able to monitor. Nobody knew how to treat it. I went to several sources. They all said they'd never heard of it. So I went ahead and treated them. Lo, and behold, we cleaned them both up 100 percent. Health Physics monitored us to the point where we knew it was all out. That was the relationship we had. One without the other was lost.

I'm the guy that fought for that [drug and alcohol treatment and rehabilitation program out at the site]. It took them seven years, number one to convince management, and number two [to] work up a protocol. But we worked hard at that, and I attended simple seminars on drug abuse and all of that. I think Kodak and Du Pont were the two originators of an alcohol rehabilitation program in [American] industry. Prior to that people just got fired if they were alcoholic. So that [alcoholism] we had worked with, but the drug program hit us when we had absolutely no way of checking. So as I said, I attended several seminars and got a lot of data on this and then worked with our personnel people in putting all of the data down into a format, which we did. That was reviewed and critiqued by I don't know how many people. Because you just can't go out there, and say, hey we have drugs, we're going to do this and that. Why are you going to do this? How are you going to do it? What effect does this have on the privacy of the individual? What effect does this have on this, that, and the other? When would it be called punitive rather than corrective? When can it be done honestly? That sort of thing. All of that had to be ironed out so that the thing's absolutely foolproof so that nobody would be discriminated against or picked on. In fact we even got it to the point where a computer picked the people to come [for testing]. That program turned out to be probably one of the best in the country for that period of time. Wilmington eventually pretty much adapted that program for general Du Pont use. The Atomic Energy Commission, later the Department of Energy, worked for years and years trying to come up with a program. Eventually I was a member of a committee to set a program up for the Department of Energy. All we did is take our program from Savannah River Plant, went down the list of everything, modified a few things that did not fit the government, and that was their program. So, it has been a huge success.

Source: Oral Interview with Dr. George Poda, June 21, 1999. SRS History Project.

(Opposite Page) Dr. George Poda, 1955. Courtesy of SRS Archives, negative M-1790-5. (Above) Nurse Norma Hedrick with ambulance, 1974. Courtesy of SRS Archives, negative 18520-7.

Plant Communications

The operations newspaper—The *Savannah River Plant News*—began in February 1953 and was published every other Wednesday. The coverage was similar to that of the *SRP News and Views*, with like attention paid to safety, general interest stories, and management introductions, but additional efforts were made to bring employees' opinions to the forefront. Columns presented employees' views on issues from the World Series to products they would like to see developed. Employee contributions and suggestions for stories were accepted. Stories also ran showing readers how various aspects of the site operated through full-page spreads with numerous photographs, covering activities such as payroll, the benefits plan, and the variety of jobs that were part of production at a site so large that some employees may never even see all of it. A lot of ink was allotted to promotions, including articles that featured photographs and biographies of people upgraded to Wilmington Salary positions.

Suggestion programs provided employees an avenue for communicating their ideas to managers for both construction and operations employees. Employees were encouraged by recognition and monetary rewards for suggestions that saved the company money and promotions like an occasional "Idea Day" that gave further incentive.

Later another means of communication was provided via the counselor program, begun in 1961. Managers designated as counselors were relieved of all other duties so they could devote their full attention to employee ideas, suggestions, and criticisms. Much of their time was spent walking through the areas they were assigned, talking to employees. The counselor program gave employees the opportunity to air grievances, and served a similar function as a shop steward in a union organization. Having this avenue of communication in place likely helped convince Savannah River employees and those at other Du Pont plants where the program was in place, from voting to unionize.



(Above) Mail Room workers stuffing *SRP News and Views* in manila envelopes for distribution, 1954. Courtesy of SRS Archives, negative 1729.

formal employee safety meetings were organized the September after the Central Safety Committee was formed. Safety slogans were common, as were other means of instilling safety consciousness in the workers. Joe Kirkpatrick, a labor superintendent during the original construction phase, presented a "Dog House" and hardhat each week to the labor department with the highest safety violation frequency rate.[54] In a 1954 plant newspaper article, safety was directly related to the Cold War defense effort: "'Without safety we cannot be productive, and only by being productive can we be strong and preserve the freedom of America,' [construction field project manager Robert K. Mason] declared."[55] Safety themes such as "fit safety in first," the 1962 plant theme, were chosen in employee contests. Personnel who had safety suggestions adopted in operations were publicly commended in the newspaper. Safety flags were given to operations areas that achieved safety milestones.[56] And a poem appealing to the extension of the safe work ethic to offsite practices appeared in one early plant newspaper:

> There was a young worker named Mose,
> Unable to see past his nose.
> Safety shoes were too dear,
> He'd rather buy beer,
> Now he's learning to walk without toes.[57]

Safety shoes were provided at no cost to employees for use at work (shoes for offsite use were sold at discount rates), as were safety glasses, gloves, and hard hats.[58] Offsite safety was rigorously promoted, especially traffic safety. A tally of the number of traffic accidents, warnings, and arrests was printed on the front page of most issues of the construction employees' newspaper, the *Savannah River Plant News and Views*.

These efforts have been quite successful throughout the history of the site. Only one employee has received an exposure exceeding five rem per year, and that occurred in 1956.[59] Forty-eight employees received exposures exceeding three rem annually during the period of 1951 to 1988, quite low compared to the nuclear weapons complex as a whole—35 employees at Department of Energy sites received exposures surpassing three rem just in 1986, and the commercial nuclear industry had 728 employee exposures of more than

five rem during 1980. Savannah River had one of the best safety records and lowest radiation exposure rates of the entire nuclear weapons complex, and it has also been noted to be one of the safest industrial plants in South Carolina.[60]

Awards recognizing safety achievements have come from Du Pont headquarters during its Cold War-era operation of the site, as well as from governmental organizations. The first award came from the Du Pont Wilmington office and was called the General Manager's Safety award, posted in October 1952, noting the accumulation of 1.3 million hours of safe operations. Two months later, the President's Safety Award commemorated the accumulation of nearly 2.4 million safe hours. However, the top Du Pont safety award, the Board of Directors Award, which required 200 days of operations without any injury that caused an employee to miss a day of work, would elude the plant for more than a decade. Finally during 1966, all 12 contractor and employee groups working at Savannah River worked an entire year without a disabling injury, earning the award; by the first month of 1967 the plant was eligible for its third Board of Directors Award. The plant went on to win 35 more of these awards through the remainder of the Cold War. It also won the Atomic Energy Commission's "Best Ever" award 1970 for accumulating the largest number of injury-free person-hours of any AEC contractor.[61]

SUPPORTING SERVICES



Traffic and Transportation Maintenance, Central Shops, 1956. Courtesy of SRS Archives, negative 3109-6.

A number of support services were developed to make the plant self-sufficient. Traffic and Transportation was integral to all operations across the site, from breaking down beaver dams that imperiled site roads to moving mammoth heat exchangers into the reactors. Originally, it consisted of five divisions: Traffic, Labor and Heavy Equipment, Automotive and Equipment Maintenance, and the Railroad Division. A large multi-bay automotive shop (Building 751-A) was constructed in A Area to handle automotive maintenance. A 1955 SRP news article noted that the cumulative mileage for one month for all the site's vehicles add up to a total of 835,000 miles, "a distance also equal to 33 trips around the earth or over three trips to the moon." To run the fleet of trucks, tractors, and light equipment alone required nearly 800,000 gallons of gasoline monthly along with 50,000 quarts of oil. Heavy equipment (riggers, cranes, bulldozers, etc) needed to handle a miscellany of site operations was garaged in Central Shops. Traffic and Transportation was responsible for road construction and maintenance, as well as all onsite shipping by truck or by rail.

Savannah River's railroad operations were stretched over 60 miles of standard gauge track; the Classification Yard near the Dunbarton town site was the hub of activity. This division was responsible for the operation of the rolling stock and maintenance of the site's tracks. The site's tracks connected with the Charleston & Western Railroad at the site of Ellenton and the Atlantic Coast Line tracks at the site of Dunbarton. Four crews were assembled to handle the workload in 1955 in which the site's eight diesel engines

"Your Job is Just as Big as the Man Pushing the Buttons in the Reactor"

When I first come in, why I got hired so fast, the first thing, when they opened up a plant, they need what? Janitors. So I applied for a janitor. I wanted to get in there. So they applied me for a janitor. I worked as a janitor eleven months, then I went to T and T, transportation. I was in the old schoolhouse in Ellenton. That was my first job, down in the schoolhouse down there. I was a janitor down there. They had an office down there, in Ellenton, South Carolina. So that was my first job.

What happened, you cannot force no one to do the right thing. You've got to let them do it on their own. You've got to carry yourself in the way they will give it to you, and not you go try to take it. See, I could ask you for something, you will give it to me, but I try to take it, you're going to rebel. You're going to take longer giving it to me. So we decided we wouldn't do that. Most of them came up through the segregation world, and we know how, and we were trying to make it better for our kids by going along whatever they do.

We knew we couldn't go in the cafeteria and eat like other people; we had to go in the corner. We'd bring our lunch. We sat in a group and eat. We know we didn't have bathrooms to go to, wash our hands. When we'd go in the field to do jobs, we would carry fifty-five gallon drums with water on it to wash our hands. So we didn't rebel.

As it come, and when it did come—they integrated all the bathrooms—we didn't just run in there, and say, "I'm going to take this locker, I'm going to take that locker." We eased into what locker was available, easing in. So, trying to make it better for the next generation to come. So that is how we worked it.

Now these things here, the supervision didn't know nothing about. We talked that among ourselves, and we tried to be a part of the plant. Just like I'd tell them, said, "Now we may not run the reactors, we might not run the powerhouse, we might not run the administration building, but we repair the roads for them to get there. We're making a big contribution toward the plant. We repair the roads to get here, we repair the waterlines, we do that. We're making a great part of it for these people who are running the reactor, because they couldn't run the reactor if they couldn't get to it. They couldn't run the reactor if they didn't have water. So we're doing the greater part. Your job ain't low. Your job is just as big as the man pushing the buttons in the reactors.

I associated a lot with the minority of black. Their lives changed tremendous from poor to middle class. They got a better life out of that, by this plant coming, because just like I was trying to tell some of the guys that were working. I said, "You ought to be thankful the plant come here, because this land you was farming was just something to keep the earth together, the land was so poor." I said, but now most of them own homes, nice homes and all, so they benefit.

So I learned a lot from out there, and I hope that we continues to keep the plant. I worked the whole plant. I worked the whole plant. If somebody wanted something did, after I came to be a supervisor, I was over all the heavy equipment in roads and grounds. If they wanted something did, I'd try to get it did. Regardless of how it was, I tried to get it done. And then nine times out of ten, I got it did, because I had good peoples, and the onliest way to work with good peoples is to be good to them, and let them be a part of what's going on, make them feel a part of what you do. So we'd get in the line-up meeting in the morning. "We done got this job and we've got this going on there, so we're going to do so and so today. How do you want to do it?" And they've got some good ideas. So we get together, we go do it, and we can do it the easiest way and the safest way.

We had some of the dangerous work out there. We didn't have no accidents. We turned one motor-grader over since I was there, one of the motor-graders turned over, but nobody didn't get hurt. But we relied on each other. And something they're doing right now in T and T that I started when I was there, I did not work two blacks together, I did not work two whites together; I mixed them. You get a better line of work safety-wise and production when you do that. The two men, they compete. They didn't have nothing in common last night. Their wives didn't go out to eat together last night. They ain't got nothing to hide from

handled about 2,700 cars (including coal deliveries) a month.[62] The Railroad Division was also responsible for the delivery of materials within the site, particularly irradiated fuels from the 100 Areas to the 200 Areas. Fuel elements and targets were delivered to the 100 Areas by truck.

The 700 Area was the Site's main support center and its public face. Within its boundaries lie the main administration building, an imposing two-story building with four wings, and a host of other service buildings that housed the site's security headquarters, telephone exchange, medical facilities, stores, fire station, and automobile maintenance. The Savannah River Laboratory, discussed later, was also part of the 700 Area but was set

Shepherd Archie, Traffic and Transportation Department

each other, to share with each other. The only thing they got in common is their safety and their job, and they did a tremendous job together by working like that. I left that—they are still doing it now. In the CSWE [Central Services Works Engineering], it's working like that, and that's working out fine.

Most everybody benefit by this plant coming here, and by that Savannah River Plant coming here, it not only helped that people that moved out of the area, the people that worked out there, but the industries inside Augusta and in the surrounding area. [They] had to go up and match the salary, or come close to matching the salary at the Savannah River Plant, the people at Babcock and Wilcox, Miriam Brothers and everybody, they had to go up and match the salary, or come close to matching the salary at the Savannah River Plant to keep their employees.



So that being that Savannah River Plant over there, it helped the whole area. Helped everybody. It didn't just help the people that worked out at the Savannah River Plant. The people at Babcock and Wilcox, Miriam Brothers and everybody, they had to bring their salaries up to keep their employees, because they were leaving here and going out there. Even the police department. They were going, leaving the police department, going to work for Du Pont security department and different places.

[The area has] changed. Some of the peoples left and some—the guy next door there, he worked over there, but he died in '81. But it's been the same. Kind of changes everywhere—you don't have no hard feelings about the plant out there. Everybody really cared for the Savannah River Plant, because why, they felt like they were kind of safe with the Savannah up there, but they don't trust these chemical companies here now. But Savannah River Plant, they trusted Savannah River Plant. Savannah River Plant tried to practice what they preached.

And another thing that made Savannah River Plant great, they hired inside the families. See, I have a son working out there now. My wife and I raised her sister's boy, a nephew. He's out there. And I have a niece out there. See, a big part of the safety record was to—see, I brought safety home with me. I'd tell my kids about house safety and what to do, what to don't do, how to drive a car, what they don't do, and Savannah River Plant helped a lot of families. You hardly ever hear kids, that their family was employed at the Savannah River Plant, get in trouble, because of the family, the peoples, the family that took care of them.

That man out there, he have five kids. He have two sons, three daughters, and they're always doing well. And nine times out of ten, everybody that had families worked at the Savannah River Plant, they did good. I sent all three of my kids to college, from working at the Savannah River Plant. My son, he's out there now, in the fire department. The one on the end out there, she's a doctor in Morehouse College, Atlanta. And this one right there in the middle (points to photograph), she went to Paine College.

So the Savannah River Plant really upgraded this section of the Southeast, not only here, all around Beaufort and all of those places down there. I worked with a lot of peoples from down there. So I think that it did us a good thing by moving in here. That's why I hope they keep it there.

Source: Oral Interview with Mr. Shepherd Archie, April 20, 1999. SRS History Project. Photograph: Courtesy of Shepherd Archie.

to the east of the administration complex. The Main Administration Building contained offices for both the AEC and Du Pont management teams and administrative staff. Communications, Purchasing, Records, Mail, Reproduction, Payroll and Stores were all based in the 700 Area, as well as the main cafeteria and Employees' Credit Union.

All of these support groups allowed the site to be an independent industrial entity that, in size and complexity, could best be likened to a city. The use of satellite support facilities in the process areas and the distribution of key personnel within each building or process area enabled each area to act independently of one another. The next chapters provide more detailed discussions of the main process areas: heavy water, reactors, and separations.

A Area Views

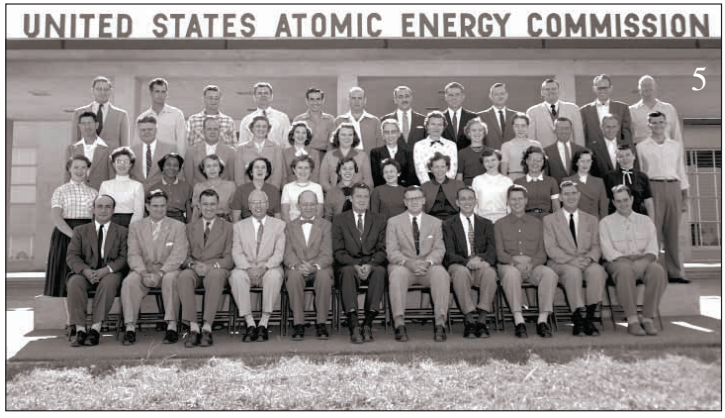

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Security





1. 700 Area Fire Department, 1957. Courtesy of SRS Archives, negative 4279-18. 2. Credit Union Committee. Signing of charter application of Savannah River's proposal for a New Employee Credit Union, 1960. Courtesy of SRS Archives, negative 6500-4. 3. Document Control. Courtesy of SRS Archives, negative 3360-4. 4. Personnel Orientation in 719-A, 1978. Courtesy of SRS Archives, negative 27210-2 5. Atomic Energy Commission Extended Staff. Courtesy of SRS Archives, negative M-400-4. 6. Group of newly hired engineers, 1962. Courtesy of SRS Archives, negative 8031-1. 7. Summer Youth Program, 1956. Courtesy of SRS Archives, negative 3434. 8. Clerical Pool's Bea Talbert gives Liz Smith an assignment, 1957. Courtesy of SRS Archives, negative 27204-2. 9. Cafeteria view in A Area. Source: *Savannah River Twenty-Five Year Dinner*. Courtesy of SRS Archives. 10. S.W. O'Rear and Jim Hill pose in awe over increased technical report production, 1960. Courtesy of SRS Archives, negative 6673-12.





12 Heavy-Water Production

Savannah River's pioneers in heavy-water research and production have good reason to characterize the history of heavy-water production at the two Du Pont plants—Savannah River and the Dana plant—as a historical saga.[1] As the following narrative shows, the drama of discovery, ardent experimentation, dangerous working conditions, critical need, and achievement all play a role in the history of heavy-water production at Savannah River.



Deuterium was discovered by Harold Urey and his co-workers at Columbia University in 1931. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38, negative 201-2016.

HEAVY WATER AND ISOTOPIC SEPARATION

H_2O, the water that we drink, is composed of two atoms of hydrogen (H) and one atom of oxygen (O). Hydrogen is the smallest and simplest of all the chemical elements and is assigned an atomic mass or weight of 1. Despite its size and simplicity, hydrogen has three forms, or isotopes, that act the same but have different masses. The most common form of hydrogen found in drinking water has an atomic mass of 1. However, in 1 of about 5000 hydrogen atoms, the atomic mass is 2. This heavy hydrogen atom is identified as deuterium, with the symbol D. Tritium, the third known isotope of hydrogen, has an atomic weight of 3 and a symbol of T.

When deuterium is combined with oxygen, the result is heavy water, chemically deuterium oxide or D_2O. Heavy water looks no different than plain water and we encounter it naturally in small quantities. Each time a person uses 52 gallons of water, an ounce of heavy water is present, and there is a pound of heavy water in every three tons of plain water.[2]

The fact that deuterium is so rare in nature made the recovery of large quantities of heavy water a difficult and expensive proposition. Because isotopes of an element have essentially the same chemical properties, common methods were not applicable for separating deuterium from regular water. Scientists instead looked to chemical differences between the isotopes and developed methods based on quantitative differences in reaction rates and reaction equilibrium constants to identify workable separation processes. In their favor was the fact that the physical and chemical differences between hydrogen and deuterium were relatively large, due to their twofold mass

ratio. Still, a great deal of research and development was needed to identify the process that would be both safe and economically feasible to produce heavy water on an industrial scale.

Educating the Public about Heavy Water

"Heavy water, which looks just like ordinary water, has an important part in the operation of certain types of reactors or atomic furnaces.

To understand, a look at the neutron is first necessary.



With the exception of simple hydrogen, all atoms occurring in nature are built of neutrons, protons, and electrons. Because it can transmute or change one element to another, a neutron has the leading role in the operation of reactors.

Neutrons, electrically neutral, serve as projectiles or bullets in piercing the hearts of atoms to cause abrupt internal changes. When a reactor has been loaded with fuel—uranium—and placed in operation, neutrons go flying out of the center of the atoms of uranium-235, flow though a "moderator" that surrounds the uranium slugs, enters other slugs of uranium, and wind up in the nuclei of atoms of uranium-238. This makes new heavier atoms of uranium. These atoms go through a series of internal changes to adjust themselves to the extra weight and finally become plutonium, which is useful in an atomic bomb. Reactors are also used to produce changes in the internal structure of stable atoms of many elements, which then emit radiation useful in medicine, industry, and agriculture.

Generally the more neutrons available in a reactor, the greater is the rate of splitting of the U-235 atoms, with consequent release of greater amounts of energy, and greater production of plutonium and other products.

Since U-235 is a scarce commodity, neutrons are precious. So the reactor is built in such a way that as few neutrons as possible are wasted. And materials are used that soak up as few of them as possible—the more busy neutrons there are, the cheaper and more efficient the reactor is in producing the materials desired.

Besides the fuel (uranium), the moderator is another main component of a reactor. The moderator brings us back to heavy water. Here's why:

When neutrons are emitted from uranium, they have very high velocities. It is necessary to have their velocities considerably reduced before they can be efficiently used. A bridle must be put upon them. If not, they bypass the U-235 and scatter about. This slowing down is accomplished by the moderator, which is placed around the uranium fuel. The neutrons go through many collisions with the atoms of the moderators. In each collision the neutrons reduce their velocity until finally they attain the proper velocity for greater efficiency. Two of the most used moderators in production reactors are graphite and heavy water. Graphite is used in the atomic energy installation at Hanford, Washington. Graphite is composed of carbon, the same substance that ordinary coal is made of. However, it is denser and purer than coal and has a different crystal structure.

It takes over 6,000 gallons of water to make one gallon of heavy water.

Heavy water is more efficient than graphite as a moderator because it slows down neutrons more quickly and also absorbs fewer neutrons in the process, giving a greater supply of the particles."

Excerpted from: Atomic Energy Commission Press Release on Heavy Water (No. 83), *SRP News and Views*, April 16,1955.

PREVIOUS RESEARCH

Harold Urey and his co-workers at Columbia University discovered deuterium in 1931. American research and development into economical separation of deuterium from light water was conducted at Columbia University during the 1940s. The first rough separation was by fractional evaporation of liquid hydrogen. Later, G. N. Lewis, with his research assistant Ronald T. MacDonald of the University of California, used electrolysis



Electrolysis plant at Vemork under German control during World War II. In 1943, the high concentration plant's heavy water cells and stock were successfully demolished by saboteurs, actually ski commandos of Norway's Linge Company, to slow Germany's progress on its "uranium project." Courtesy of Norsk Industriarbeidermuseum, Vemork, negative UF-131.

The original heavy-water, high concentration cells at Vemork, Norway. Norsk Hydro plant in Vemork, Norway, above the Maane River gorge, was the world's largest electrolytic hydrogen plant in the 1930s. By mid-1934, plant apparatus was modified to produce heavy water that was concentrated to better than 99% purity. Courtesy of Norsk Industriarbeidermuseum, Vemork, negative UF-113.



to concentrate deuterium oxide from a large quantity of water.[3] Early heavy-water research was devoted to discovering more about the two isotopes and their compounds and to evaluating deuterium's possible use as a tracer in biochemical processes and chemical reactions. The demand for heavy water was small, but it was produced commercially as a sideline industry within manufacturing plants that were already producing hydrogen and oxygen electrolytically. The Norsk Hydro plant in Vemork, Norway, the largest electrolytic hydrogen plant in the world in the 1930s, was producing heavy water by 1934. Historical documents show that the Norwegian plant shipped heavy water to researchers around the world, including Harold Urey at Columbia.[4]

By 1940, interest in heavy water heightened as scientists began to research its potential as a neutron moderator. A research and development program established at Columbia University under Urey began to investigate how heavy water could be mass-produced. This research, under the auspices of the Office of Scientific Research and Development, was carried out at other American universities and in industrial research laboratories as well.[5] After obtaining funding, Urey set up a pilot plant in Louisiana that was operated by the Standard Oil Company. The pilot plant was charged with studying the liquid–gas phase exchange reaction under high pressure, while Urey worked on developing a catalyst.[6] Heavy-water research continued, but the effort moved from Louisiana to Canada. In a cooperative effort between the United States, Britain, and Canada, Harold Urey worked with Hans von Halban, who was to head a heavy-water research program for the British. The program was located at Trail, British Columbia, near the American–Canadian border. An existing hydro-powered, electrolytic-hydrogen plant for ammonia production was in operation at Trail, owned by Consolidated Mining and Smelting Company of Canada LTD (Cominco). Cominco converted a loop in their ammonia plant for heavy-water production. By mid-June the plant had produced enough deuterium for Enrico Fermi to make measurements which proved that deuterium was an excellent moderator.[7] Unfortunately, the conclusive tests occurred six months after CP-1's success at Stagg Field in Chicago. Once the graphite-moderated reactor went into operation, heavy-water research was "relegated to a secondary role as the moderator for the second generation of nuclear reactors."[8]

Heavy-water production continued at three heavy-water plants, called P-9 plants, operated by Du Pont during the war. Du Pont successfully produced 32 tons of heavy water at their wartime plants. The chemical firm used excess steam from existing Department of War facilities at Morgantown, West Virginia; Childersburg, Alabama; and Newport, Indiana, to operate the plants. An electrolysis unit for final concentration and purification that served all three plants was located at Morgantown.

The Du Pont heavy-water facilities operated for two years, producing collectively 2,400 pounds of 99.8% heavy water each month. Wartime production included vacuum distillation of water followed by electrolysis for final concentration, because these processes offered little risk of failure and the needed materials were available. "The Columbia group and the Du Pont engineers who designed the wartime plants believed that stainless steel would be the only satisfactory material of construction for the H_2S process; the quantities required would have been prohibitive. After contemplating the building of a small demonstration plant, they set the dual-temperature process aside."[9] At the close of the war, sufficient heavy water had been produced for Argonne's planned heavy-water-moderated test reactors, so the Du Pont units were closed down.

Between 1940 and 1945, five primary separation techniques for recovering heavy water had been developed: distillation of hydrogen, fractional diffusion of hydrogen gas, electrolysis of water, distillation of water, and gas–liquid exchange processes (both dual- and single-temperature processes). In 1942, a dual-temperature, single-stage chemical exchange method of concentrating deuterium in an H_2O/H_2S system was completed in glass on a bench scale at the SAM laboratories at Columbia University.[10] Jerome Spevack, working in the Columbia University laboratory program, patented the dual-temperature process at this time and suggested its use with the water–hydrogen sulfide system.[11] Work on the development of the dual-temperature process at Columbia was suspended after

Squaredancing, Towers, and Cascades

"The chemical exchange process of isotopic concentration with which this study is concerned is based on two facts (scientifically established phenomena).

The first is that chemical molecules perform a kind of square dance in which there is an exchange of partners. We think of the oxygen in water as having each hand held by a hydrogen atom, thus H-O-H, with the hydrogen atoms releasing the oxygen and then joining hands with other oxygens while the first oxygen also gets new partners. Since the oxygens prefer not to be alone, only one hydrogen is exchanged at the time, thus:

HOH H + OH HOH HO + H

Hydrogen Sulfide, H_2S, exhibits similar behavior, thus:

HSH H + SH HSH HS + H

If some of the hydrogens are deuterium, some of the water molecules can be represented H-O-D (HDO) or even D-O-D (D_2O)—heavy water.

Now, if we mix H_2O, which contains a low concentration of deuterium atoms, and H_2S which also contains the same concentration of deuterium atoms, the hydrogen and deuterium atoms are continually exchanging partners, a particular H or D being now with an O and later with an S, etc. If the selection of partners were truly random, the exchange phenomenon would not alter the concentration of deuterium in either the water or the hydrogen sulfide. If, however, the deuterium should happen to prefer oxygen to sulfur, then after the chemical exchange has gone on for a while, the water would be enriched in deuterium and the hydrogen sulfide would be impoverished in deuterium due to this preference. This actually occurs. A measure of this preference is called the equilibrium constant (K). The existence of this equilibrium constant is the second fact necessary for the chemical exchange process. If there were no preferences, then the equilibrium constant would be unity or 1.000. Where the equilibrium constant is substantially different from unity, as is the case for the H_20/H_2S system, deuterium can be concentrated in water by mixing water and hydrogen sulfide and keeping them in contact so as to promote the chemical exchange phenomenon.

When one of the substances is a liquid and the other is a gas, the chemical exchange process is conveniently carried out by the use of countercurrent flow in fractionating columns. A fractionating column or tower is a well known device for obtaining intimate mixing of fluids by the placing of obstructions called 'plates' in the path of flow of the fluids. In laboratories these columns are small glass units, but in full-scale plants they are metal and may vary in diameter from a few inches to many feet, while several stories (50 feet) in height is not unusual. Usually some of the gas is dissolved or mixed in the liquid or vice versa.

In a system of countercurrent flow of two phases, it is convenient, and on a plant scale it is economical, to use two or more fractionating columns of decreasing size, transferring a portion of the enriched phase from the first column to the smaller second column and so on for as many units as desired. Each of these units is called a 'stage.' This technique is not novel with chemical exchange process for isotopic concentration, but it is an old chemical engineering expedient to achieve economy in capital and operating costs. Such multistage apparatus may be referred to as a 'cascade,' and the transfer of fluids between stages can be called 'cascading.'"

Source: Hagley Museum and Library, Wilmington, Delaware, Records of the Atomic Energy Division, Hugh K. Clark, *A Study of the Evidence Available to E. I. du Pont de Nemours and Company Concerning the Validity of U.S. Patent No. 2,895,803 issued July 21, 1959 to Jerome Spevack, August 30, 1968*, Accession 1957, Series II, Box 6, Folder 19.

1943. While laboratory-scale tests and some corrosion work had been accomplished, a semiworks demonstration of the process, which became known as the GS process, did not progress beyond the planning and design stage.[12]

The selection of heavy water as a moderator for the new reactors for the AEC expansion program in 1950 reintroduced investigations into the three potential production processes that could increase the one part in 7000 of deuterium in plain water by a hundredfold. These were vacuum distillation of water, distillation of liquid hydrogen, and exchange of liquid water with hydrogen sulfide (H_2S) gas in a dual-temperature cycle. The drawbacks on each were studied and compared in the light of the impending events and the availability of materials.[13]

In 1949, the Girdler Corporation, a Louisville, Kentucky-based firm, was asked to study the feasibility of converting the old Du Pont P-9 facility at the Wabash River Ordnance Works (WROW) to a low-pressure dual-temperature production plant under the guidance of the AEC's New York Operations Office. Given that the WROW facility was designed for vacuum operation, it could not be converted into a high-pressure production system. It was estimated that the converted plant could produce 2.5 tons of heavy water per month at lower pressures. In a report (NYO-681), Girdler recommended that a new, more efficient, high-pressure facility could be constructed at the same cost as the conversion of the existing facilities.[14] Girdler also reviewed a report to the AEC (NYO-508) by Jerome S. Spevack, titled "Pilot Plant Testing of the Dual-Temperature Heavy Water Process."[15] Spevack, a member of Urey's group at Columbia University in 1942, had been hired as a consultant by the AEC in 1948 to prepare a report on the dual-temperature process for isotopic concentration. Spevack improved his 1942 design by increasing heat efficiency with interstage cascading.[16] The Girdler review stated that the process suggested by Spevack appeared technically feasible, and it recommended pilot-plant tests. Reuse of the federal property in Indiana and some of the original P-9 facilities would substantially reduce costs that had heretofore been considered prohibitive.[17] If the pilot-plant tests at WROW were successful, then the facility could be expanded.

While Girdler's studies were ongoing, the AEC also funded work with the hydrogen-distillation process, requesting that Hydrocarbon Research, Inc., design a plant based on this process. On March 1, 1950, the commission approved construction of the second pilot plant. In this design, hydrogen gas would be cooled to liquid temperatures and fractional distillation would be used to separate deuterium from the gas.[18]

When Du Pont contracted with the AEC to construct the Savannah River Plant, they evaluated the three methods and decided that the Girdler sulfide (GS) process showed clear advantages, as long as three drawbacks were addressed. These drawbacks were difficulty in process control, the toxicity of the gas, and its tremendous corrosive power. Du Pont's engineers began to work cooperatively with Girdler personnel in the design and later operation of the Dana Plant, which was situated at the WROW. Girdler's primary engineers on the project were R. M. Reed, E. A. Comley and N. Updegraff. In a critical meeting between the two firms in early November of 1950, Du Pont's Explosives Department was represented by V. R. Thayer, D. F. Babcock, W. P. Bebbington, J. B. Tinker, W. H. Holstein, A. J. Schwertfeger, and M. S. Bloomsberg. The Engineering Department sent S. I. Winde, J. M. Hoffman, A. E. Daking, and A. K. Shadduck for design; C. S. Robinson and R. T. Matthews for power; H. E. Houck for electrical; E. B. Showell and C. S. Moore for water treatment; and J. R. Boyer as a specialist on blower

seals.[19] The strength and numbers of the Du Pont team underscored how important the design and construction of the pilot plant was to the overall Savannah River Project.

Girdler had become a subcontractor to Du Pont on November 1, 1950. Its scope of work was to design and initially operate the pilot plant until December 15, 1950, when it would be turned over to Du Pont's operations staff. The main production facilities at Dana were by contract to include six GS units, each with a capacity to produce 40 tons of heavy water per year, a distillation (DW) plant, and an electrolytic (E) plant. This projected output was considered sufficient to put Savannah River's two proposed reactors in operation.



(Right) Aerial of Dana Plant and (Below) Safety Platform, 1952. Source: The Girdler Corporation, *Dana Plant Construction History, Du Pont Project 8987*. (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1952).



The ordnance works property, located west of Indiana State Highway No. 63 in the east central portion of the WROW reservation, had been the site of one of Du Pont's largest wartime heavy-water production sites.

At this point, Du Pont joined Girdler with primary responsibility for oversight of design and development activities, including operation of the pilot plant to demonstrate operability and process control. Du Pont's experience with hazardous materials gave optimism that dedicated safety procedures and equipment could handle gas toxicity, and an extensive corrosion research program was initiated within the Du Pont Engineering Research Laboratory to confirm and extend preliminary conclusions that conventional materials of construction could be used. Du Pont engineers worked with Girdler on process design and materials of construction. Girdler engineering personnel were very capable and cooperative, and this collaboration worked well. Construction of the pilot plant was nearing completion and about a dozen Du Pont people were transferred there to oversee operations. We were

there on duty in late November 1950, when the Savannah River Site was announced. That heavy-water facility soon became known as the Dana plant, named for the nearby village of Dana, Indiana.[20]

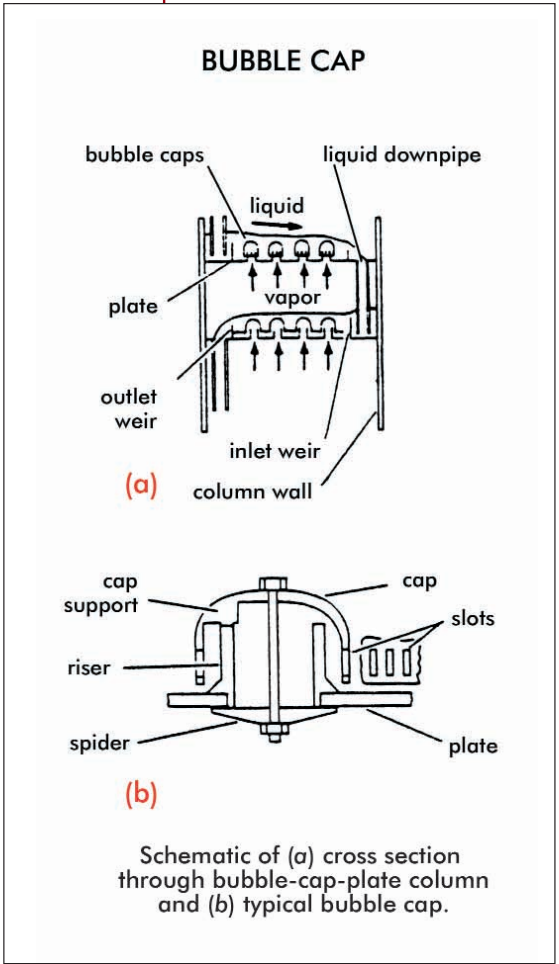
DANA AND THE GIRDLER SULFIDE (GS) PROCESS

Dana's design reflected the concept developed by Girdler under its original contract with the AEC. Water from the Wabash River was fed into six GS units (a total of 96 towers), each having five stages of cold–hot tower systems. The first stage of each unit contained four pairs of parallel hot–cold towers that were 120 feet high, 11 and 12 feet in diameter, and contained 70 separative trays. The second stage had one tower set with the same dimensions as the first stage, and the remaining three stages involved towers of equivalent height but decreasing diameters, 6 feet at the third stage and 2.5 feet at the fifth stage.[21] The gas and liquid streams from the first-stage tower pairs were combined for heating and cooling and then redistributed among the towers.

At the heart of the GS process is a pair of gas–liquid contacting towers, one of which operates at 30 to 35º C (the cold tower) and the other at 120 to 140º C (the hot tower). Ordinary water enters the system, flows downward through the cold tower and then upward through the hot tower, all the while flowing countercurrent to a stream of hydrogen sulfide gas. The towers are stacked with "bubble-cap trays" that force the gas to pass through the water. Deuterium is absorbed from the gas in the cold tower, and stripped from the liquid in the hot tower. Having completed a stage, the concentrated deuterium can be withdrawn from the base of the cold tower and from the top of the hot tower for use as the "product" as is, or can move on to a second stage to be further concentrated. The hydrogen sulfide gas, which is the transport medium for deuterium, circulates in a closed loop within the process.[22]

At Dana, a major problem with the process as envisioned—process control—was solved. For the system to work, very tight control of the ratio of flows of gas and liquid was needed. Bebbington states that the ratio had to be precisely that called for by process theory.[23] Deviation from that control led to poor productivity, and instrumentation at that time was not able to ensure operation of the optimum ratio. Dale F. Babcock, the senior member of Du Pont's task force at Dana, solved this dilemma. Babcock observed that if the concentration of deuterium at the middle plate of the cold tower is the same as at the middle of the hot tower, then the flow ratio was correct. This principle—the comparison of mid-column concentrations as a basis for process control—was used to guide the pilot planning, and the ratio was used regularly during production.[24]

More information about the GS process evolved as the research at Dana moved forward. A first stage was built, composed of two steel towers, each 3 feet in diameter and 110 feet in height with 70 bubble-cap or separative trays. Successful operation of the first unit occurred on October 26, 1950, slightly more than a month before the Savannah River



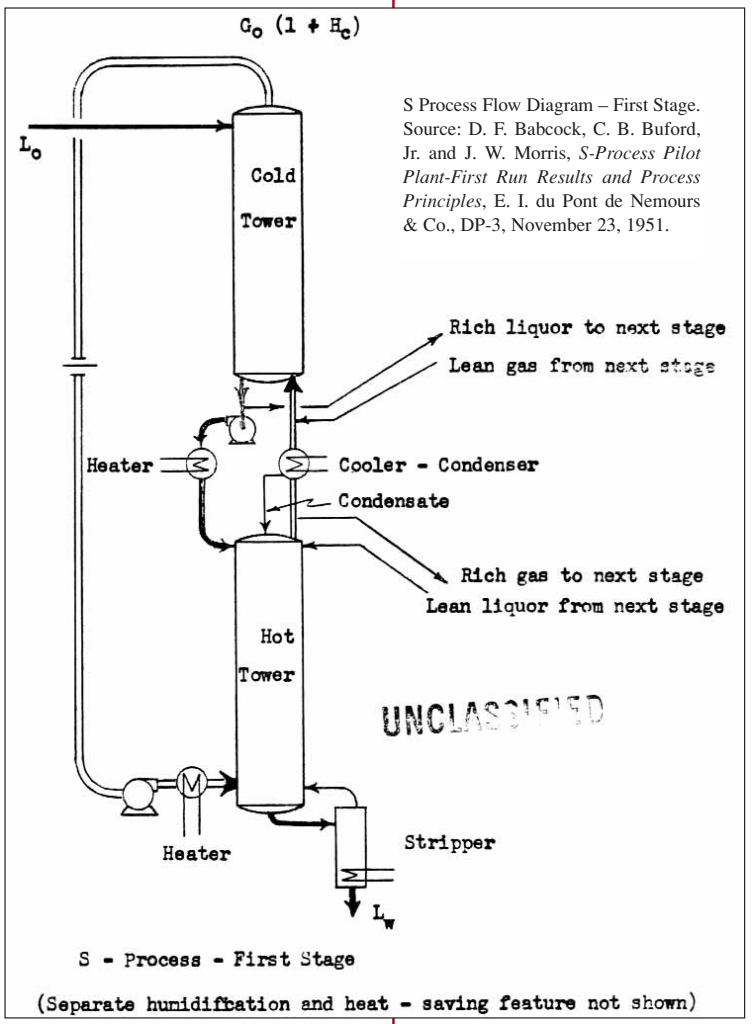
Schematic of (a) cross section through bubble-cap-plate column and (b) typical bubble cap.

Each GS tower was stacked with bubble cap trays that forced the gas to pass through the water. Savannah River's first stage GS towers (24 cold and 24 hot) had 70 trays in each cold tower and 60 in each hot tower. The cold towers were 11 feet in diameter; hot towers were one foot wider. Source (image): *McGraw-Hill Dictionary of Scientific and Technical Terms*, editor Sybil P. Parker, Fourth Edition, New York.

(Opposite Page) 400 Area 1. 412-D, negative 4-419-10; 2. Control Room, 412-D, April, 1957, negative 4121-3; 3. Concentrator Building, 420-D, negative 4-412-5; 4. Finishing Building and "E" Process Cylinder Loading, 421-D and 421-1D, negative 4-389-9; 5. Powerhouse, the largest built at Savannah River, 484-D, negative 698-28; 6. Flare Tower, 419-D, negative 1273-3; 7. Shops, Stores, and Change House, 717-D, negative 4-406-3; 8. Central Laboratory and Supervisor's Office, 772-D, negative 4-382-7.

announcement. At this point, Du Pont's engineers, Dale Babcock, C. B. Buford and J. W. Morris, referred to the GS process as the "S" process.[25] The first 300 hours of operation demonstrated the effectiveness of the Babcock ratio and determined that the bubble-cap trays were at least 45% effective in the two-column test system. "Taken as a whole, the pilot plant operations and data were judged adequate to justify the choice of the GS process for the production plant."[26]

Due to operational considerations and the possibility of the loss of heavy water through high-pressure leaks, it was decided that the GS process would be used to extract deuterium oxide from natural water and concentrate it to 15 to 20%. Vacuum distillation (the DW process used at Du Pont's wartime plants) would further concentrate the heavy water to 90% and a third process, batch electrolysis, would bring it to reactor-grade purity of 99.75%. Morris *et al*. point out that the bulk of the separative work and costs of the heavy-water production processes emanated from establishing and operating the GS process, which had never been attempted on an industrial scale. The other two processes were well known and had been demonstrated before their use at Dana and SRP.[27]

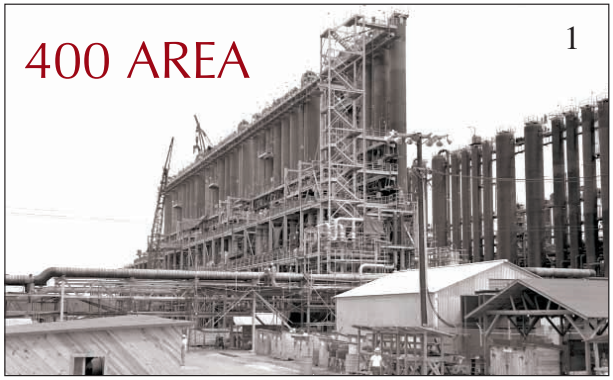


S Process Flow Diagram – First Stage. Source: D. F. Babcock, C. B. Buford, Jr. and J. W. Morris, *S-Process Pilot Plant-First Run Results and Process Principles*, E. I. du Pont de Nemours & Co., DP-3, November 23, 1951.

The first startup of a Dana GS unit in the winter of 1951–1952 was unsuccessful. The cold Indiana weather caused the hydrogen sulfide and water to form a solid hydrate, collapsing the interior trays. Moreover, some of the slotted bubble caps on the trays were broken because they had not been annealed. The corrosive power of the hydrogen sulfide gas also became "painfully evident" when internal roller bearings shattered on both the gas blower, which circulated gas through the towers, and its spare. The cause was hydrogen-sulfide stress-corrosion cracking. A great deal of research would be dedicated to learning about the effect of the gas on metal and the stress the process placed on it. Accordingly, changes were made in procedures and equipment to correct these challenges. By August, the lessons learned in the earlier attempt paid off, as the first of Dana's GS units went into operation.[28]

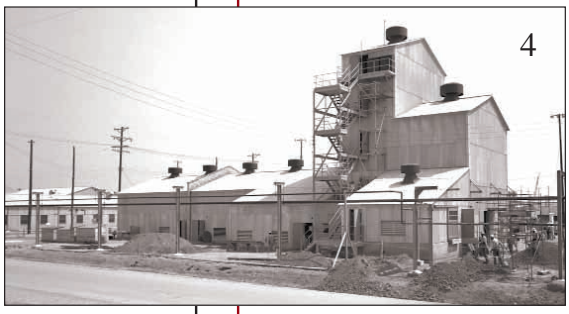
The experiences at Dana were compelling. Experimental data, coupled with operations information from each of the plants, led to research on construction materials and methods that could be applied to the programs at both plants. The corrosive power of the hydrogen-sulfide gas made this research and development program critical. Carbon steel was used for process vessels and for heat exchanger shells and piping. Tests were performed to find defects before use. The bubble-cap trays in the exchange towers were stainless steel. Carbon steel, "low alloy" steel, and stainless steel had to be heat treated to relieve stresses that were imbedded during fabrication. Bolts posed a special problem. If exposed to a

400 AREA


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hydrogen-sulfide leak, the bolt can absorb hydrogen. If it is stressed beyond a certain threshold, it will crack. To avoid this, all bolts were heat treated and installed to a predetermined stress level with torque wrenches. Metal parts in which stress or hardness was necessary were designed in isolation from the gas. Maintenance procedures were devised and minimum thickness holes, 1/8-inch in diameter, partially drilled through a pipe from the outside, were used to better gauge the effects of corrosion and give early warning of problems.[29]

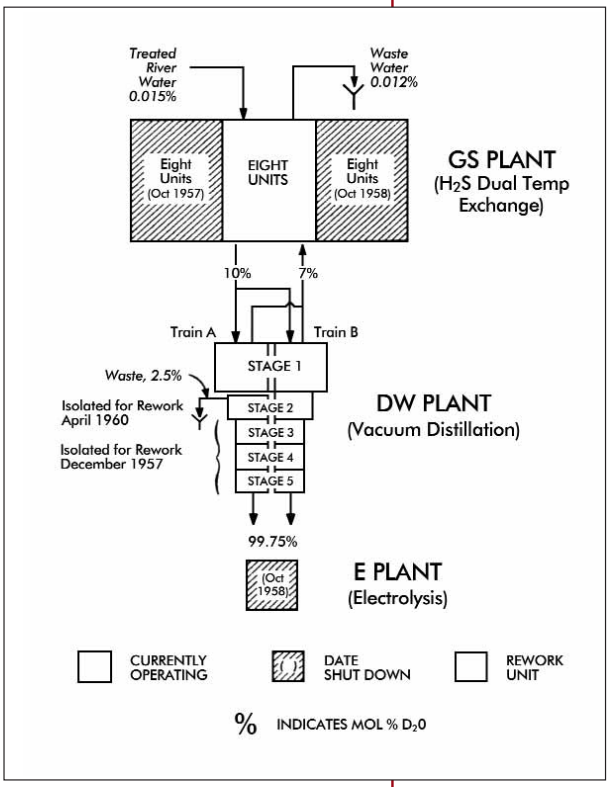


Diagram of D Area Processes, circa 1962. Source: W. P. Bebbington, J. F. Proctor, W. C. Scotten, and V. R. Thayer, "Production of Heavy Water in the United States" in *Proc. Third International Conference on the Peaceful Uses of Atomic Energy, Vol. 12 Nuclear Fuels–III Raw Materials* (New York: United Nations, 1965), 334.

SAVANNAH RIVER'S 400 AREA

The initial estimate of heavy water needed for SRP reactors was increased when the expansion program went from two to five reactors. The Dana Plant's heavy-water production capacity, designed to handle the needs of two heavy-water reactors, was not equal to the task. Also, the original estimate of 150 tons of heavy water per reactor was raised to 200 tons per reactor as the result of a Du Pont study. A second plant was immediately deemed necessary, and that plant became SRP's 400 Area.

SRP's 400 Area received top construction priority because, without heavy water, the reactors could not operate. Du Pont shifted gears, and responded to this critical change in scope by hiring the Lummus Company to design the SRP facilities. They shortened the Lummus Company's learning curve by hiring the Girdler Company as SRP consultants.[30] The facilities at Savannah River included a hydrogen-sulfide generating plant that produced 15 tons a day, an inert gas plant, water treatment facilities, a massive coal-burning powerhouse, and a river pumphouse.

The problems resulting from the operational complexity of Dana's staging led to design changes at Savannah River, principally in eliminating interrelated process flows. The 400-Area GS units were simpler in design and operated independently from each other. Twenty-four first-stage tower units were erected, each with its own second-stage towers that were larger than those at Dana. As a consequence, each second-stage tower at SRP had more than twice as many separative trays as the towers in the Dana design units.

SRP's DW plant, a multi-staged operation, started up in 1952. This second step in the concentration process at SRP included bubble-cap tray towers and was divided into five stages of enrichment and distillation until, in the fifth stage, the product was approximately 98% deuterium oxide. The E process, batch electrolysis, was the final purification step. The concentration of the deuterium oxide solution was raised to 99.8% through electrolysis in this last step. After removing impurities, the D_20 was distilled, an electrolyte was added, and the fluid was fed through a number of cells through which passed a current of 1000 amperes. After this step was completed, the heavy water was stored in aluminum drums, ready for immediate use or later sale.

Savannah River's 400 Area was in operation by May of 1953. In the spring of 1953, a small plant was constructed in the D Area to produce deuterium gas from heavy water by

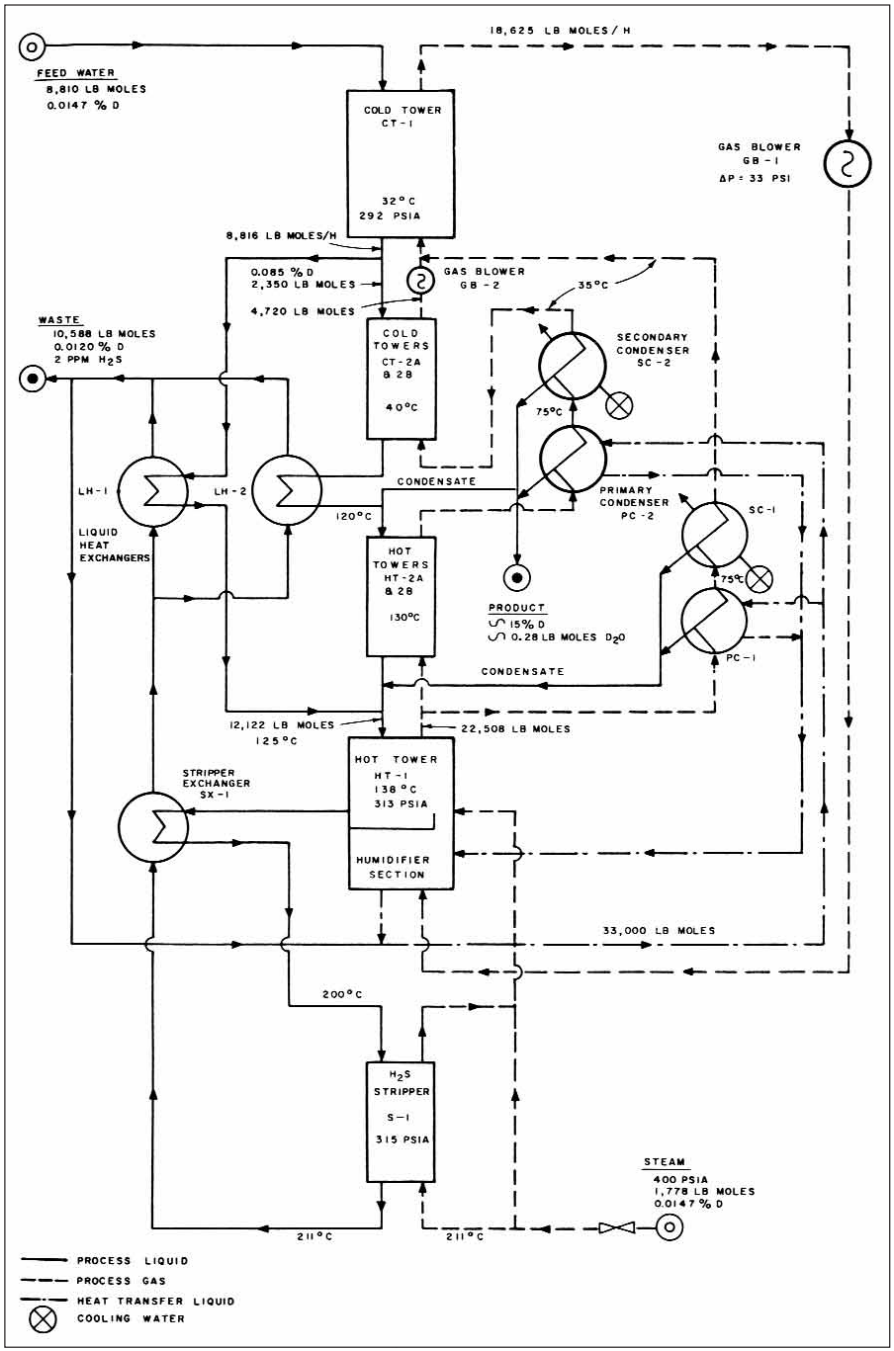
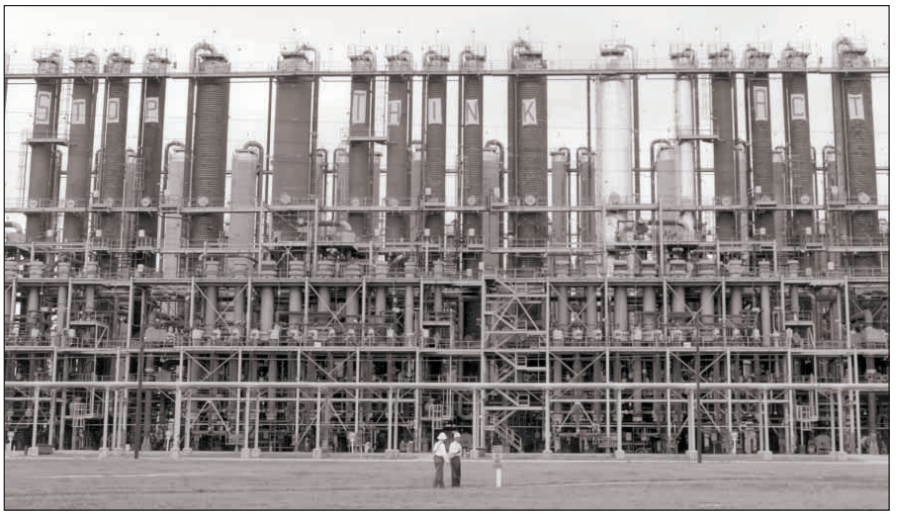


Diagram of the Savannah River GS Process. Source: W. P. Bebbington, J. F. Proctor, W. C. Scotten, and V. R. Thayer, "Production of Heavy Water in the United States" in *Proc. Third International Conference on the Peaceful Uses of Atomic Energy, Vol. 12 Nuclear Fuels–III Raw Materials* (New York: United Nations, 1965), 334.

electrolysis. Some of this deuterium was used at Savannah River in the Tritium Facility (tritium reservoirs were actually filled with a mixture of tritium and deuterium), and some was sent to the Oak Ridge Site to be converted to the lithium deuteride used in the secondary assemblies of thermonuclear weapons. A second, larger, deuterium plant was constructed in the D Area in 1954.[31] A 1962 estimate of the AEC's capital investment in D Area at Savannah River was quoted at $145 million with $110 million, or 75%, of that

total devoted to the piping, towers, heat exchangers, structures, instrumentation, and switch gear involved in the GS process. D Area's steam and electric power plant, the largest of all of Savannah River's power facilities, represented a $15 million investment. The vacuum distillation plant was estimated at $2.5 million, the electrolytic plant at $1.5 million, the H_2S plant at $1 million. The remainder was invested in water treatment, gas storage facilities and flare tower, and general plant facilities.[32]



DANGERS AND HAZARDS

The GS process used at Dana and at Savannah River's 400 Area involved the use of large quantities of hydrogen sulfide. Hydrogen sulfide is an extremely toxic, flammable gas that forms explosive mixtures with the air. Its odor, similar to that of rotten eggs, is noticeable even from small concentrations, and while some concentrations can be tolerated for a short period, contact can prove fatal. Moreover, after prolonged exposure, individuals lose their ability to smell it, thus exacerbating the danger. Leaks in piping, the distillation towers, or the heat exchangers and any other components within the GS units could cause such a release. To prevent and guard against any incidents, a number of safety measures were designed and implemented at both plants.

At Dana, a gas monitoring division was established in July 1951 and an elaborate communication system put in place. Monitors carried devices to detect leaks, and all personnel were well trained in first aid. Evacuation procedures, if needed, would be given from the monitor headquarters that kept tabs on the wind direction.[33] At SRP, monitoring instruments continuously sampled the air and sounded the alarm when the gas was identified.

> Each man carried a small dispenser of H_2S sensitive paper that would reveal presence of the gas even if he could not smell it. All personnel in the area were issued gas masks containing adsorbent carbon, and the workers in the units carried masks that had their own cylinders of compressed breathing air.

D Area experienced the site's only fatalities. Two men, working within a confined space on a GS unit support structure, unplugged a process drain valve and were unable to avoid the hot water and steam that was released. Access openings on the units were enlarged after this tragedy.

The need for vigilance was very real. D Area reported at least two serious releases of hydrogen sulfide due to the failure of a seal on a blower and a failure of a screwed joint in a pipe. Fortunately, neither incident caused any personnel injuries. Author W. P. Bebbington notes that the hydrogen sulfide plant was shut down during early days of operation when two D Area employees were overcome by gas. The plant was shut down until the equipment was fixed despite the urgent need for its product. Source: The Girdler Corporation *Dana Plant Construction History*. Subcontractor for Engineering Department, E. I. du Pont de Nemours & Co., Wilmington, Delaware. Du Pont Project 8987, December 1952, DPEG-17. William P. Bebbington, *History of Du Pont at the Savannah River Plant*, (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).

(Right) STOP THINK ACT, D Area safety signs mounted on GS Towers, 1956. Courtesy of SRS Archives, negative 3970-3.

(Below) Gas monitoring team at work with resuscitator, fully equipped safety carry-all in background.



> Perhaps the most important precaution was procedural. Workers in and near the GS units worked in pairs so that if one man was overcome, the other could summon help, put on his own mask and pull his "buddy" to safety. The buddies were required to stay several feet apart so that both would not enter an area of high concentration simultaneously and both had to have special training. An untrained person entering the GS area had to be accompanied by two trained people.[34]

During operation, when a GS unit needed inspection or maintenance, the hydrogen sulfide gas was returned to the hydrogen sulfide plant in 400 Area where it was compressed and stored in tanks. If an emergency demanded, the gas could be released to a 400-foot flare tower to be ignited by its pilot flame, burned to sulfur dioxide, and released to the atmosphere. The use of these measures gave the 400-Area workers a strong record of safe work performance with no serious injuries from exposure to hydrogen sulfide.[35]

WORKFORCE

From the outset, Dana had its own administrative offices. In December 1950, the AEC's Dana Area Office's three branches were headed by B. C. Samples. H. N. Hinchman worked in administration. C. W. Reilly was the chief of construction, C. E. Williams was responsible for safety, and F. J. Holtzner handled security. E. J. Grabowski and C. A. Konwinski were in the Technical Branch.[36]

The original lead for Girdler's staff was R. M. Reed, the technical director for the Dana Project. R. E. Alexander was project engineer, and the process engineer was E. R. Comley. On November 1, 1950, there were 389 employees on the Girdler payroll. Peak construction employment occurred in July 1951 with 5,111 employees. The force was reduced by over 2,000; subsequently, on the basis of new estimates, a new peak occurred of 5,458 occurred in February 1952. While some Girdler employees stayed to help orient Du Pont's incoming operations personnel, all of the subcontractor's employees left by mid-January 1951.[37]

From July 1951 to December, Du Pont's forces at Dana grew from 594 to 969 individuals. The total operating force at Dana consisted of 926, of whom 170 were supervisory personnel. The largest number of employees, 405 individuals, was in maintenance, underscoring the need for a strong inspection and proactive maintenance program at the GS facilities. Two hundred and thirty were directly involved with the operation of the process facilities, and 63 worked in technical.[38] Don A. Miller was Dana's manager initially. He was transferred over to SRP to manage the plant. R. Paige Kelly took over at Dana for Miller, with J. A. Monier as his assistant plant manager. Kelly remained as manager of the plant until it was closed in 1957. Some of the Dana staff would move over to Savannah River, providing a core group of experienced operating and



D Area Committee in November 1956 included Les Ahrens, GS department superintendent; J. H. Nuzum, area superintendent; S. P. Brown, Captain Herman Caldwell, H. R. Casebolt, L. R. Di Fillipo, H. V. Graybeal, W.H. Keeter, W. S. Marting, H. M. Moore, R. D. Pillsbury, Dr. George A. Poda, R. M. Radford, K. W. Brendell, M. A. Werner, and A. D. Williams. The committee was composed of representatives of various departments that were part of D Area operations. Source: *Savannah River Plant News*, November 9, 1956. (Not all D Area Committee members are shown.)

technical staff at the younger plant. J. W. (Bill) Morris served as technical superintendent at Dana until 1953 when he was assigned to the Savannah River Laboratory, and W. C. Scotten, who was part of Dana's Works Technical in 1951–1952, was transferred to SRP in 1952 to serve in Extraction Area Process Assistance.

At Savannah River, organizational charts show that the GS Department or 400 Area was one of six departments under Du Pont's Production Department. F. H. Endorf was head of the GS Department and J. H. Nuzum was area superintendent in 1954, with A. J. Sauerborn as area superintendent for finishing. A Heavy Water Technology Section, with W. P. Bebbington as superintendent, provided process, mechanical, and operational assistance to the GS Department that held responsibility for 400 Area operations in 1954.

Les G. Ahrens became superintendent of the GS Department in 1956 and J. H. Nuzum remained as the area superintendent. The early workforce of about 900 operations staff was drawn from a number of Du Pont's departments including Reactor and Reactor Materials Works Technical, Health Physics, Instruments, Service, Maintenance, Traffic and Transportation, and Power and Security. Ahrens remained superintendent until 1964 when Ken French, who was also responsible for the Heavy Water Components Test Reactor (HWCTR), was assigned to the GS Department as superintendent.

PRODUCTION

The required quantity of heavy water for each of Savannah River's reactor was 200 tons; the Process Development Pile, a test reactor in the 300 Area, required 110 tons. As the Dana Plant and D Area went into operation, estimates on production levels could be made. On the basis of production figures for Dana, then D Area between May 1952 and March 1953, it was projected that the quantity needed to charge the reactors would not be produced until 1955.[39] This production schedule worked well as the plants, sized to produce the necessary amount of heavy water to charge the reactors, produced sufficient heavy water for each reactor as it was constructed. The staged construction of the five reactors thus was linked to the heavy-water production rate that progressively increased in output.

HEAVY-WATER PRODUCTION, 1952–1953

Date	Dana Plant	D Area	Cumulative combined production (tons)
1952			
May	0.83		0.83
June	2.50		3.33
July	5.33		8.66
August	9.25	0.68	18.59
September	13.80	2.02	34.41
October	15.00	4.93	54.34
November	15.00	7.59	76.93
December	15.00	10.50	102.43

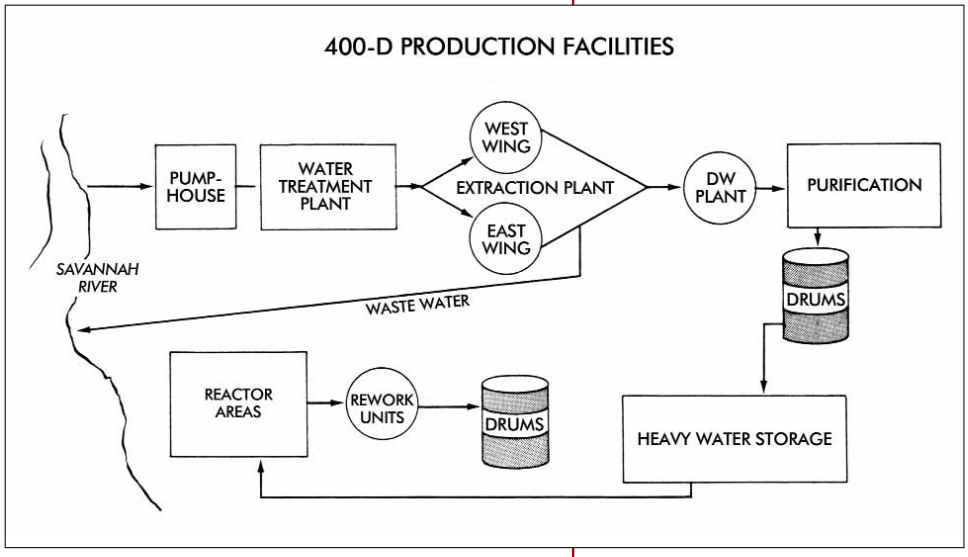
1953			
January	16.00	13.40	131.83
February	16.00	16.10	163.93
March	16.00	16.80	196.73

Source: Control Division, "Heavy Water Production and Production Costs Fiscal Year 1951 Through August of Fiscal Year 1956," DPW-4742-1, March 11, 1952. National Archives, Records of the Atomic Energy Division, A-1957, Series II, Box 45, Folder 14.

The need to continue heavy-water production lessened after the reactors were in operation and an adequate stock of heavy water had been stored for future use. Both plants were designed for a production rate of 240 tons of heavy water per year; they exceeded these original projections after three years in operation.[40] In 1956, the GS Department's net production of heavy water was 478.13 tons.[41]

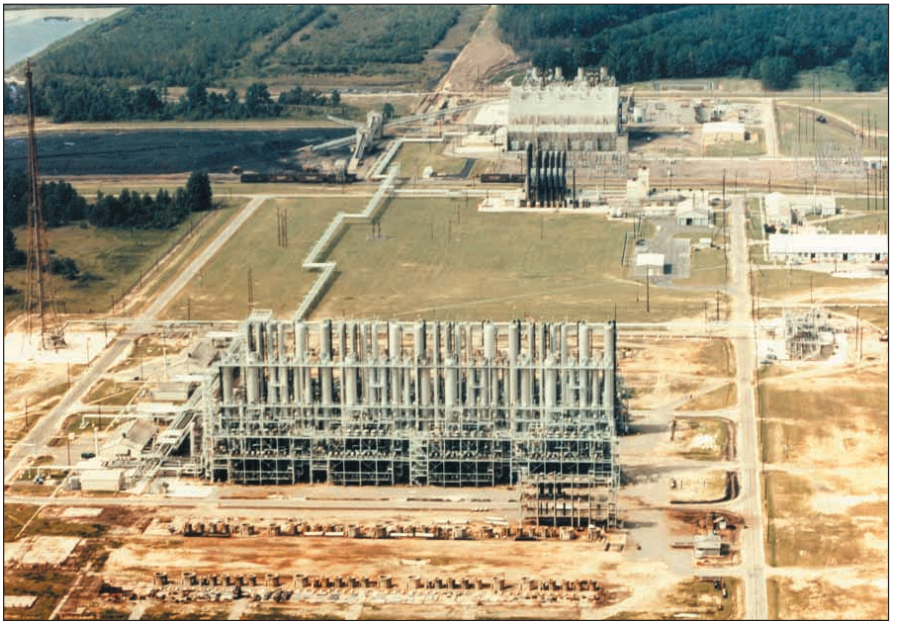
In 1957–1958, the Dana Plant and two thirds of Savannah River's D Area GS units (Facilities 411-D and 413-D) were shut down. The plants had proven successful, producing sufficient heavy water for SRP reactors including the test reactor and a stockpile for other uses. Dana's closure was predicated on needed repairs that would have proved costly and slightly lower productivity levels that stemmed from the GS unit's complicated design. The same winnowing occurred at SRP. The GS unit with unclad towers, suffering from more corrosion than its counterparts, was dismantled beginning on October 4, 1957. The E Plant was also shut down as the concentration of the final product could be handled in the DW Plant without a "significant loss in production."[42]

As a result, Dana's staff was reduced to a skeleton crew of 12; some members of the operations staff reported to Savannah River's GS Department. However, the closing of D Area facilities also reduced the staff at Savannah River. In 1957, D Area had 588 employees, after 145 positions had been cut in response to the closing of Building 411-D. More than 149 jobs were cut the next year when Building 413-D was closed, reducing the D Area workforce to 435.[43] In 1959, a workforce of 395 produced 185.33 tons of heavy water in the remaining eight extraction units in Building 412-D and 9 of the 12 towers in the DW plant. The other three DW towers were used as a rework unit for the reconcentration of degraded heavy water from the reactors containing tritium.[44] Du Pont was officially released from responsibility for the Dana Plant in July of 1959 after the purging of all equipment with nitrogen. The U.S. Army Corps of Engineers assumed responsibility for the plant at that time.



Flow Chart showing Processes in D Area, 1970s. Source: D Area Tour Booklet, not dated. Courtesy of SRS History Project.

Between 1959 and 1964, D Area would steadily lose more staff. In 1964, a force of 322 produced 345.26 tons of heavy water.[45] Total production of heavy water grew between 1959 and 1964 as the operating staff worked with economy and focus with the remaining facilities. The plant histories for this time period show rework assuming greater importance in D Area's operation, while the costs of maintaining older facilities, now closed down, grew steadily.



Aerial view of 400 Area after dismantlement of 411-D, only the tower's cylindrical foundations remain. 412-D was the last group of original GS towers to operate. Courtesy of SRS Archives.

Tons of Heavy Water produced at Dana and Savannah River and exported by December 1963

Canada	276.00
Germany	132.00
France	70.00
United Kingdom	66.00
Sweden	57.00
Japan	48.00
India	36.00
Euratom	28.00
Norway	25.00
Switzerland	23.00
Denmark	17.00
Australia	13.00
Italy	10.00
Israel	4.40
Netherlands	1.60
Belgium	0.25

Source: W. P. Bebbington, J. F. Proctor, W. C. Scotten and V. R. Thayer "Production of Heavy Water in the United States of America," *Chemical Engineering Progress 55* (9), September 1955; 335.

"ITS PRODUCTS GO FAR"

Heavy water was the Savannah River Plant's first direct contribution to the Atomic Energy Commission's vigorous campaign to develop atomic energy for peaceful purposes. When Commission Chairman Lewis L. Strauss visited the plant in March of 1955, he announced that the United States had agreed in principle to sell 10 tons of heavy water to the Italian government for use in Italy's first research reactor.[46] The market price in 1956 for heavy water was $28 a pound or $14,000 a drum. By 1957, Sweden, Canada, Switzerland, France, Australia, Norway, and the United Kingdom had received substantial shipments of Savannah River and Dana's heavy water for use in research reactors and incipient power reactor programs. Italy, Denmark, Japan, Israel, West Germany, New Zealand, Pakistan, and South Africa had pending commitments with the AEC for purchase of the plant's heavy water through the Commission's "Atoms for Peace" agreements.[47] Sales continued briskly through the 1970s. In 1970, a final shipment for a $27 million dollar sale of heavy water for use in Canada's Ontario Hydro Pickering Station rolled off-site in tractor trailers. Pickering Station was one of four reactors being built by the Ontario Hydro-Electric Commission near Toronto.[48] The national laboratories also received heavy water from SRP and Dana; Brookhaven National Laboratory received 100 tons of Dana's product in 1966 after the Indiana plant closed.[49]



Tests and preparations for 1969 shipment of heavy water valued at $9 million to Sweden, 1968. In 1969, the AEC negotiated sales of 450 tons of heavy water for an estimated value of $42 million dollars. Courtesy of SRS Archives, negatives (Above) DPSPF 12818-8 and (Below) DPSPF 12818-11.



HEAVY-WATER TECHNOLOGY AND EXPERTISE

While Savannah River's heavy water traveled far, so did its technology and its operations know-how. The AEC and Savannah River, under a bilateral agreement between the USA and Canada, worked cooperatively with Atomic Energy of Canada, Ltd., in the overall field of heavy-water production and heavy-water reactors. Canada's decision to found

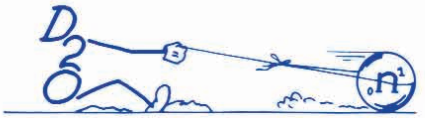
Mass Spectrometers and Heavy-Water Analysis

During World War II scientists involved with heavy-water production used the sole unique characteristic of heavy water, its "heaviness," to determine the concentration of their product. Using comparisons of liquid densities, they were able to control their experiments, and these comparisons allowed them to gauge their progress in concentration efforts.

The mass spectrometer, which was a research laboratory tool prior to 1950, became a common analytical instrument used by personnel at Dana and SRP. The development of the mass spectrometer, able to differentiate between the masses of water molecules and to measure directly the ratio of heavy to light molecules, was a boon to heavy-water producers. Mass spectrometers were installed in the GS control rooms and were used as the plant's major source of analytical control data in its heavy-water production.

"Why Heavy Water Is So Good." Cartoon figures coupled with serious facts bring home the positives about heavy water. Source: Savannah River Laboratory, *Nucleonics of Tomorrow in the Making Here Today* (Aiken, South Carolina: E. I. du Pont de Nemours and Company, not dated).

WHY HEAVY WATER IS SO GOOD



Heavy water slows fission neutrons to thermal energies without absorbing them. It does this important job more efficiently than any other substance. Its moderating ratio, $\Sigma_s \xi / \Sigma_a$, is 70 times that of graphite, the next best moderator. Being a liquid, it can serve as both coolant and moderator. For experimental work, it is wonderfully flexible. You don't have to drill holes in *this* moderator!





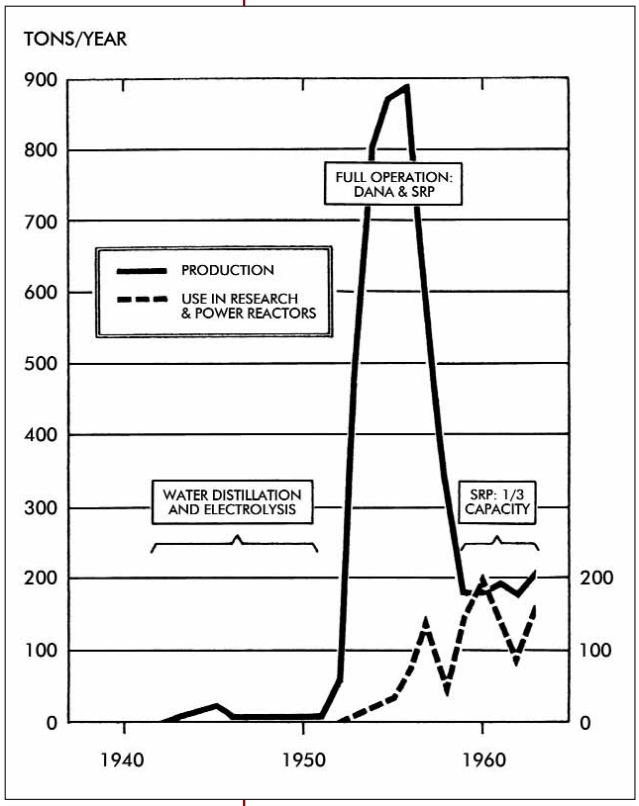
With heavy water, natural uranium can be used as fuel. Enriched uranium is not necessary. Power systems based on D_2O have important economic and politico-economic potentialities. They are being developed with vigor, particularly by the United States, Canada, Norway, and Sweden. Production systems based on D_2O show unsurpassed neutron economy.

The Savannah River Plant makes practically all of the free world's supply of heavy water. A sensation was created at Geneva in 1955 when the AEC offered to sell D_2O at one-third of the previous world price. Already, more than $23 million worth have been sold.



their commercial nuclear power industry on heavy-water-moderated reactors solidified earlier technological ties between the U.S. and Canada that had developed during World War II. Canadian researchers were able to learn from operations staff. They watched closely Savannah River's operation of the Heavy Water Components Test Reactor between 1962 and 1964, even sending a researcher to participate in the project launched under the auspices of the Atoms for Peace Program. Other countries interested in heavy-water technology, including India and Argentina, also benefited from the experience of Savannah River's heavy-water experts. The 400 Area hosted chemical engineers from India, providing them with first-hand knowledge of large-scale, heavy-water production.

The first heavy-water plant constructed outside of the USA was built at Glace Bay on Cape Breton Island, Canada, as a joint venture between Deuterium of Canada Ltd. (DCL) and the province of Nova Scotia. The plant was unable to operate as designed, and Du Pont was asked to consult in diagnosing the problems and in offering recommendations for future operation. Bebbington notes that the plant was rebuilt with modifications that were patented by a retired Du Pont heavy-water expert.[50] The La Glace facility was to have supplied heavy water for an Argentinean reactor. Due to delays at the Canadian facility, Argentina acquired heavy water from the AEC that had been taken from Savannah River's L Reactor, then on standby. Later Canadian heavy-water plants built by General Electric of Canada Ltd. and Ontario Hydroelectric also benefited from experience gained from the design and operation of heavy-water facilities at Dana and Savannah River. Du Pont engineers were involved in each Canadian plant, and Canadian representatives were sent to Savannah River to learn from D Area operations. With the closure of D Area, these Canadian facilities became the world's largest heavy-water production facilities.



Graph showing production and use of heavy water between 1945 and 1965. Source: W. P. Bebbington, J. F. Proctor, W. C. Scotten, and V. R. Thayer. "Production of Heavy Water in the United States" in *Proc. Third International Conference on the Peaceful Uses of Atomic Energy, Vol. 12 Nuclear Fuels–III Raw Materials* (New York: United Nations, 1965), 334.

SUMMARY

Between 1951 and 1982, the towers erected in Savannah River's D Area and at the Dana Plant in Indiana yielded about 7,500 tons of heavy water for the nation's atomic energy program. The Dana Plant operated from 1951 until 1957, when an adequate supply of heavy water was on hand. Two of Savannah River's three GS units were closed in 1957–1958 for the same reason, leaving one in successful operation through 1982. Morris *et al*. recollect the camaraderie that existed between the sister plants along with good-natured competition in safety and productivity. The heavy water they produced for our nation's production reactors and the heavy water that led to nuclear energy research around the world and SRP's first Atoms for Peace product, is a remarkable legacy.

13 Reactors, Fuels, and Power Ascension (1955–1963)

Reactors, and nuclear technology in general, are the aspect of the Savannah River Plant's operation that are best known to the general public. The reactor areas, where the plant's fissionable material and other essential isotopes were created, were crucial to the operation of Savannah River. This chapter chronicles their development in the first years of their use, when they were subject to almost constant improvements. These improvements supported increasing power levels that eventually pushed the reactors far beyond the expectations of the original designers. From an initial rating of 378 megawatts (MW), the Savannah River reactors were pushed to an average of over 2000 MW by 1964, when the oldest of the five reactors became the first to be shut down. The power ascension of the late 1950s and early 1960s greatly increased the production capacity of the Savannah River reactors, which was crucial to the increased production requirements set by the Atomic Energy Commission.

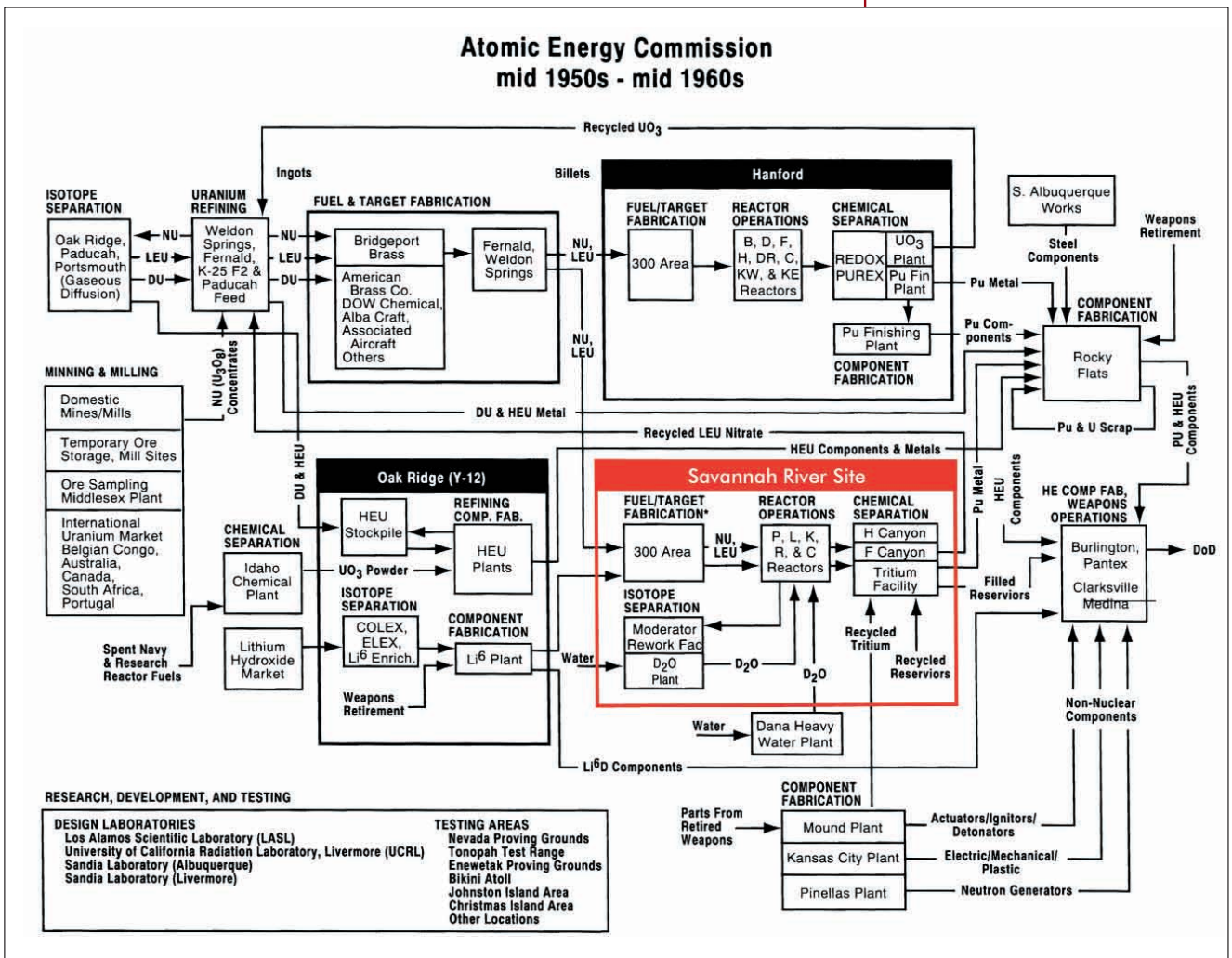
To understand Savannah River Plant's reactor development in the late 1950s and early 1960s, it is important to keep in mind the urgency of those years. The Korean War, which began in June 1950, did not end until an uneasy truce was established in 1953. The fighting was exceptionally bitter, and atomic weapons were seen as a way to develop enough of an edge to prevent any future recurrences of wasting ground wars. The fact that the Soviets had the atom bomb by this point only made the race more determined. And Savannah River was simply one of the brighter stars in a whole constellation of new facilities designed to ensure that the United States did not fall behind the Soviets in the nuclear arms race. It was, also, one of the main stars in the AEC firmament, because it was designed to produce tritium, required for the hydrogen bomb that had not yet been perfected. The urgency of that period forced the AEC to push all of its programs simultaneously: while Savannah River was under construction, so were a host of other nuclear facilities, as was the development of the H-bomb itself.

EXPANSION OF THE AEC AND DEVELOPMENT OF THE H-BOMB, 1950–1954

In the wake of the Korean War, Congress authorized a major expansion of Atomic Energy Commission facilities in October 1950. This expansion included money for the construction of the Savannah River Plant. This phase of work was followed by a second

expansion program, approved in January 1952, which allowed the AEC to virtually double the size of both Oak Ridge and Hanford. Yet another expansion program passed Congress in July 1952, with allowances for additional plants for producing fissionable materials. Construction of these new facilities began in the fall of 1952, and they raised the nation's investment in AEC facilities to $7.5 billion, five times what it had been in 1947.[1] The Cold War may have been the impetus for this expansion, but it was also made possible by the discovery of new fissionable resources in the early 1950s. As late as 1951, much if not most of the nation's uranium supply still came from the Belgian Congo.[2] By 1953, just two years later, there were nine uranium mills on the Colorado Plateau, with exploration opening up new resources all the time, both in this country and in Canada.[3]

Among the new facilities opened up or greatly expanded during the early 1950s were the gaseous diffusion plants at Paducah, Kentucky, and Portsmouth, Ohio, in addition to the main facility at Oak Ridge. These were devoted to the production of enriched uranium.[4] Dana was set up to produce heavy water, primarily for the Savannah River reactors, while the Fernald Plant, operated by National Lead, was commissioned to turn uranium



Flow of materials through the nuclear weapons complex after startup of operations and through the mid 1960s. Source: U.S. Department of Energy Office of Environmental Management. *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences* (Washington, DC: U.S. Department of Energy, 1997), 123.

compounds into a metal form for the reactors, both at Savannah River and at Hanford.[5] At the end of the process, nuclear weapons were made at Sandia in New Mexico, Pantex in west Texas, and Rocky Flats in Colorado.[6] To complement the original weapons laboratory at Los Alamos, a second weapons lab was established at Livermore, California. Long pushed by Edward Teller, the Lawrence Livermore Laboratory was devoted to the development of thermonuclear weapons. Reactor research continued at the Argonne National Laboratory; its original facilities in Illinois were now complemented by new facilities in Idaho, specifically the National Reactor Testing Station.[7] Training facilities were not neglected. The School of Reactor Technology, run by the Oak Ridge National Laboratory, was established in 1950.[8] Prospective operators of the Savannah River reactors were among the first attendees.[9]

This series of expansions led to an enormous increase in the work force devoted to the AEC programs. By the end of 1952, some 146,300 workers were employed through the AEC, and this number peaked at 151,695 in August 1953.[10] This huge personnel increase led to a modification of the original Atomic Energy Act of 1946. According to the so-called "Security Amendment" of April 1952, the primary responsibility for AEC contractor background checks was shifted from an overwhelmed FBI to the Civil Service Commission.[11] Despite the great increase in the AEC workforce, and despite shortages in housing and other facilities at Savannah River, Paducah, and other places, the AEC refused to establish any new government towns.[12] In fact, the Commission went ahead with plans for self-government and the privatization of residential and commercial properties at the existing government towns of Oak Ridge and Hanford.[13]

Before Savannah River could go into production, the burden of nuclear materials production fell to Hanford, which not only produced plutonium for atomic bombs, but also made the first tritium for the testing of thermonuclear materials. The first post-World War II reactors, H and DR, went on-line in 1949 and 1950, respectively. Hanford's C Reactor, under construction in 1951, went critical the following year. The jumbo reac-

Korean War and the Oppenheimer Affair, 1950–1954

The Korean War was a bitter experience, and the end was inconclusive. Even though the U.S. had achieved victory over Japan with atomic weapons, they were not used in Korea, at least in part because the Soviets now had them as well. A costly ground war resulted, and American policy makers were determined that it should not happen again. Several months after the war, Secretary of State John Foster Dulles, announced a major change in U.S. policy. Based on "massive retaliation," there would be no more Koreas. In the case of similar small aggressions, the United States would go right to the source, and use nuclear bombs. Dulles left no doubt that the targets would be Moscow and Peking.

With nuclear bombs the centerpiece of American defense, the heat was turned up after the Soviets exploded their first thermonuclear device, "Joe IV," on August 12, 1953. Even though the Soviet device was relatively primitive, based on Teller's arrangement, it was still enough to send ripples of concern through the U.S. military establishment and the AEC. In late 1953, the big question in those quarters was why we waited until 1950 to push ahead with the hydrogen bomb, rather than begin that work right after World War II, as Teller had wanted to do. For many, the answer seemed to be Robert Oppenheimer.

By 1953, Oppenheimer's influence was definitely on the wane at the AEC. Lewis L. Strauss began serving as AEC chairman in July 1953, and he was a fierce opponent of Oppenheimer. He did all he could to strip Oppenheimer of his influence over the General Advisory Committee, with the goal of eventually removing his "Q" security clearance, which would effectively bar him from participating in the upper levels of the AEC. By December 1953, a wall had been erected between Oppenheimer and the upper reaches of the government, from President Eisenhower down to the GAC. Later that same month, Oppenheimer was told of the accusations against him.

The AEC inquiry into the question of Oppenheimer's loyalty led to a formal hearing that lasted from April 12 to May 6, 1954. Everyone from Leslie Groves to Edward Teller was called. The hearing revolved around two basic points. The first was Oppenheimer's evasions about contacts he had had with a Soviet agent in 1943, and the second concerned his "delay tactics" in hydrogen bomb research in the years before 1950. The findings, produced at the end of May, established Oppenheimer's loyalty, but also found him to be a security risk. After he was stripped of his "Q" clearance, Oppenheimer's long association with the AEC came to an end.

Source: *Plutonium: The First 50 Years. United States Plutonium Production, Acquisition, and Utilization from 1944 to 1994, (Washington DC:* U.S. Department of Energy, 1996).

tors, K-East and K-West (KE, KW) were under construction during this period and began production as early as 1955. Although much larger than the original World War II reactors, and designed to produce both plutonium and tritium, the new reactors were graphite-moderated.[14] Tritium was also produced in H Reactor, using highly enriched uranium slugs and lithium deuteride target slugs.[15] Producing tritium, however, did not produce a hydrogen bomb, and the effort to perfect a thermonuclear device was perhaps the most important of the AEC programs in the early 1950s.

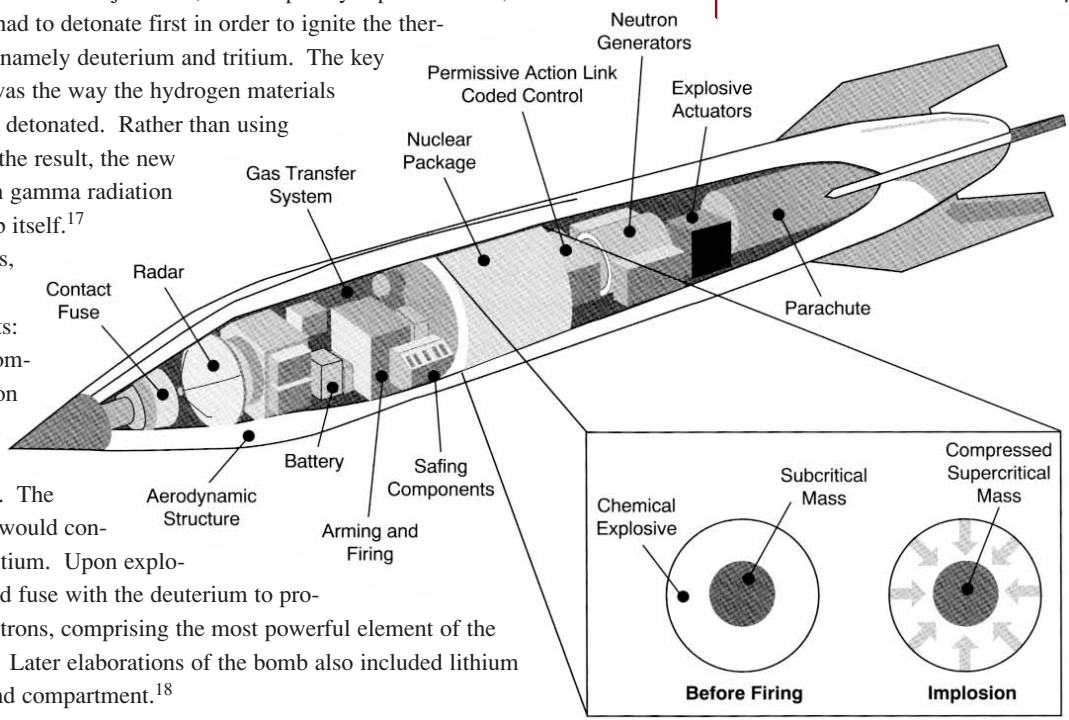
First at Los Alamos and then at Lawrence Livermore, research on the hydrogen or thermonuclear bomb, virtually dormant since World War II, sprang to life beginning in 1950. Even then the basic configuration conceived for the device was a variation on Edward Teller's design, known as the "Super." According to this plan, the new bomb would be a variant of the plutonium device. The mathematics required to arrange the materials was daunting, requiring the work of the earliest computers. ENIAC, at the Aberdeen Proving Grounds in Maryland, was put to this task as early as June 1950. Its successor, MANIAC, took three years to build and went online at Los Alamos in 1952. Despite this assistance, the design could not be made to work effectively. As early as February 1950, when work resumed on the thermonuclear device, it appeared that the classic Super design was flawed.[16] While it might work, it could never release the full destructive potential inherent in hydrogen fusion.

This impasse led to a theoretical breakthrough in 1951 provided by Stanislaw Ulam and perfected by Edward Teller. This bomb arrangement, known since as the Teller-Ulam configuration, completely scrapped the idea of the Super, with its complicated internal arrangement of fission and fusion elements. In the Teller-Ulam configuration, the thermonuclear materials would be adjacent to, but completely separated from, the fission bomb, which had to detonate first in order to ignite the thermonuclear materials, namely deuterium and tritium. The key to the configuration was the way the hydrogen materials were compressed and detonated. Rather than using implosion to achieve the result, the new arrangement relied on gamma radiation from the fission bomb itself.[17]

By the mid-1950s, the standard H-bomb had two compartments: the first or primary compartment for the fission reaction, followed by the second required for the fusion booster. The second compartment would contain deuterium and tritium. Upon explosion, the tritium would fuse with the deuterium to produce high-energy neutrons, comprising the most powerful element of the thermonuclear bomb. Later elaborations of the bomb also included lithium deuteride in the second compartment.[18]

Nuclear explosions are produced by initiating and sustaining nuclear chain reactions in highly compressed material which can undergo both fission and fusion reactions. Modern strategic, and most tactical, nuclear weapons use a nuclear package with two assembles: the primary assembly, which is used as the initial source of energy, and the secondary assembly, which provides additional explosive release. The primary assembly contains a central core, called the "pit," which is surrounded by a layer of high explosives. The "pit" is typically composed of plutonium-239 and/or highly enriched uranium (HEU), and other materials. HEU contains large fractions of the isotope uranium-235. Source: U.S. Department of Energy Office of Environmental Management. *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences*, (Washington, DC: U.S. Department of Energy, 1997), 118.

Generic Design Elements of a Modern Nuclear Weapon



The development of the thermonuclear bomb can be seen in the various tests that heralded its progress. Operation Greenhouse, in 1951, saw the first burning of deuterium and tritium in what was essentially a boosted bomb. The first complete thermonuclear blast was Mike I, part of Operation Ivy on Enewetak Atoll in the Marshall Islands. Weighing 62 tons, too heavy to be carried aloft, Mike I was detonated on November 1, 1952, with an explosive force of 10.4 megatons of TNT. It was a thousand times more powerful than the Hiroshima bomb.[19]

Two years later, on March 1, 1954, Operation Castle Bravo detonated the greatest thermonuclear device ever set off by the United States. Again set up on Enewetak Island, the Castle Bravo detonation was expected to produce a 5-megaton blast, but instead produced 15, due to unexpected nuclear activity (the Castle Bravo series was the first to use lithium deuteride as a component of the bomb's second compartment). The fireball alone achieved a diameter of almost four miles, and the radiation threat to the Marshall Islanders, and even Japanese fishermen in the vicinity, was both considerable and widely publicized.[20]

Nuclear testing was not limited to remote Pacific islands. In 1951, the Las Vegas Bombing and Gunnery Range (later designated the Nevada Proving Grounds) was opened for business some 60 miles from Las Vegas. The Ranger–Able blast, on January 27, 1951, was the first exploded in the continental United States since Trinity. This was followed by many more, with atomic blasts becoming part of the tourist draw to Las Vegas.[21]

By this time, the nuclear arms race was in full swing, and was only accelerated by the news that the Soviets had detonated their first hydrogen bomb on August 12, 1953, less than a year after Mike I.[22] The demand for plutonium and tritium for atomic and thermonuclear bombs increased every year, making the completion of the new tritium facility at Savannah River a great national priority. And at the very core of that production facility were the reactors.

SAVANNAH RIVER REACTORS, 1950–1955

To understand the importance of the Savannah River reactors, it helps to know something about the materials that are created or modified in a typical production reactor. This will be followed by a discussion of the types of reactors considered for Savannah River in 1950, as well as the design and construction of the reactors themselves between 1950 and 1955. This in turn will be followed by a discussion of the first fuel and targets that went into the Savannah River reactors, as well as the facilities that were constructed to produce fuel and target elements.

An atomic bomb requires fissionable material, and production reactors make fissionable material from "fertile" materials. Basically stated, fissionable materials are capable of nuclear fission, while fertile materials are those that can be made into fissionable materials through neutron bombardment. As a rule, fissionable material is limited to uranium-233, uranium-235, plutonium-239, and plutonium-241. Of these, only uranium-235 exists in any quantity in nature, and it is difficult to isolate. All the others must be created artificially through the neutron bombardment of fertile materials. The three basic fertile materials are thorium-232, uranium-238, and plutonium-240. The first two are found in nature; the third is artificial. Thorium can be bombarded to produce uranium-233; uranium-238

can be bombarded to make plutonium-239; and plutonium-240 can be similarly treated to produce plutonium-241.[23] In the case of a fusion or thermonuclear bomb that requires hydrogen isotopes as well as fissionable material, lithium-6 serves as a fertile material for the production of tritium.

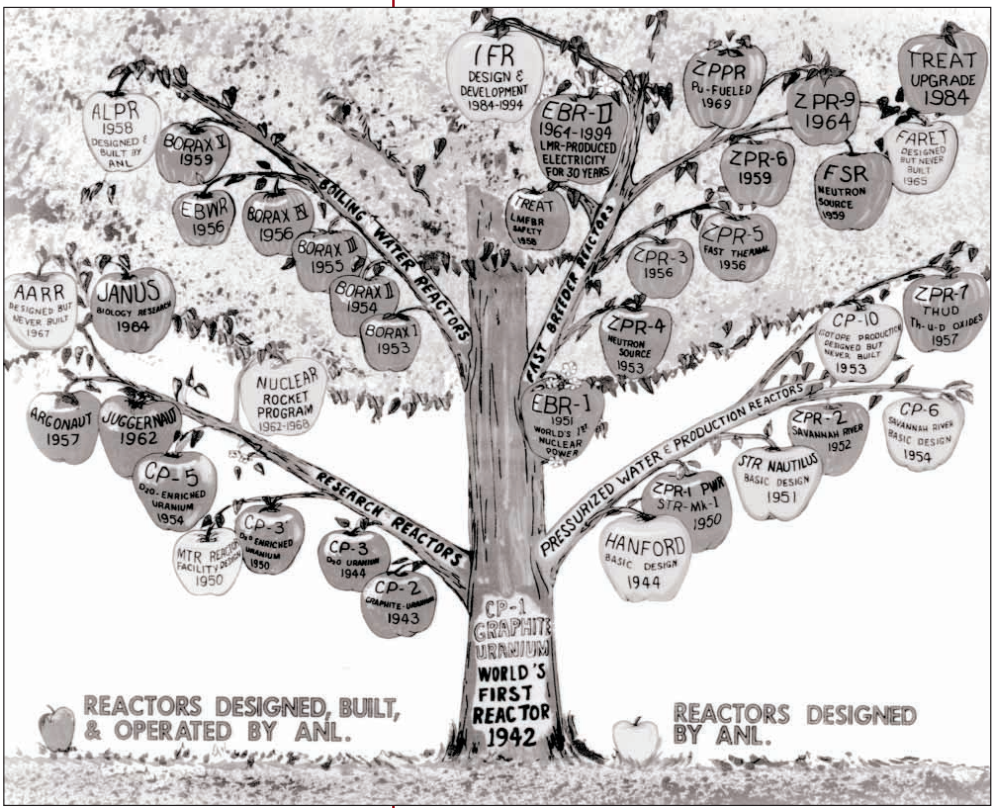
Nuclear production reactors require a combination of fissionable material to provide the neutrons or the "fuel," and fertile material to serve as targets. In most reactors, the fissionable material is uranium-235, which supplies the neutrons. The mixture of fissionable material and fertile material should be nearly balanced. However, there usually has to be an excess of fissionable material to override the loss of neutrons that escape or are captured by non-fertile materials and the constant problem posed by xenon-135, as well as other fission products created in the reactor that absorbed neutrons.[24] A heavy-water reactor will work fine with natural uranium, which contains a small percentage of uranium-235, but most reactors work better with enriched uranium, where the percentage of uranium-235 has been increased above its natural occurrence. Low-enriched uranium (LEU) is concentrated enough to sustain a chain-reaction in light water. It is normally used as fuel in light-water reactors. Highly enriched uranium (HEU) has its uranium-235 boosted. When uranium is strongly enriched, it is considered weapons-grade material, suitable for fission bombs. By 1950, gaseous diffusion was the only method still used in the United States to make enriched uranium.

Most World War II era reactors, and all of those designed and built at Hanford in the late 1940s, used graphite as the moderator. By 1950, however, scientists at Argonne and at Oak Ridge had already studied the superior neutron efficiency of heavy-water-moderated reactors. The first experimental heavy-water reactor, CP-3, was constructed at Argonne in the spring of 1944, and by 1950 the technology and physics were well understood, even if the technology was still basically untried. Except for a small facility at Chalk River in Canada, there was not a single full-scale heavy-water reactor in North America.[25]

By 1950, most Argonne scientists championed heavy water over graphite, and this was particularly true of Walter Zinn, head of reactor research. Not only did heavy water have greater neutron efficiency, an important characteristic in every kind of reactor, it also handled xenon poisoning better than graphite. Even though heavy-water reactors tended to be more difficult to control during startup and power changes, they were, as a rule, considered safer to run.[26] For the reasons above, and because the Savannah River reactors would have to be versatile enough produce both plutonium and tritium, Walter Zinn envisioned the Savannah River reactors as heavy-water tanks. This assumption was based on the success of the first heavy-water reactor, CP-3, as well as initial plans for CP-5.[27] The heavy-water system was further studied at Argonne's other heavy-water test reactors: the Argonne Exponential Tank, the North American Exponential Tank, and the Zero Power Reactor II (ZPR-II). The basic design of the first Savannah River reactors was developed most closely from work done on ZPR-II, with the final Savannah River reactor design formally designated CP-6.[28] Drawing on these designs, the versatility of the Savannah River reactors was not limited to specific products; it also encompassed potential increases in the power levels.[29] Considering the alterations made to the reactor design in the first two years of Savannah River construction, it was almost a miracle that they worked at all.

In the summer of 1950, when Savannah River Plant was nothing more than an idea, it was expected that there would be just two production reactors.[30] At that time, the AEC

had established certain guidelines for the new reactors: they were to follow certain Argonne designs, use heavy water for cooling and moderation, and operate at about 300 megawatts. The rest was left to Du Pont.[31]



Argonne Laboratory's reactor "genealogy," 1942-1994. CP-1, at the base of the trunk, was the world's first reactor. Each main limb denotes a reactor type-boiling water reactors, fast breeder reactors, research reactors, and pressurized water and production reactors-and its evolution. The basic design of the Savannah River reactors was designated at Argonne as CP-6. Courtesy of Argonne National Laboratory Archives, managed and operated by The University of Chicago for the U.S. Department of Energy under Contract No. W-31-109-ENG-38.

Du Pont's first idea for the Savannah River reactors was the "Pi-Pile," worked up in August 1950. Advanced by Du Pont's Atomic Energy Division Technical Division, it represented a number of improvements on the basic heavy-water reactor design proposed by Argonne. Among these improvements was a highly flexible control system, the loading of producer material in the control rods, the possibility for multiple fuel loadings, and the use of downward coolant flow, with a header system at the top of the reactor. Even though the multiple fuel loadings were later abandoned, the other features of the Pi-Pile were incorporated into the basic as-built Savannah River reactor design. During this period, in 1950, the control rods were envisioned as horizontal.[32]

In the fall of 1950, Du Pont worked on the details of its reactor design, which entailed a number of research visits to Argonne. Top shield details, fuel element dimensions, and shut-down cooling arrangements were worked out during this period. The greatest question, however, was whether the reactors should be designed more for the production of plutonium or tritium. Initial plans called for a concentration on tritium, which would require more heavy water for better neutron efficiency, but the AEC also wanted reactors that could produce plutonium just as well. The Du Pont engineers reached a compromise that accommodated both: they moved the fuel rods closer together, allowing the reactors to reach higher power levels as needed. It was also decided to concentrate on a "pilot pile," a first reactor that could be used to check the design work needed for the other reactors to follow; it could also be used for full-power tests of fuel elements and lattice arrangements.[33] For this reason, the plans for the first reactor, R, were more carefully studied than the others, leading to a series of calculation books (C Books) not used in subsequent construction.[34]

Even though the Savannah River Plant was originally conceived as a tritium-production facility, from 1950 through 1951 at least, the AEC had not yet decided whether to concentrate on the production of tritium or the production of plutonium at the new plant.

For a period, there was actually a leaning toward plutonium, and the first two reactors were constructed with that emphasis in mind. In the later construction years, the AEC leaned back toward tritium, and the later reactors were constructed for that purpose. Because the AEC could not make this final decision during the construction era, Du Pont kept as much of the design open as possible. By the time plans were finalized, the reactors would work for either isotope, and for others besides. Plans were also made for substantial power increases, if that was needed.[35]

Du Pont worked around these problems with remarkable ease, in part because it fit into their corporate concept of "design flexibility." Unlike much pre-planned design and construction work done today, Du Pont specialized in a level of flexibility that was almost institutionalized. Key choices were routinely postponed until the best design could be determined, and options were built into the system to deal with changes in operation.[36] It was a system that Du Pont had used at Hanford, and, in the case of the extra fuel rods used to override xenon poisoning, was quite possibly the salvation of the entire Plutonium Project.

Du Pont also had built-in double checks within its own organization. Hood Worthington, head of Du Pont's Atomic Energy Division (AED) Technical Division after 1955, once fended off criticism that the company failed to use outside design consultants by stating that the reactor designs had already been checked critically by various groups within the company.[37] Among those responsible for the design work on the Savannah River reactors were John Wheeler, who did design work at Argonne, and Bob Menegus, who had to be called back from sabbatical in the Pacific to work with Wheeler. Among the others were Hal Ring and Dan St. John.[38]

Reactor construction planning began in October 1950 and was overseen by A. E. Church, who had established an 11-point scope of work for the Design Division of Du Pont's Engineering Department. Using the preliminary reactor design, details were worked out for the tanks, fuel elements, lattices, control rods, monitoring features, moderator purification features, the gas system, the shields, and the charging and discharging of irradiated materials. Du Pont also made the decision to use the old Hanford-type solid fuel slugs, for the simple reason that no others had been so thoroughly used and tested. Whenever possible, Du Pont's own Engineering Design Standards were used to save time.[39]

Church reviewed four plans for the reactor buildings and selected one as the generic 105 Building.[40] The basic reactor design had already accommodated the five functional areas of the reactor: the assembly area for materials going into the reactor; the process area, where reactor materials were irradiated; the disassembly area; the purification area for the heavy-water moderator and the helium blanket gas; and the various support facilities needed to serve each reactor area.[41]

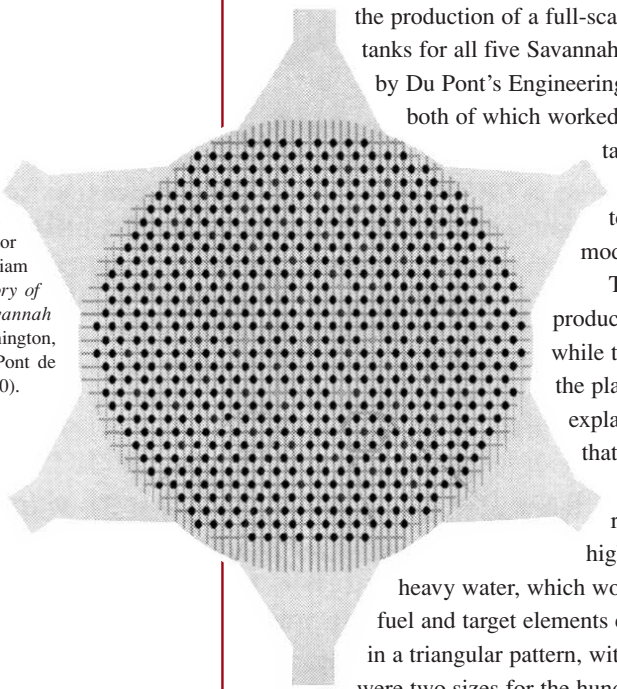
By December 1950, the AEC had decided on five reactors rather than two, allowing Du Pont designers to make the final placement of the reactor areas. As already discussed, the five reactors were to be situated along a horseshoe curve, with a minimum of 2.5 miles between any two. There was also to be a six-mile buffer between the reactors and the site boundaries. At that time, the plans called for one side of the reactor building to be clear of all support structures, just in case an additional reactor was installed in each reactor area. This feature was incorporated into the final as-built plans for the first two reactors, R and P, but was discarded for the last three.[42] In the first two years, there were tentative plans

for additional reactors at Savannah River Plant. A sixth reactor was approved by President Truman in February 1952, but those plans were abandoned by the AEC a few months later.[43]

The reactors themselves were altered over time. The first reactor designs called for a vertical arrangement of the heat exchangers. By February 1951, this had been changed to a horizontal arrangement. The most radical change came very late in the design plans, in May 1951, when the idea of horizontal control rods was abandoned in favor of a vertical arrangement. This change greatly reduced the anticipated size of the reactor process area. Other decisions made at this time included a lattice formulation of fuel and control rod positions on a seven-inch triangular pitch. The reactor was also divided into two zones: a central flat zone and a buckled zone on the periphery. The number of fuel and control rod positions was also stabilized during this time; fuel positions were in the majority with a much smaller number set aside for control rods and gas tubes. Each fuel position was to be filled with a quatrefoil housing tube, each with four channels. The control rod positions were to be filled with septifoils, or seven-channeled tubes, with each septifoil having a combination of cadmium rods and producer rods of lithium–aluminum alloy.[44]

In June of 1951, another refinement came with the development of the semi-permanent sleeve. This allowed the upper portion of the fuel assembly, the part not irradiated in the reactor tank, to be reused, requiring only that the quatrefoil itself be chopped up and sent to the burial ground. The following month saw the final round of redesign, with plans that more or less represented the way the first reactors would be built.[45]

Months before this time, in April 1951, New York Shipbuilding Corporation (NYS) of Camden, New Jersey, was selected to fabricate the Savannah River reactor tanks. The NYS contract was part of an experimental program identified as "NYX," which called for the production of a full-scale prototype and the construction of stainless steel tanks for all five Savannah River reactors. The NYX program was coordinated by Du Pont's Engineering Department and its Atomic Energy Division (AED), both of which worked closely with New York Shipbuilding. The R Reactor tank, made by NYS in 1951–1952, was the first product of the NYX program. It would be installed before testing was complete on the prototype, which would be modified to serve as the K Reactor tank.[46]

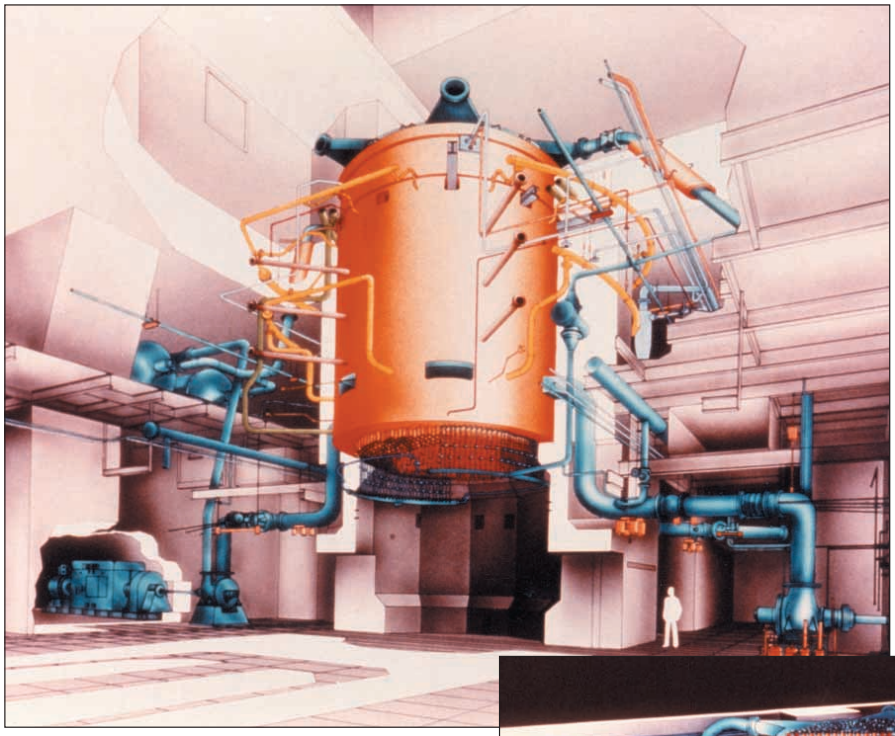


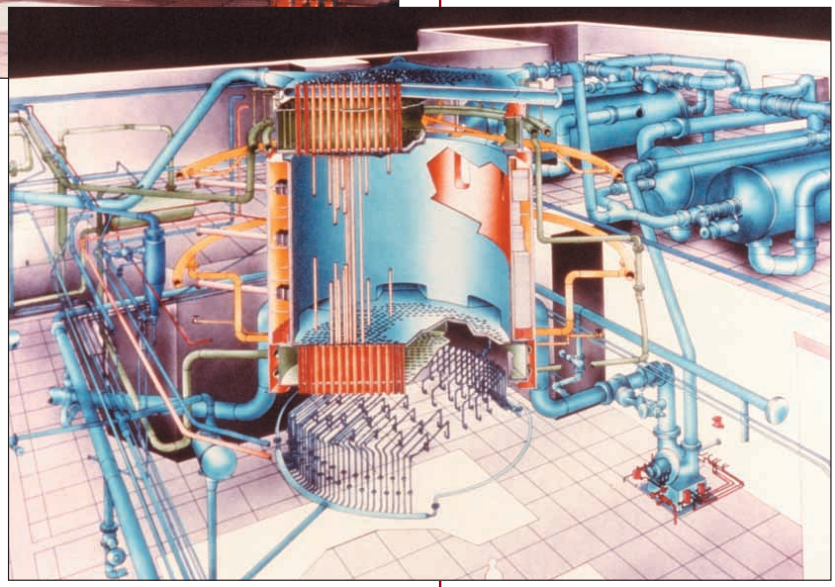
Schematic of a Savannah River reactor lattice. Source: William P. Bebbington, *History of DuPont at the Savannah River Plant*. (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).

The first Savannah River reactor technical manual was produced in 1953, when R Reactor was virtually finished, while the construction of P Reactor was well under way, with the plans for L and K reactors largely set.[47] This manual explained the arrangement and workings of the elements that were essential to reactor operation, with an emphasis on the production of plutonium. The Savannah River reactor tanks were cylindrical and, in size, roughly as high as they were wide. The tanks would be filled with heavy water, which would serve as both coolant and moderator. The various fuel and target elements entered the tank from the top, with elements arranged in a triangular pattern, with seven inches between basic lattice positions. There were two sizes for the hundreds of openings or lattice positions that accessed the reactor tank. Known as principal and secondary lattice positions, the former had larger

diameters than the latter. The principal lattice positions were to be filled with quatrefoil fuel assemblies, loaded with uranium slugs, and septifoil assemblies that contained control rods; a small group of positions acted as gas ports located along the periphery of the tank. The secondary positions were reserved for safety rods, bismuth irradiation rods, and instrument rods or "thimbles." In later years, some of these positions would be occupied by source rods, used to provide a neutron source for instrument detection.

The principal lattice positions were arranged to form two different lattice arrangements within the reactor. The central area, comprising 65 percent of the core, was the "flat zone" or FZ lattice, so named because the radial distribution of the neutron flux was





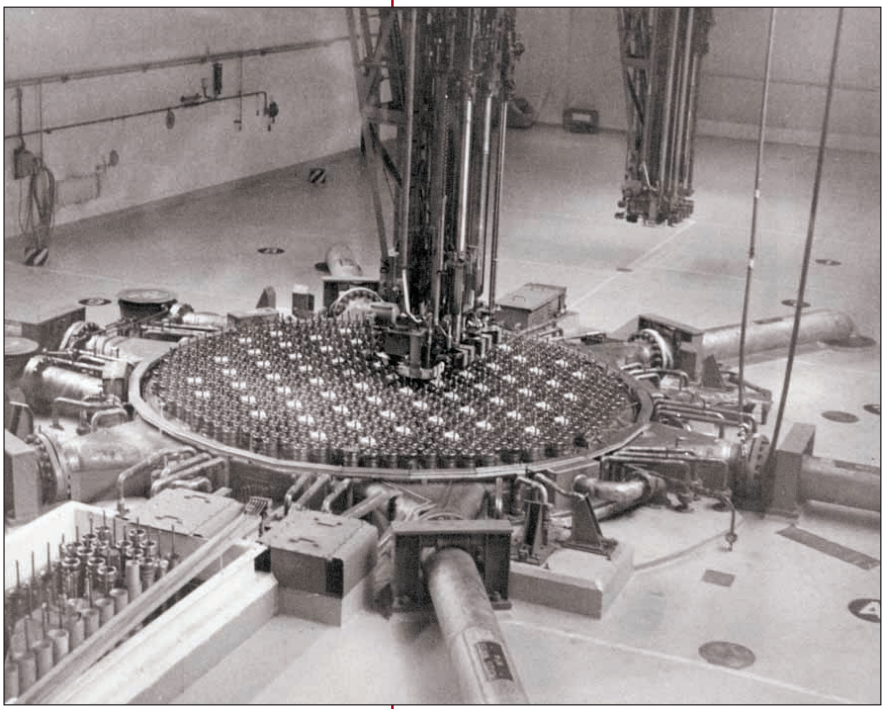
Savannah River's reactors are comprised of a main tank on which a radiation shield of normal water is placed. Inlet nozzles allow cooled heavy water to enter the plenum that lies atop the tank. The plenum distributes the heavy water among the fuel and target assemblies; the heavy water is discharged at the base of the tank into nozzles that take the heavy water to the circulating pumps. These pumps compel the heavy water to flow through horizontal, cylindrical heat exchangers and then return it to the plenum. Due to a shortage of heavy water, only a few heat exchangers were installed initially. The number of heat exchagers doubled later. The other piping shown in these drawings carries ordinary water coolant, heavy water side streams for the cooling of the control rods and continuous purification, and helium gas. The latter is an inert blanket over the moderator. Below the reactor vessel is the "Pin Room"; above the reactor is the "Forest", the safety and control-rod actuator, which is lowered to sit on the plenum. Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant*, (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).

Drawings completed by Voorhees, Walker, Foley & Smith. Courtesy of SRS Archives, negatives 43190-1, 3.

constant or "flat." The outer 35 percent was known as the "buckled zone" or BZ lattice, where neutron flux decreased rapidly with distance from the outer edge of the flat zone. All of these positions were identified by a rectangular system of coordinates, with the x axis identified as the north–south line, parallel to the long axis of the reactor room.[48]

Heavy water served as both moderator and cooling agent, with 94 tons in the reactor tank, and another 106 tons in the circulating system. In the first reactors, six pumps circulated heavy water through the reactor system. The design called for heavy water to enter the reactor tank

from six inlet nozzles spaced around the top of the tank, or water plenum. Heavy water would then leave the tank through another six nozzles placed around the base. The heavy water would be reused after being forced through six heat exchangers, where it would be cooled by light water pumped from the Savannah River at a rate of 67,000 gallons per minute.[49] The decision to install only six heat exchangers in the first reactors was made because of the shortage of heavy water. Provision was made for the addition of another six for a possible total of twelve.[50]



Closeup of plenum while reactor's charge and discharge machines are at work. Courtesy of SRS Archives, negative DPSPF-11395-9.

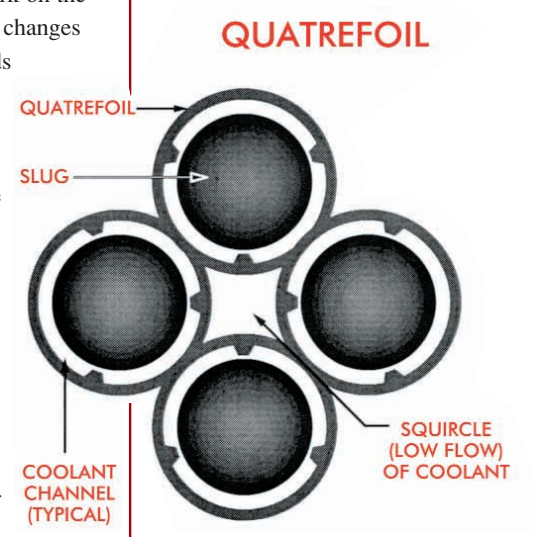
Construction details of the reactor areas have been discussed in other chapters, but the speed with which the reactors and the auxiliary buildings were completed is an achievement that would be difficult to duplicate today. R Reactor, the first to be built, was also the first to achieve criticality, on December 28, 1953. P Reactor followed on February 20, 1954. L Reactor went critical on August 11 of that same year, as did K Reactor on October 14. C Reactor, the last of the five to be constructed, was raised to criticality on March 28, 1955.[51]

The five Savannah River production reactors are basically similar, but there are some differences, especially between the first, R, and the last, C. In essence, the R Reactor building is larger than the others, and had more elaborate facilities. As some of these were found to be unneeded, they were either reduced in size or eliminated all together. While the tanks in R, P, K, and L are essentially identical, the tank in C, the last reactor built, was made larger to accommodate a D_2O reflector which increased the size of the high-power flat zone and, hence, total reactor power.

The R Area was not only the first to be constructed, it also contained the largest of the five Savannah River reactor buildings and it was complemented by a huge river-water clarification plant, that had an 80,000 gallon/minute-capacity. At the time of R Area construction, it was thought that the cooling water pumped from the Savannah River would have to be treated in order to serve in the heat exchangers. Shortly after construction, tests performed at the Corrosion Mock-up Experimental facility (CMX) determined that no treatment of the river water was required. As a result, water clarification plants were not constructed in the other reactor areas. A partial exception was P Area, where construction on the facility had been started, but was altered to create a much smaller reservoir for general power and service.[52]

The C Reactor tank, the last to be fabricated, was also the most unique. Design work, conducted in late 1952 and early 1953, called for a number of different features. The initial moderator flow was raised to 85,000 gallons/minute, with provision for a future flow of 120,000 gallons/minute. The reactor structure and thermal shield were designed for

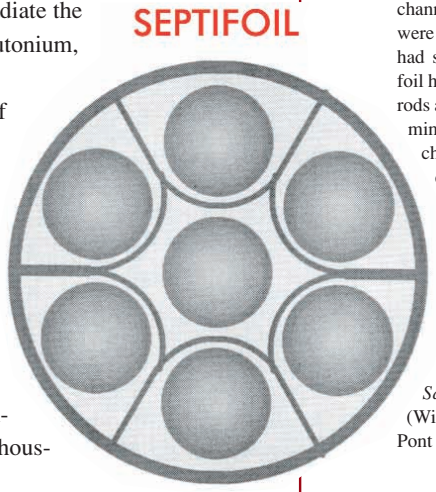
higher power levels, up to 2000 MW, with a moderator exit temperature as high as 95º C—a full 15 degrees higher than the other reactors. The cooling river-water supply pipes were to have a capacity of 96,000 gallons/minute. Also, C Reactor would have an integral heavy-water reflector inside the reactor tank, immediately outside the lattice configuration. This required increasing the tank wall radius.[53] New York Shipbuilding began work on the C Reactor tank in April 1953, but the summer and fall of that year saw even more changes to the design. Twelve new control positions were added to the tank and safety rods were added to handle the higher neutron flux anticipated in the peripheries of the reactor. In August, it was decided to install additional heat exchangers, making C the first reactor to have more than the original complement of heat exchangers. Another design change made was the addition of a curved knuckle joint to replace the T-joint used by the other reactors between the tank wall and the bottom shield. This provided a small improvement in the tank's temperature stress burden, but even more important, it allowed workers to x-ray all of the pipe's welds, something not possible with the earlier reactors.[54] When the fabrication was complete, C Reactor tank was the largest of the reactor tanks produced for Savannah River. The radial heavy-water reflector was a foot thick around the core. As a result of this feature, there were more control positions and fewer fuel and target positions than were in the other reactor tanks.[55] The reactor reflector was an important innovation. By acting as a "mirror," bouncing neutrons back into the main reactor zone, it helped contain the neutrons essential to the irradiation process.[56]



FUEL AND TARGET ELEMENTS, CIRCA 1955

Throughout the life of the Savannah River reactors, the main production materials would be plutonium and tritium, produced with a combination of both fuel and target assemblies in the principal lattice positions. Fuel assemblies contained materials capable of fission; these assemblies produced the neutrons needed to irradiate the target materials, which would then be transformed into either plutonium, tritium, or other special radioisotopes. The basic fuel used at Savannah River was uranium-235. The basic targets consisted of uranium-238, which would be turned into plutonium, or lithium-6, which would be transformed into tritium.[57]

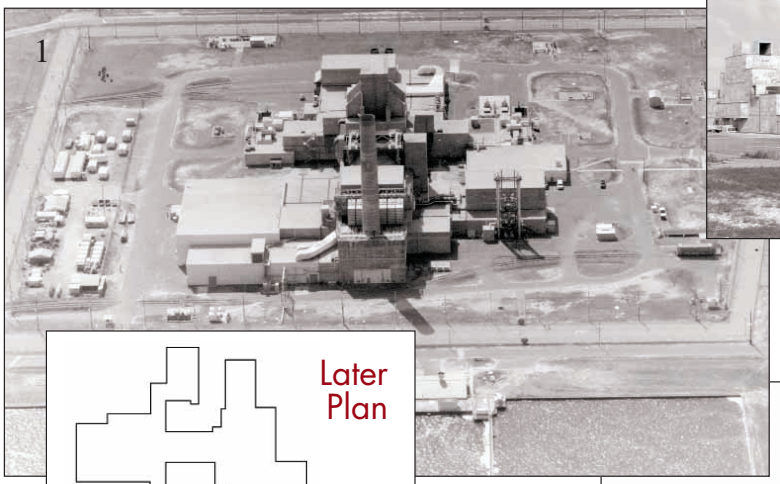
In 1955, when all of the Savannah River reactors were on-line, the fuel assemblies were loaded into quatrefoils for the production of plutonium. Each quatrefoil was a four-chambered tube that would hold four columns of uranium slugs. Each slug was a solid natural-uranium cylinder, clad in aluminum to prevent corrosion from exposure to the moderator. Vertical ribs inside the four tube-chambers helped maintain channels for the coolant to pass between the slugs and the quatrefoil housing.[58]



Savannah River reactor design called for a vertical arrangement of the control rods; the lattice structured the fuel and control rod positions. Each fuel position was to be filled with a quatrefoil housing tube, each with four channels. The control rod positions were to be filled with septifoils that had seven channels, with each septifoil having a combination of cadmium rods and producer rods of lithium-aluminum alloy. When a reactor was charged or discharged, the whole quatrefoil was removed and replaced with one loaded with new slugs. Conversely, individual control rods were removed when necessary and the septifoil, an extruded aluminum insert, stayed in place. Source: William P. Bebbington, *History of DuPont at the Savannah River Plant*, (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).

To make a reactor critical, the safety rods had to be withdrawn, after which the control rods were withdrawn sequentially from the septifoil housing in such a way as to control the reaction. Each septifoil was a seven-chambered aluminum tube that contained two cadmium rods, lithium-aluminum rods, and lithium-aluminum rods. The cadmium was a

Comparing Reactors



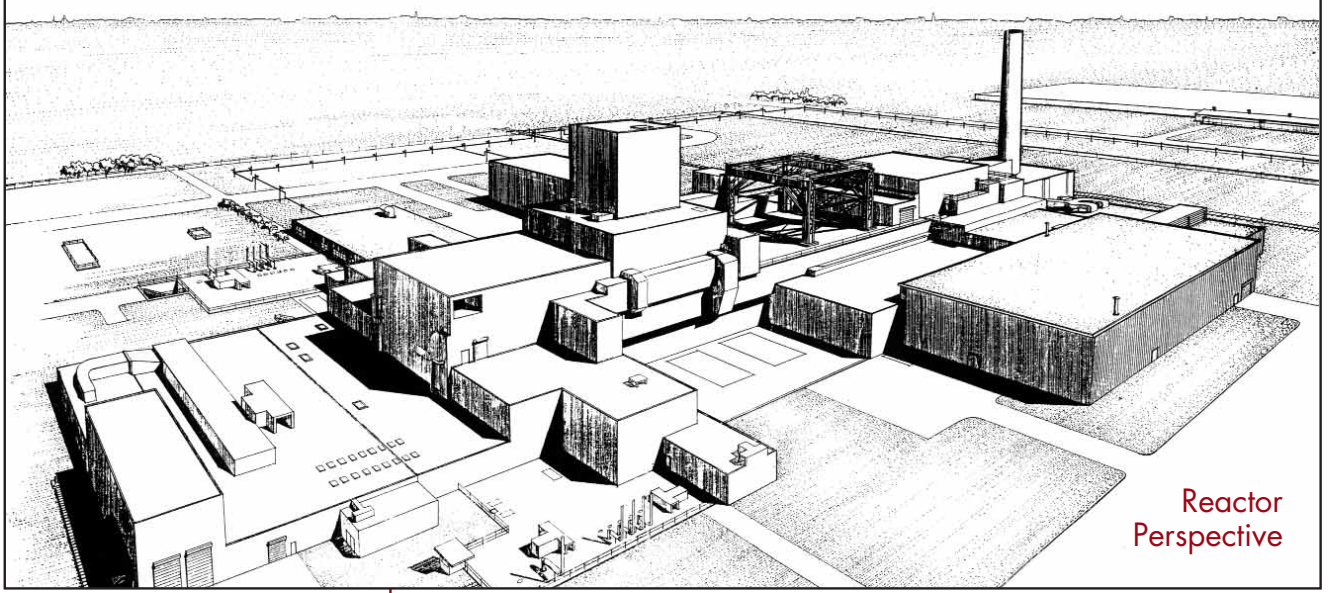
Later Plan



Early Plan



1. Negative 46156-15; 2. Negative DPESF 1-972-4; 3. Negative DPESF 1-1244-3. All photographs courtesy of SRS Archives. Source (reactor plans): Atomic Energy Commission, Savannah River Operations Office Savannah River Plant. Basic Information Maps by Area, 1956.



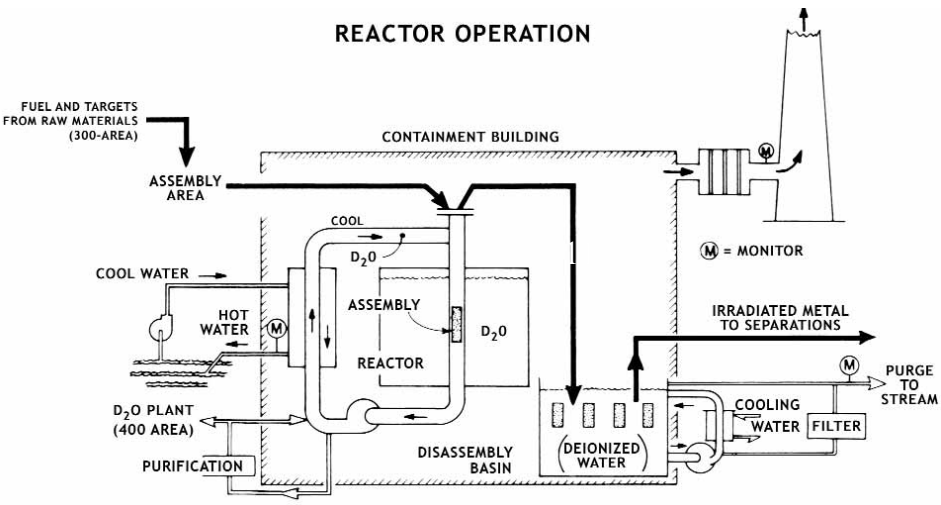
Reactor Perspective

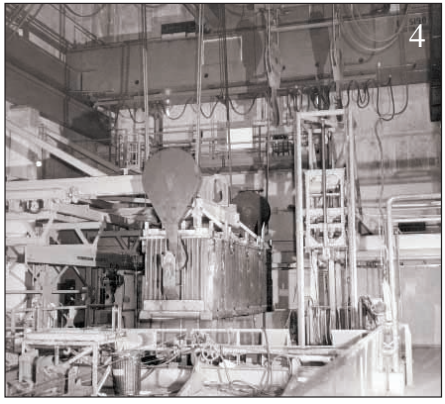
Views of Reactor Operations













1. Fuel and Target Assembly and Storage Area, negative 27225-5. 2. 105-L Disassembly Area, 1956, negative 3728-2-1. 3. Reactor Control Room. 4. Transfer Area showing cask used to transfer irradiated fuel and targets from the reactor areas to separations. The cask is loaded underwater, negative 8930-9. 5. Cask is placed on flatbed in 105-K for delivery to separations, negative 3943-2-23. All photographs courtesy of SRS Archives (Drawing) Fuel and Target Assembly Area. Source: William P. Bebbington, *History of DuPont at the Savannah River Plant,* (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).



Safety and control rods withdrawn in P Reactor. Courtesy of SRS Archives, negative 27226-12.

Aerial View of M Area showing major manufacturing facilities, circa 1985. Courtesy of SRS Archives.

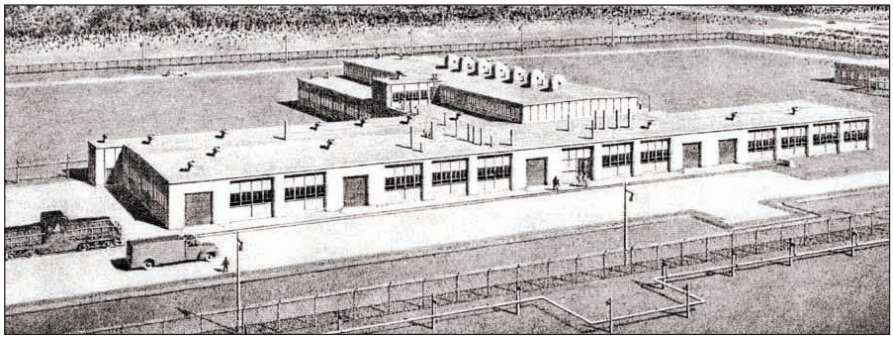
neutron absorber, or reactor "poison." The lithium in the control rods absorbed neutrons to make tritium. In the first year of full operation, the only tritium produced at Savannah River came from the lithium bombarded in the septifoil control rods.

In 1955, the fuel slugs loaded into the quatrefoils were based on the form that had been perfected at Hanford and tested at Brookhaven.[59] These slugs were designated Mark I, to distinguish them from the future designs that were already on the drawing boards.[60] Mark I, and the fuel and target assemblies that followed, were manufactured at Savannah River Plant in the Manufacturing Area, also known as M Area or 300 Area, located adjacent to the main Administrative Area and the Savannah River Laboratory. The bare uranium slugs were made at National Lead of Ohio and shipped to Savannah River for canning. The Mark I fuel slugs were finished in the Fuel Slug Manufacturing Building, which was built beginning in the summer of 1951. This building was designed for the preparation of natural-uranium fuel slugs, using basically the same process developed at Hanford. In the



case of Mark I, the slugs were eight inches in length, with a one-inch diameter. After delivery to the Fuel Slug Manufacturing Building, the slugs were canned in an aluminum sheath for protection from water corrosion; the original method for doing this was known as "Al-Si dip canning," developed at Argonne. The first uranium fuel slugs finished in this fashion were completed in September 1952.[61]

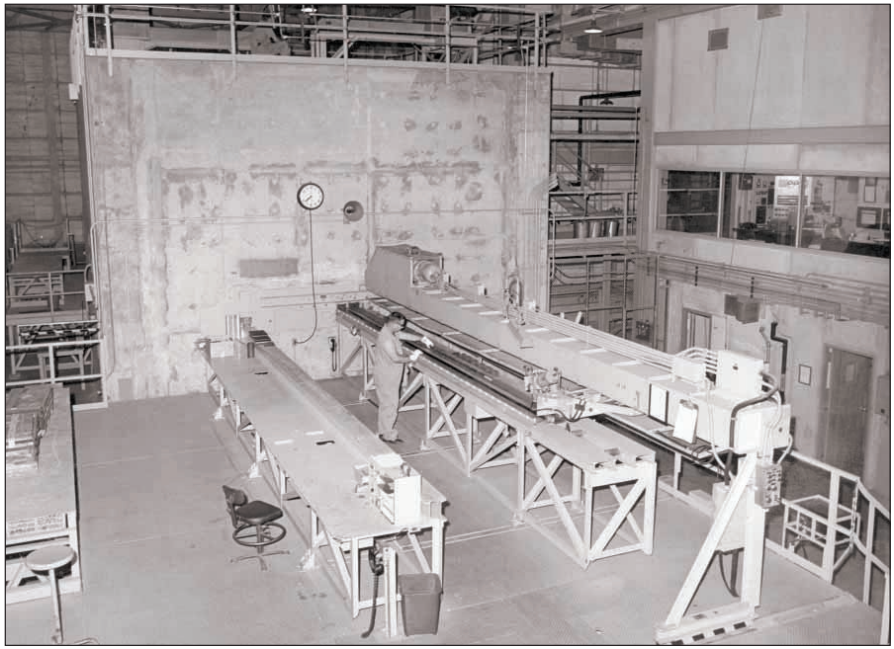
The summer of 1951 also saw initial construction on the Target and Control Rod Manufacturing Building. The main function of this facility was to cast, extrude, and can lithium-aluminum alloys and to assemble and seal the canned lithium-aluminum slugs into aluminum control rods.[62] Unlike the slug canning process, which was borrowed from Hanford, the Savannah River M Area operation was largely devised from scratch, based on the needs of the Savannah River reactors. Lithium was alloyed with aluminum, and then cast into ingots. The ingots were then extruded into rods (slugs). The slugs were inspected, cleaned, and placed into aluminum cans before being capped. After the lithium–aluminum slugs passed inspection, they were placed into aluminum tubes. The tube ends were machined, with end fittings welded to the tube to create a permanent seal.[63] When



Drawing of Canning Facility as designed. Drawn by Voorhees, Walker, Foley & Smith. Courtesy of SRS Archives.

the Target and Control Rod Manufacturing Building went into service in 1953, it produced slugs for use as control rods as well as production purposes.[64]

Essential to both the M Area and the production reactors were the test piles located in M-Area. Here, materials destined for the reactors were tested for suitability. This was primarily done in the Slug and Rod Testing Building. The central feature of this building was the test pile, which tested the quality and neutron absorption of feed materials made in M Area's manufacturing buildings. The test pile was a graphite-moderated reactor, based on designs developed at Hanford. In early 1951, Du Pont's Atomic Energy Division added additional features, which included a blanket of inert gas (helium), a laboratory or "counting room," and a bomb shelter for the buildingpersonnel. As built, the graphite moderator

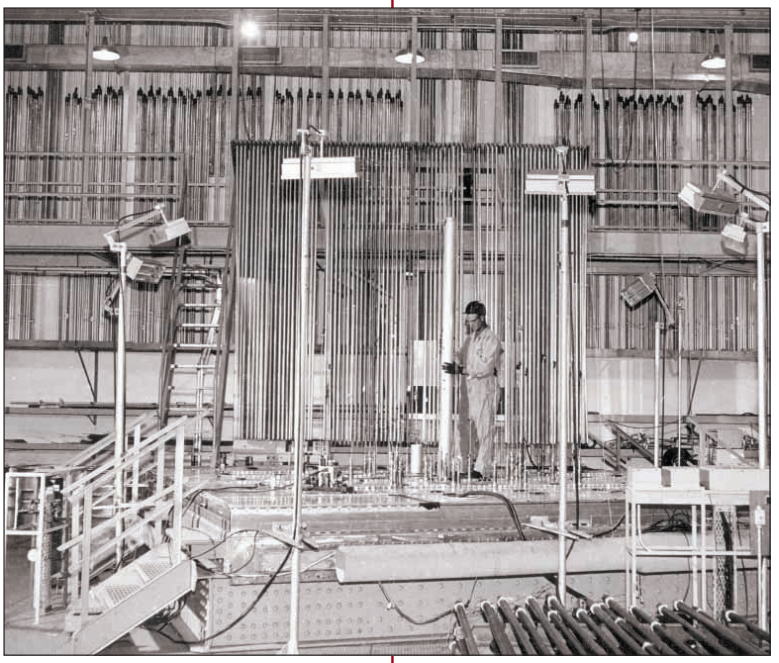


Graphite Test Pile. with control room to the right. Courtesy of SRS Archives, negative 38887-1.

was roughly square, with 47 layers of graphite blocks. There were almost 400 horizontal channels for the uranium rods. In addition, there were holes for safety rods and various instruments; some of these were vertical, but most were horizontally positioned.[65] The graphite moderator was laid up in the summer of 1952, and the test pile went critical for the first time in September of that same year. Testing on a production basis began in December 1952.[66] Its most important functions were to sample uranium fuel slugs for

uniform reactivity, and test all lithium–aluminum slugs and control rods for neutron absorption capability.[67]

The test piles in the Physics Assembly Laboratory were more experimental in nature. The physics laboratory was a technical facility for the experimental development of reactor operating techniques and designs, as well as a testing site for the calibration of various standards and monitoring devices. In addition to the graphite-moderated Standard Pile (SP) and the heavy-water-moderated Subcritical Exponential Tank (SE), the largest of the test reactors was the heavy-water-moderated Process Development Pile, better known by its initials PDP. Like the production reactors, the PDP design was based on Argonne reactor ZPR-II. The PDP was used to test safe operational limits, as well as test loading patterns before they were used in the production reactors.[68] The PDP was a full-scale mock-up of the production reactors. Even though it did not share the same mechanical design, the PDP was similar in chemical and physical characteristics. The reactor tank was a stainless steel cylindrical tank about as wide as it was high. There were hundreds of lattice positions on a triangular pitch, just like the production reactors. Unlike the production reactors, the PDP operated at much lower power levels.[69]



The PDP, an experimental reactor, was a full scale mock-up of the site's production reactors. The reactor was comprised of a tank filled with heavy water into which fuel and control assemblies were inserted from the top. The PDP operated at very low power. Courtesy of SRS Archives, negative 8929-15.

SAVANNAH RIVER DEFENSE PRODUCTION AND POWER ASCENSION 1955–1963

Between 1955, when all five of the reactors were on line, and January 1964, when President Johnson called for a reduced production of nuclear materials, the demand for plutonium and tritium mushroomed. During this period, the U.S. nuclear arsenal became the front line of the nation's defense. As a result, the Savannah River Plant underwent almost continual change. These alterations were designed to increase the production of plutonium and tritium. At Savannah River, increased production meant a steady increase in the power of the reactors, an increase several times higher than the rated power of the reactors in 1955. In order to accommodate this increase, almost everything that went into the reactor had to be improved, and this included developing new fuel and target elements and new fuel and target canning procedures, and improving the water cooling system. With the higher power came a greater concern for safety, and these measures too had to be tightened to accommodate the change.

OUTLINE OF BASIC ORGANIZATION AND OPERATION (1955)

All five production reactors were in operation by early 1955 and before the year was out, the original Savannah River Plant was considered finished, with full production and

delivery of both plutonium and tritium to the Atomic Energy Commission. At this time, the plant was operated with a work force of just under 8,000, a much smaller group than the tens of thousands required to build the place.[70] The organization of Savannah River Plant also changed, as the construction force was replaced by the operating staff.

Because Du Pont was a proven commodity based not only on its commercial success but also its record at Hanford, the AEC allowed the company more leeway in the operation of Savannah River Plant than was usually granted to other subcontractors. This meshed perfectly with Du Pont's corporate policy of flexibility within its own staff and organizational departments.[71] Du Pont's system for control was decentralized, with relatively little reliance on traditional control techniques or formal statistical reports. As a rule, the managers and management staffs of the various divisions within the company exercised control. The system operated with built-in overlaps, as workers from across division lines worked on similar tasks. It was a system developed over the years by Du Pont, and it served them well.[72]

Two major departments, Engineering and Explosives, within the Du Pont organization were concerned with Savannah River. The first had the role of architect, engineer, and general contractor. As the construction phase of Savannah River Plant came to a close, the Engineering Department bowed out in favor of the Explosives Department, which would run the plant. The Explosives Department, headed up by a general manager, was in charge of Du Pont's AEC programs, and within that umbrella was the Atomic Energy Division (AED). The AED was a direct tie between Savannah River and Du Pont headquarters in Wilmington, Delaware.[73]

At Savannah River, the two organizations that ran the reactors were the Reactor Section and the Reactor Technology Section, both of which operated under the AED. They ran the reactors through a system of almost parallel authority. The Reactor Section was in charge of production and was responsible for day-to-day operation.[74] The Reactor Technology Section was in charge of the physics, and was responsible for engineering changes and improvements to the reactors. The Reactor Section, which was later designated a department, was run by a superintendent and his assistant, below whom were superintendents for each of the five reactor areas, below whom were supervisors for the different shifts.

The Reactor Technology Section provided technical support to the Reactor Section. It not only provided the procedures needed to operate the reactors, but was also responsible for any technical support required for solving new problems. In this sense, the Reactor Technology Section was the connection between the Savannah River Laboratory and the Reactor Section: the lab would test new solutions, and the Reactor Section would put them into effect.[75] In the 1950s, the Reactor Technology Section was directed by A. A. Johnson, more commonly known as A^2, who served as superintendent until 1961. Below him was the Reactor Technical Assistance chief supervisor, followed by senior supervisors for each of the five reactor areas. Among those who served as senior supervisors in the 1950s were R. C. Axtmann at R Reactor, D. H. Wingerd at P, and L. W. Fox at L, F. E. Kruesi at K, and R. C. Holmes at C. Below each reactor boss were two broad categories of technical staff, physicists and engineers. At each reactor there were three or four physicists and four or five engineers. In 1955, some of the more prominent were K. E. Plumlee, Physics Process Supervisor at R; J. M. Boswell, engineer at K; and E. O. Kiger, engineer at C. Separate from Reactor Technical Assistance but still under A^2 Johnson and the Reactor Technology

A.A. Johnson directed the Reactor Technology Section from its inception until 1961. Source: *Savannah River Plant News*, Volume XVI, No. 25, January 10, 1969.



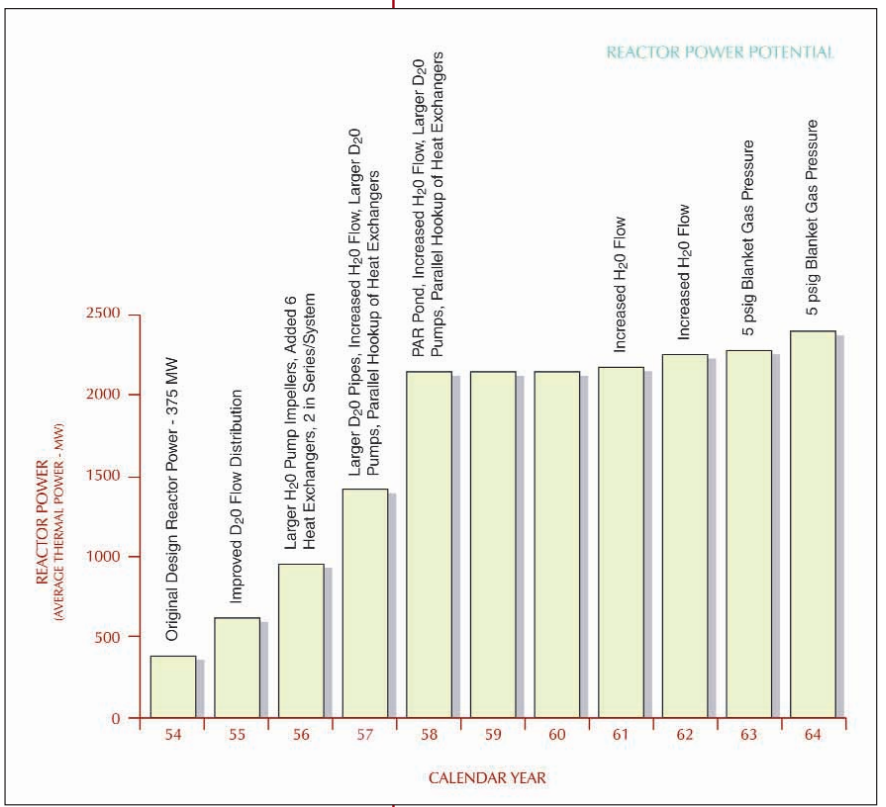
Section, were the people in charge of Reactor Physics and Reactor Engineering. The chief supervisors were M. M. Mann and P. A. Dahlen, respectively.[76]

POWER ASCENSION AND ITS PROBLEMS

In 1955, when the Savannah River reactors were completed and in operation, their "nameplate rating," or power rating was listed as 378 MW, a rating based on using Mark I assemblies with a maximum surface temperature of 80º C.[77] The first power ascension occurred as early as 1954–55, using the Mark I fuel assembly, with P Reactor serving as the pilot. By the end of 1955, still using the Mark I assemblies, power levels at the reactors had been driven up as high as 877 MW. Power ascension really began in 1956, as work began on new fuel and target assemblies and better ways were sought to remove heat from the process water. By the end of 1956, power levels had been pushed as high as 1380 MW, and this was just the beginning. By the end of 1957, it was 2250 MW; by the end of 1958, 2350 MW. This was the last year of the major jumps in power, but power still continued to rise. C Reactor reached 2575 MW in 1961, and remained at a high level until 1964, when President Johnson announced in the State of the Union message in January, that the United States would, for the first time, begin reducing the production of nuclear materials. Even so, C Reactor reached its peak power performance in 1967, when it attained 2915 MW, the highest level for any Savannah River reactor.[78]

Power ascension required solutions for a number of problems. The fact that they were anticipated did not detract from the difficulties posed by their solution. One of the first dilemmas was the increase in xenon poisoning. Even though it has a half-life of only around 12 hours, xenon-135 is a strong neutron absorber commonly produced in operating reactors. At Hanford, xenon poisoning had simply been overpowered by adding more fuel. At Savannah River, where the reactors soon operated at much higher power and at a greater neutron flux, this was not always possible. Xenon buildup soon led to unwanted power oscillations, as normal control-rod manipulation had difficulty staying ahead of the curve of xenon buildup and decay. Scientists at Savannah River and elsewhere—among them Dan St. John—analyzed this problem, which finally resulted in a program of control rod use that was far more sophisticated than anything employed during the Manhattan Project.[79]

Another constant that had to be dealt with was plutonium-240. This unwanted isotope was created along with plutonium-



Reactor Power Potential in Megawatts. Source: William P. Bebbington, *History of DuPont at the Savannah River Plant*, (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990).

239, and was made when a plutonium-239 atom absorbed a neutron rather than fissioning. Its presence poses a problem since it can later fission spontaneously or "fizzle," releasing neutrons and generating high heat. Because it is a constant factor in the production of plutonium, it is used to grade plutonium as suitable for different purposes. Weapons-grade plutonium has the least percentage of plutonium-240; fuel-grade plutonium slightly more, while reactor-grade plutonium has the highest percentage. The basic quandary is that while longer irradiation periods produce more plutonium-239, they also produce more plutonium-240. As a result, all irradiation of uranium to produce plutonium-239 requires some sort of compromise on time.[80] In August 1956, the AEC announced that by early 1957, all natural uranium exposures would have to be doubled over the previous production exposures. While this would double the amount of plutonium produced per cycle, it would also raise the percentage of residual plutonium-240. The first full load to produce plutonium with an acceptable percentage of plutonium-240, was completed in P Reactor in October–December 1956.[81] The same methodology remained in use until at least the 1980s for plutonium production.

DEVELOPMENT OF NEW FUEL AND TARGET ASSEMBLIES

The greatest solution to the problems posed by reactor power ascension was the creation of new fuel and target assemblies superior to the Mark I. This led to a whole chain of new assemblies until the optimum fuel and target assemblies were established in the early 1970s. There were at least 79 different Mark designations, most of which were designed at Savannah River. The purpose of a Mark designation was to clearly identify a complete fuel or target assembly, which would include fuel, target, and housing. Most of the 79 assemblies never left the drawing board, and few were used extensively. Only the most significant assemblies, fewer than 20, are mentioned in this book. For future reference, Marks I through XII were designated with Roman numerals; all subsequent Marks were written in Arabic numerals.[82]

There was a relatively simple progression in the development of the new assemblies. The original fuel elements were small-diameter solid slugs. In the late 1950s, this design was altered in favor of small-diameter hollow slugs, which provided more surface area to improve fuel cooling. In the early 1960s, the hollow slugs were scrapped in favor of large diameter tubes.[83] This progression was particularly apt in the development of the plutonium producing charges and—with the exception of the hollow slugs—was also followed in the development of the tritium producing charges. Even though both plutonium and tritium charges were developed simultaneously from 1955 through the early 1960s, it will be easier to follow that progression by first reviewing the development of the plutonium charges, followed by the tritium charges. The Mark I, III, and VII designs were used with quatrefoils until tubular assemblies were introduced with the Mark V series; this series was used to produce plutonium. In 1955, tritium was produced at Savannah River only in the control rods, which were set up to contain a certain amount of lithium–aluminum. As the demand for tritium increased, and as power levels rose, the first tritium-producing assemblies were introduced, allowing tritium to be created in the principal lattice positions. The first assembly of this sort was the Mark VIII, designed in 1955 and first used in the reactors in 1956. It was followed by the Mark VI series, which included the Mark VI-B, the "work-

horse" tritium producer of the 1960s. The tritium producers were improved and eventually perfected with the development of the Mark 22. Since these events occurred in the years after 1964, they will be discussed in Chapter 16. The early Mark assemblies and their progression are summarized in the table below.

PLUTONIUM PRODUCERS

Mark version	Dates	Design features
Mark I	1955–1956	Solid fuel natural-uranium slug based on a Hanford design that was tested at Brookhaven.[84] U-235 served as the fuel, and U-238 served as the target.[85] This assembly could not withstand high temperatures caused by increases in reactor power.[86]
Mark III, Mark III-A	Developed 1955–56	Full-length uranium fuel plates designed to allow greater coolant flow around the fuel.[87] This assembly was never used due to problems with fabrication, monitoring, and reactivity.[88]
Mark VII	1956–1957	Similar to Mark I in size, but with a cavity running through the axial length of the slug. The first of the hollow slugs, also called I & E slugs (internally and externally cooled slugs).[89]
Mark VII-A	1957–1960	Slightly larger than the VII and designed to be used with the largest quatrefoil possible.[90] The slug size was increased to accommodate the greater water flow from the new Bingham reactor pumps (see "Water Cooling Upgrades," below). After this, the quatrefoil was abandoned in favor of tubular fuel assemblies.
Mark V-B	1960–1962	After two years of tubular design work, first used in R Reactor in March 1962.[91] This assembly could not withstand higher temperatures caused by the reactor power increases.[92]
Mark V-E	1963–1964	Tubular assembly with a slightly enriched uranium core (0.95 wt% uranium-235), which led to a higher reactivity. Because of the higher reactivity, designed to be used with Li-Al blanket assemblies, tritium could be produced in the blanket around the reactor core.[93]
Mark V-R	1964	Modified Mark V for lower enrichment at 0.86 wt% uranium-235. (See Chapter 16).

TRITIUM PRODUCERS

Mark version	Dates	Design features
Mark VIII	1955–1957	Similar in size and shape to the first solid-slug plutonium assemblies; used in quatrefoil.[94] Contained

		both fuel slugs (enriched uranium) and target slugs (Li–Al).[95]
Mark VI-J	1958–1961	A target slug with a hollow, air-filled Li–Al core and a single outer fuel tube. Highly enriched uranium (HEU) fuel.[96]
Mark VI-B	1960s	The tritium-production workhorse of the 1960s.[97] The first to have both inner and outer target tubes, with the outer target tube serving as the outer housing for the assembly itself. Could also endure higher power levels and longer exposures than its predecessor.[98]

NEW BUILDINGS AND CANNING TECHNIQUES

As fuel and target assemblies advanced from solid slugs to tubular assemblies, a whole host of manufacturing techniques had to be altered to produce and check the new materials. New buildings were required to house the machinery for tube manufacture, and better canning techniques were developed to seal the uranium and lithium in their protective aluminum sheaths. The change to tubular assemblies also required improved methods of testing or checking the new products. These changes began just a year after the original Savannah River Plant was completed, and continued throughout the 1960s.

The first tubular production work at Savannah River was done in the Alloy Building in mid-1956, but this work was soon transferred to the Manufacturing Building, which was built in 1956 and 1957 specifically for the manufacture of tubes.[99] The Manufacturing Building was reserved for the fabrication of thin-walled tubes, first for tritium production and later for plutonium target tubes.[100] The techniques used here had been researched for years at the Savannah River Laboratory. In fact, the first research into the use of tubular elements had been done as early as 1951 by Nuclear Metals, Inc., at the behest of Du Pont. Nuclear Metals pioneered the use of "co-extrusion," which was the simultaneous formation of a tubular fuel core and the aluminum cladding on both inner and outer surfaces of the tube. It soon developed that fuel and target tubes had to be ribbed, to preserve their position and to create coolant channels with accurate dimensions to assure consistent cooling around the tube. In the 1950s and through most of the 1960s, ribbed tubes were produced from smooth, unribbed billets.[101]



Interior of Canning Building, showing canning process, 1956. Courtesy of SRS Archives, negative 3486-9.

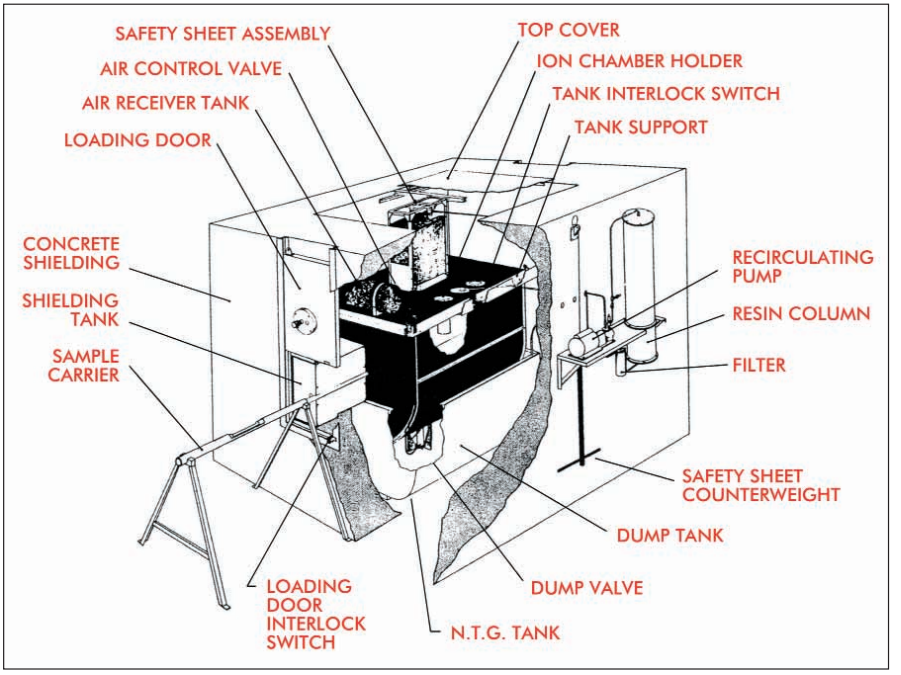
The use of tubes and the rise in reactor power levels also required improvements in canning techniques. In 1955, the method of canning was the Al–Si bond discussed above.

Its eventual successor, particularly for canning hollow slugs, was hot-press bonding, a technique developed by Sylvania–Corning Nuclear Corporation in 1955. The use of this new method was delayed at Savannah River because of the anisotropic growth of the irradiated uranium hollow slugs and tubular elements as a result of high metal temperature. Sylvania–Corning did all hot-press bonding of Savannah River slugs until 1960, when the Canning and Storage Building was converted to the new process.[102]



Extrusion Press and Control Panel, 1956. Courtesy of SRS Archives, negative 3486-2-8.

The new tubes also required improvements in the testing process that followed manufacture. In this area, the biggest improvement occurred in Building 305-M. The original graphite test pile, which was based on a technology perfected at Hanford during the Manhattan Project, took up to 10 minutes per test and required a large well-trained crew to operate. It was simply not adequate for the production schedule required at Savannah River.[103] As early as 1955, the work of the graphite test pile was supplemented by the first Neutron Test Gage or NTG, a slightly subcritical light-water-moderated facility.[104] The NTG was a six-foot cube with an adjoining measuring area. While the test pile was used to examine materials with natural uranium and depleted uranium, the NTG was used to test materials that had enriched uranium.[105] The NTG was smaller than the test pile, required only a small crew, and could check nuclear materials ten times faster.[106]



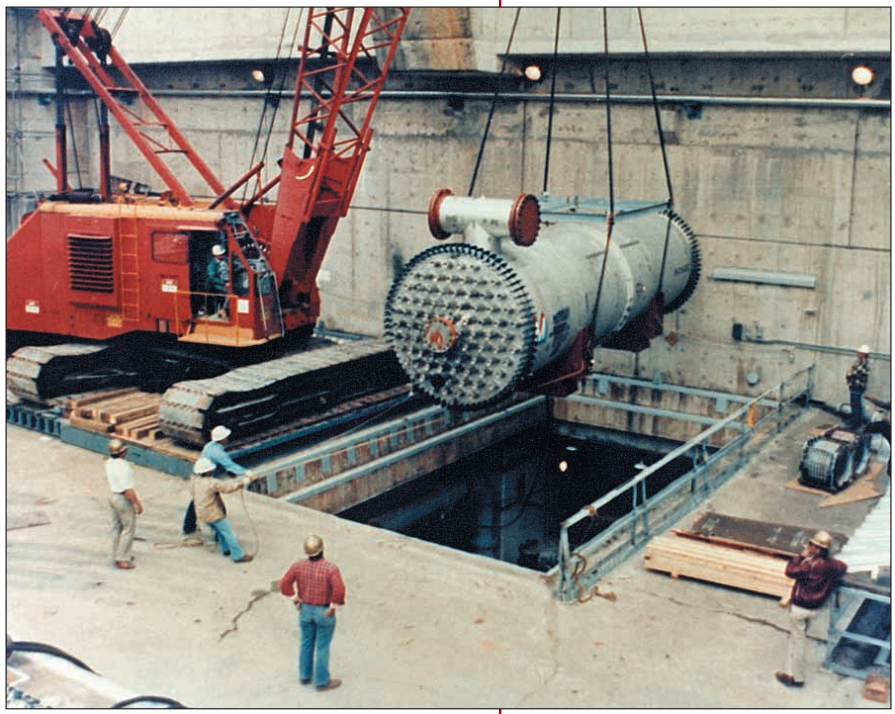
Cut away and photograph of Nuclear Test Gauge, 1960. (Drawing) Source: Thomas F. Parkinson and Norman P. Baumann, "The Nuclear Test Gage," *Proceedings of the Symposium Fifty Years of Excellence in Science and Engineering at the Savannah River Site*, WSRC-MS-2000-00061. Courtesy of SRS Archives, negative 6986-2.

WATER COOLING UPGRADES

None of the preceding changes to the reactors would have been possible without equally great changes made to the cooling-water system that served the reactors. After 1955, the limits of reactor power were often established by hydraulic limitations established either by the amount of water available or by the heat of the water. From the beginning, provisions were made to transport Savannah River water to the five reactors. From headers on the river, water was pumped to the five sites through large diameter concrete pipes. Just upstream from the headers, the Clarks Hill Dam, completed shortly after Savannah River Plant construction began, not only eliminated some of the fluctuation in seasonal river-water temperature, but also lowered that temperature by an average of 3.2º C.[107]

Shortly after the reactors went critical, there were changes to the reactors to improve the water flow. In April 1956, "tailored flow zoning" was used to better control the heavy-water flow from the plenum to the fuel assemblies. About the same time, the septifoils were first perforated to distribute the heavy-water coolant more effectively.[108]

An even greater change took place between March and June 1956. Six additional heat exchangers were installed in each of the R, P, L, and K reactors. These were installed in series, since series piping was already in place for the original six heat exchangers. This brought the total number of heat exchangers to 12 in each of the five reactors. (The 12 original heat exchangers in C were set up in parallel from the beginning.) In addition, larger pump impellers were installed in each reactor area to help the light-water cooling pumps overcome the greater flow resistance created by the additional heat exchangers.[109]



Heat exchanger upgrade orchestrated by Traffic and Transportation personnel. Courtesy of SRS Archives, negative DPSPF-50954.

Beginning in 1956 at C Reactor, and completed in 1958, the original Byron–Jackson pumps in each reactor building were replaced with new lower-head, higher-capacity Bingham-process water pumps. As part of this replacement process, the heat exchangers in the L, K, R, and P reactors were changed from series to parallel for additional power. The process-water piping was also improved with larger-diameter pipes.[110] These alterations to the cooling flow increased process-water flow by 75 percent, and cooling-water flow by 70 percent.[111]

These changes led to the construction of Par Pond. Named for the two reactors it served, P and R, Par Pond was a 2,600–acre reservoir on Lower Three-Runs Creek. The use of a reservoir was investigated as early as 1956 at a number of different locations,[112] and Par Pond was constructed in 1958 and was ready for service by the end of that same

year. The reservoir took the effluent flow from both P and R reactors, and also allowed water to be recycled for cooling. Since P and R reactors were the farthest from the river, this cut the amount of flow that had to be pumped to those sites, allowing more river water for the other three.[113]

By the early 1960s, the successive power increases and chloride stress corrosion had taken a toll on the reactors, despite improvements to the water coolant system. "Diapers," or large plastic bags, were used around the heat exchangers after January 1961 to collect valuable heavy water that was beginning to leak from the heat exchangers. This led to improvements in the heat exchanger seals.[114] By 1962, high reactor-power levels led to a totally unexpected problem: corrosion in the stainless steel reactor tanks.[115] In 1963, four heat exchangers failed and leaked process heavy water into the Savannah River. This led to a new type of closure installed in the replacements; the other heat exchangers were replaced by the end of 1966. One of the last projects to help upgrade power levels in the reactors was an increase in the helium-blanket gas pressure, from slightly above atmospheric pressure, to five psig. Much like a pressure cooker, this allowed the reactors to operate at higher levels



Par Pond Pump House, 1978. Courtesy of SRS Archives, negative 27375-8.



View of Par Pond. Its name derives from its geographic location between P and R areas at the headwaters of Lower Three Runs Creek. The 2,600-acre lake was completed by 1958. Courtesy of SRS Archives.

All of the cooling water effluent from P reactor went into the pond where it was cooled by evaporation. Water from Par Pond was pumped to R and P reactors, replacing some of the water that had been pumped to them from the river, allowing more river water for L, K, and C reactors. Bebbington notes that Par Pond allowed an increase in the total flow of cooling water from 650,000 to 775,000 gallons per minute. This translated into a gain of 850 megawatts in the overall power output of Savannah River's reactors. A 1960 upgrade to the river pumphouses and the addition of three pumps at Par Pond played a critical role in C reactor reaching a peak power level of 2,525 megawatts in 1961. Source: William P. Bebbington, *History of DuPont at the Savannah River Plant*. (Wilmington, Delaware: E. I. du Pont de Nemours & Co., 1990), 68-69.

without boiling. The increase in helium gas was undertaken between 1962 and early 1964.[116]

REACTOR SAFETY

As power levels increased in the late 1950s and early 1960s, there was increasing attention to reactor safety, an issue taken seriously by both Du Pont and the Atomic Energy Commission. By 1956–57, safety and the problems associated with radioactive waste became subjects for an AEC major activities report.[117] By this time, it was fully recognized that radiation was not only potentially dangerous, but was particularly harmful to genetic materials.[118] At Savannah River Plant, the Health Physics Department was established to monitor radiation levels.[119]

Heightened AEC concerns about the dangers of radiation dovetailed with the already well-established safety culture long fostered by Du Pont. For the vast majority of Du Pont employees who worked at Savannah River, the company's safety culture was a reality, not just company propaganda. As any former Du Pont employee could tell you, "safety was a condition of employment." Anyone who deliberately disregarded the safety rules was summarily dismissed. One of the company's many operating safeguards was a policy that "no operation shall be performed without a detailed written procedure that has been reviewed and approved by a Technical Organization other than the group responsible for the operation."[120]

During the 1950s and 1960s, Du Pont's industrial safety procedures were highlighted and popularized in weekly safety meetings during which safety films were shown to all employees. Of the almost 200 old 16-mm films found in the basement of Building 777-10A during the course of this research, an estimated 85 percent are safety films covering a wide array of general issues, from "lock and tag" procedures to emergency procedures in case of reactor incident. This attention to safety issues is indicated in the statistics. According to the AEC radiation report, there was only one incident of radiation exposure at Savannah River Plant up to 1957, the date of the report, and this was relatively minor: one operator inhaled seven rads of radioactive gas on June 16, 1956. Savannah River's record of safety accidents was far lower than those of other AEC facilities.[121]

With higher power levels, however, Savannah River began to accumulate "reactor incidents," all duly noted in Du Pont reports sent to the AEC. The first serious incident, on November 6–8, 1957, occurred when the cladding of an irradiated zirconium-clad Mark V fuel assembly failed while being heated in an underwater calorimeter in the R-Area Disassembly Basin. Between 5 and 20 pounds of uranium reacted with the emergency-basin water before the element could be cooled. A program had to be developed to dispose of the failed material.[122] As a result of this incident, the Spent Fuel Storage Pool water was purged to the first of six unlined earthen basins, or seepage basins, in the vicinity of R Reactor. The following year, this basin was retired and filled.[123]

On January 3, 1958, in what was later considered the second-worst incident to have occurred at Savannah River Plant, C Reactor went critical before the safety rods could be completely withdrawn. To remedy the situation, the safety rods were re-inserted, as were the partial-length control rods. This incident led to a change in reactor startup procedures. At the time of the incident, it was customary to withdraw all safety rods simultaneously in

small increments to start a reaction. Afterwards, no more than six rods were withdrawn at a time.[124]

The worst Savannah River Plant incident occurred on January 12, 1960, at L Reactor. In an attempt to override an episode of xenon poisoning, the operating staff violated various procedures, leading to a dangerous power rise that exceeded the established limit by a factor of ten. By the time the situation was corrected, only 40 seconds remained before boiling would have occurred in the reactor assemblies. This incident led to the overhaul and simplification of start-up procedures.[125] The following year saw the largest release of radioactive materials ever reported at Savannah River Plant, when 153 curies of radioiodine were released between May 30 and June 3, 1961. It should be noted, however, that this release occurred in Separations, not in one of the reactor areas.[126]



One-piece plastic suit designed for use in a tritiated environment. Courtesy of SRS Archives, negative DPSPF 4038-1.

It is important to remember that these were incidents rather than accidents. So far as is known, no one was injured in any of the Savannah River reactor incidents. This was not the case at some other nuclear facilities during this same period. One of the first major accidents of the nuclear age occurred at the Windscale Pile No. 1 in Britain on October 7, 1957. At that time, the graphite moderator caught fire when the reactor was restarted, releasing radioactive material into the atmosphere.[127] Closer to home, the Arco reactor accident in Idaho in January, 1961, led to improvements in rescue operations, and the use of more effective protective equipment.[128]

All of these events led to almost constant improvements in the operation and control procedures employed at Savannah River. Alterations and improvements were made to reactor control and safety systems almost as soon as the reactors went critical. In May 1955, the neutron source for checking instruments before startup was changed from polonium–beryllium to a permanent regenerative antimony–beryllium source rod.[129] That same year, and virtually throughout the life of the reactors, there were alterations to the emergency cooling system (ECS) provided for each reactor. ECS was a safety provision for cooling the reactors with light water in the case of heavy-water coolant loss.[130] The presence of moderator hot spots within the reactor tank led to an improved detection device known as the gamma monitor, created by Marvin Brinn around 1957–1958.[131]

Another major improvement made in the first years of operation was installation of the Supplementary Safety System (SSS). First introduced in 1957 and perfected in subsequent years, the SSS provided backup to the control rod and safety rod systems. The SSS replaced the original, manually-operated "moderator dump system," which proved too slow for shutting down the reactors. An integral part of the SSS was gadolinium nitrate, a strong neutron absorber that would be injected into the reactor moderator through six outlets near the center of the reactor core. Gadolinium nitrate became known as the "third" reactor safety device, after the control and safety rods.[132]

A persistent problem aggravated by the rise of reactor power levels was the release of very small amounts of radioactive materials from the reactors into the surrounding environment. The first and perhaps the greatest operational hazard was the problem with tritium gas, inadvertently produced when deuterium molecules in the moderator captured stray neutrons. Whenever the heavy water system had to be opened for maintenance or repair work, this tritiated heavy water created a radioactive water vapor that could be

absorbed by the body through the lungs and the skin. To counter this problem, special masks and suits were designed and used after 1956.[133]

In the early 1950s, when the Savannah River reactors were built, there was no containment or confinement system designed for production reactors. The large buffer area allowed for each reactor was considered adequate protection, and there was a certain willingness to tolerate low levels of radiation. As a result, the original reactor ventilation systems had no real filtration devices.[134] In 1958, the AEC Advisory Committee on Reactor Safeguards (ACRS) conducted a review of the Savannah River reactors, and concluded that "the buildings in which the Savannah River reactors are housed do not possess any significant containment features…. In the event of a serious accident that would breach the reactor tank and shield, the building shell in itself could not be expected to provide a third line of defense." This conclusion led to the first proposals for partial containment of the reactor facilities, beginning with exhaust-air filtration. In the years to follow, but especially in the 1960s, confinement remedial measures were implemented to augment the original safety features of the Savannah River reactors.[135]

PRODUCTION FIGURES, 1955–1964

Between 1955 and 1964, Savannah River Plant produced approximately half of the nation's plutonium and the majority of its tritium. The actual amounts of both are still classified, but some relative estimation of those amounts can be surmised from the number of reactor loads or "cycles" produced by each reactor over the course of a year. A cycle is a single load from an individual reactor. (A sub-cycle is where the targets are changed, but not the fuel). Each cycle is numbered consecutively by reactor, so that in R Reactor, for example, the first cycles would be R-1, R-2, etc. For security reasons, the cycle numbering would periodically start over again, but never according to any set schedule.[136]

During fiscal year July 1954–June 1955, 14 production loads were brought to the reactor areas, and 7 were discharged to Separations. Reactor downtime between loads was reduced from an average of 22 days to 6, and the time to discharge a full load went from 6 to 3 days. The following fiscal year, 1955–56, 42 production loads were discharged, a huge increase in the amount of nuclear material shipped to Separations. Since Savannah River switched to calendar-year accounting in 1957, the last half of 1956 stood alone as a production period: during this time, 27 reactor loads were discharged. In calendar year 1957, 31 reactor loads were discharged. Out of the 21 natural uranium fuel loads for the production of plutonium, 10 were long-exposure loads. This was the first year that tritium became a major product at Savannah River as a result of using Mark VIII and VI assemblies in reactors L, C, and K.[137]

In 1958, 27 reactor loads were discharged, with production about evenly split between plutonium and tritium. The plutonium was produced with Mark VII and Mark VII-A charges in reactors R and P. Tritium was produced with Mark VI charges in reactors L, K, and C. The gross increases in reactor power were essentially complete by the end of 1958, with all five reactors operating at close to their hydraulic limits. This entailed the use of Mark VIs and the new Mark VII-A charges in conjunction with the Bingham pumps. By the end of the year, Par Pond had been completed and was put into service, providing extra capacity for P and R reactors. Increased radiation levels within the reactors themselves

meant a build-up of ambient tritium: 30 percent of all jobs in the process areas now required plastic suits and masks.[138]

In 1959, 30 reactor cycles were completed. Plutonium was produced using Mark VII-A charges; tritium production was produced in K, L, and C reactors. Area radiation levels were almost double those of the previous year, due to longer exposure cycles and the increased incidence of fuel-element failures. The following year, 1960, saw the completion of 26 reactor cycles; as in the previous year, most of the reactor loads were plutonium.[139]

In 1961, 27 reactor cycles were completed. Again, plutonium and tritium were the main products. Plutonium was made using Mark VII-A charges in R, P, K, and C reactors; tritium was made using Mark VI-J in L, K, and C. In addition to the main products, small amounts of cobalt and transplutonium elements were irradiated for Oak Ridge National Laboratory and other institutions. Radiation in the process areas remained at about the same levels as in the previous year.[140]

Twenty-five reactor cycles were completed in 1962. Plutonium was produced in Mark VII-A charges and Mark V-B charges in R, P, L, K, and C reactors. The production of tritium was limited to Mark VI-J charges and Mark VI-B charge. Small amounts of other elements were also produced, such as americium-243, curium-244, and uranium-233. Reactor startup procedures were overhauled, with one simplified method replacing what had been four separate procedures. Another 25 cycles were completed in 1963.[141]

(Below) Sources: U.S. Atomic Energy Commission, *Fourteenth Semiannual Report of the Atomic Energy Commission, July 1953*, 18; U.S. Department of Energy, *Plutonium: The First 50 Years*. United States Plutonium Production, Acquisition, and Utilization from 1944 to 1994, 16-17; U.S. Department of Energy, Hanford Site, Washington, 2-9; U.S. Atomic Energy Commission, *20 Years of Nuclear Progress: Background Material*, 14; U.S. Atomic Energy Commission, *Seventeenth Semiannual Report of the Atomic Energy Commission, January 1955*, vii; and Arthur Kemp, *The Role of Government in Developing Peaceful Uses of Atomic Energy* (Washington, DC: American Enterprise Association, Inc., 1956), 20-21.

Peaceful Use of the Atom and the Atomic Energy Act, 1953–1954

Despite the Oppenheimer ordeal and the massive growth of nuclear arms, attention was also paid to the peaceful use of atomic power, especially in the years after 1953. In that year, Joseph Stalin died, and the end of the Korean conflict soon followed. Before the year was out, the AEC had declared that the development of economic nuclear power should be a national objective.

This was supported by President Eisenhower, who made his "Atoms for Peace" speech before the United Nations on December 8, 1953. In the speech, Eisenhower proposed the diversion of nuclear materials from weapons production to the more peaceful uses inherent in power reactors. He also proposed an international organization that would serve as a "world bank" of fissionable materials that could be drawn upon for the peaceful use of the atom. In the months that followed, the Atoms for Peace initiative led to a number of changes. Work began on organizing an international atomic energy agency under the auspices of the U.N. The AEC went forward with its plans for power reactors and even dual reactors that produced nuclear materials for weapons and also provided electricity. Perhaps most importantly, steps were taken to draft a new atomic bill in Congress that would legally permit the establishment of civilian reactors.

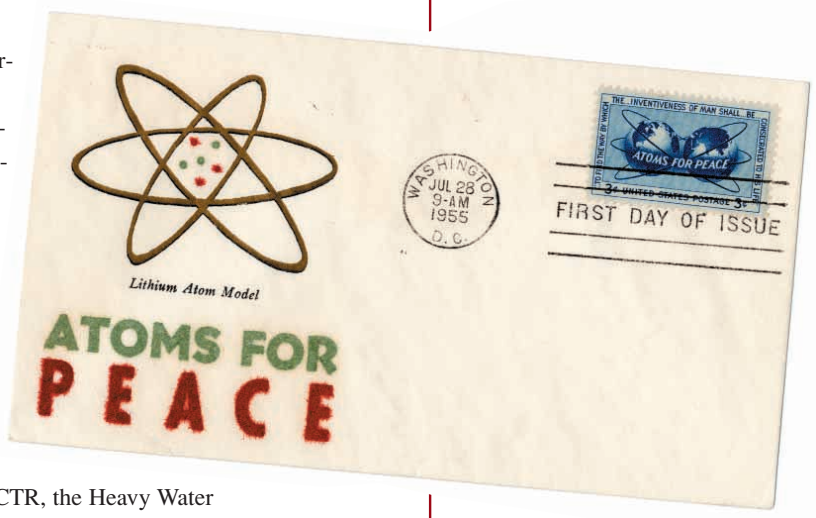
The Atomic Energy Act of 1954, the first major revision of the 1946 act, passed Congress on August 17, and was signed into law by Eisenhower before the end of the month. Even though the act affirmed that the paramount objective of the AEC was still the production of nuclear weapons for national defense, it also clearly spelled out the importance of peaceful uses of the atom. This began the slow shift from nuclear reactors used solely for production to reactors used for generating electric power.

This shift was highlighted by the United Nations Conference on Peaceful Uses of Atomic Energy, held in Geneva in August 1955. This gathering of 1400 scientists, including those from the Soviet Union, took much previously secret nuclear information and made it public record. This material was then synthesized in the "Geneva Series on Peaceful Uses of Atomic Energy." The conference also led to the International Atomic Energy Agency, established two years later.

The end of an era came in 1964. In January, President Johnson's first State of the Union message announced the reduction of nuclear materials production as part of a proposed slowdown of the arms race. This announcement was followed by an AEC letter, dated January 22, requesting that R Reactor be removed from service within six months. R Reactor, which already had several leaks, was shut down on June 17, 1964.[142] The reactor, however, did not go down without one last fight. On April 22, 1964, during the initial operations to reduce power in preparation for shutdown, an unexpected power increase occurred over a period of 2.5 minutes. This reactor incident was later deemed the third worst in the history of the Savannah River Plant reactors.[143]

AUXILIARY RESEARCH AND THE BEGINNING OF CIVILIAN USES FOR REACTORS

Long before 1954, when the new atomic law went into effect, the AEC had been interested in atomic power for civilian use, specifically for generating electricity. After 1954, this program really went into operation as the government pushed reactor technology out into the marketplace and encouraged private utility companies to embrace the new field. Up to this point, however, the main thrust of the AEC had been production reactors. Despite the various types of reactors designed at Argonne, the only large-performance power reactors had been perfected by the Navy for its nuclear submarines, and it was this technology that civilian reactors adopted. The AEC still sought to influence the development of civilian power reactors, and this led to the development and testing of HWCTR, the Heavy Water Components Test Reactor at Savannah River. Long before HWCTR, however, one of the production reactors at Savannah River was employed to discover subatomic particles known as neutrinos.



Commemorative stamp and postage envelope on first day of issue, July 28, 1955, for AEC's Atoms for Peace program launched in support of the development of atomic energy for peaceful applications.

SEARCH FOR NEUTRINOS, 1955–1956

When an isotope contains too many neutrons or protons for its own stability, those extra components will combine or change in such a way as to give off energy as well as small nuclear particles. Alpha and beta particles, as well as gamma rays, are the result of this process, but smaller particles are also released. Among the more elusive of these smaller particles is the neutrino.[144]

Named for Fermi's "little neutrons," neutrinos are very small components of the neutron–proton structure, associated with beta decay where an electron is emitted. In the early 1950s, it was known that "the difference in energy between the value of the emitted electron and the original neutron (if the neutron is altered to a proton) is not equal to [the]

known quantities [that are] present. To account for the very small difference, it was thought that another particle exists in the neutron-proton structure which is called a 'neutrino.'"[145]

The neutrino was difficult to find. It carried no charge and its mass was estimated to be two percent of the mass of an electron—so small as to be virtually undetectable. Once released, it was not attracted to matter. It was estimated that it could travel 300,000 miles through air before striking a nucleus. Once formed in a reaction, neutrinos could escape the earth without interference or detection.[146]



Dr. Clyde L. Cowan, Jr., left, and Dr. Frederick Reines, leaders of the Los Alamos Scientific team that confirmed the existence of the neutrino at Savannah River's 105-P reactor, December 1955. A plaque commemorating P reactor's role in this historic event was hung in the reactor building. Courtesy of SRS Archives, negative 3016.

As early as 1952, the AEC sponsored studies of the nucleus that would eventually lead to the search for neutrinos.[147] The existence of neutrinos helped explain a certain energy loss during nuclear reactions, but the discovery of this particle eluded the first researchers. In 1953, attempts to detect the particle near a large pile at Hanford did not prove successful. That same year, it was proposed to set up another attempt at Savannah River.[148]

As early as 1954, neutrino research was coordinated by Frederick Reines, a researcher at the Los Alamos Scientific Laboratory.[149] The following year, this research was transferred to Savannah River, where facilities in the P Reactor Area were made available to a research team headed up by Reines and C. L. Cowan. That year, they came to Savannah River with a huge electronics van and scintillator storage trailer, along with several van-loads of equipment.[150] In June 1956, Reines and Cowan announced the discovery and identification of the first free neutrinos, an achievement commemorated by a plaque at Building 105-P.[151] Reines and Cowan would later win the Nobel Prize for this achievement. Their research continued under the sponsorship of the University of California at Irvine until reactor shutdown in 1988.

DEVELOPMENT OF POWER REACTORS

As early as 1953, the Atomic Energy Commission had developed a policy on the importance of power reactors to the nation's future economy.[152] This policy went forward with no holds barred in the wake of the Atomic Energy Act of 1954. The AEC Division of Civilian Application was formed in 1955 to license commercial reactors[153] and Argonne National Laboratory, the AEC's bastion of reactor research, came into its own. In the 1950s, and in the peak years of the 1960s, Argonne would design and build dozens of different power reactors for use in the commercial market. Until 1956, when he retired from Argonne National Laboratory, all of this was done under the direction of Walter Zinn, who is often referred to as the Father of the Peaceful Use of the Atom.[154]

BREEDER REACTORS AND THORIUM RESEARCH

Ever since at least the 1940s, Zinn showed a preference for the breeder reactor as most promising for power production.[155] In theory, breeders should be able to produce electrical power while simultaneously irradiating a fertile material to produce a fissionable material, which could later be used to produce more power. In this fashion, the world's supply of fissionable material could be increased ten-, maybe a hundredfold. In the 1940s, when the known supply of fissionable material was very limited, the breeder reactor was not only an attractive idea, it was considered essential to the success of any potential civilian power program.

The basic idea behind breeder reactors was the production of enough extra neutrons in a power reactor to turn fertile material, also present in the reactor, into fissionable material, which could later be used as fuel. In a breeder reactor, the average number of neutrons given off by the fission of one atom had to be greater than two: one to keep the fission process going to produce power, and at least one more to "breed," or turn fertile materials into fissionable materials. Since some neutrons are always lost to the moderator or to the surrounding area, the number of neutrons provided by each fissioning atom had to be more than two.[156]

Zinn designed the first experimental breeder reactor at Argonne's Met Lab in 1944.[157] As early as 1951, work was done on the Experimental Breeder Reactor No. 1 or EBR-1, at Argonne's Reactor Testing Station in Idaho. Designed by Zinn, EBR-1 was the first functioning nuclear power plant in the United States, capable of irradiating uranium-238 to make plutonium-239.[158] Even though it only powered a few light bulbs in Arco, Idaho, by the end of that year, it marked the beginning of the nuclear power industry. It also demonstrated that nuclear breeding was possible.[159] The EBR used enriched uranium as a fuel, with a blanket of natural uranium around the core as fertile material. The plan was to breed new fuel, plutonium, faster than the old fuel was consumed in generating power. Since the fission of uranium-235 created 2.5 neutrons per thermal neutron fission, and since only one of those neutrons was needed to maintain a fission chain reaction in other uranium-235 atoms, the other 1.5 neutrons could be used to make atoms of fuel.[160] By 1953, if not before, the EBR had demonstrated that plutonium could be made in amounts equal to or greater than the uranium fuel consumed.[161]

After a period of experimentation, it was soon established that there were only two practical breeder systems. The first used plutonium-239 as the fuel, and uranium-238 as the fertile material, in order to make plutonium-239. The second used uranium-233 as the fissionable material, and thorium-232 as the fertile material, to create more uranium-233.[162] Each system had its advantages. The most efficient breeders were fast-neutron reactors that used plutonium-239 or even -241 as the fissionable material. Fast-neutron reactors had neutrons that traveled at their fission speed, around 30 to 40 million miles per hour. They also required relatively small amounts of moderator.

The thorium–uranium-233 system was less effective, but it had the advantage of using materials not needed by the military, and it was a type of breeding that could be done in slow-neutron, or thermal-neutron, reactors. In these reactors, the neutrons have been slowed by the moderator until they travel at about the same speed as the atoms of the moderator: around 5,000 to 10,000 miles per hour. All World War II-era reactors were thermal-neutron reactors; the first fast-neutron reactor in the world was not built until 1946 at

Los Alamos.[163] In the 1940s, when uranium was still quite rare, the thorium breeder reactor was thought to be the key to an economically viable power reactor for civilian use. In the case of a thorium reactor, the uranium-235 fuel was surrounded by a blanket of thorium metal (thorium-232), which could be irradiated to create uranium-233, a fissionable isotope. In this fashion, uranium and the much more common thorium could be made to undergo fission to generate electric power.[164]

Du Pont and the Savannah River Plant were involved in AEC research to develop thorium slugs as early as 1951.[165] Some of the first slugs supplied to Savannah River were thorium; there were around 80 such slugs at Savannah River by the end of the 1952.[166] Some of the first irradiations planned for Savannah River were for thorium, with the irradiated material to be processed at Oak Ridge.[167] The initial designs for the Savannah River reactors took into consideration the possibility of thorium irradiation.[168] Since the reactors were created to produce plutonium and tritium at a time of national emergency, the consideration of thorium at such an early date indicates just how important this program was thought to be.

Despite this initial interest, the Savannah River reactors did not begin any serious thorium irradiation until 1955, as part of Eisenhower's Atoms for Peace program. At that time, the Mark II, a thorium target slug, went into production.[169] This was followed by the first production of uranium-233 in 1955–56.[170] Uranium-233 was produced intermittently at Savannah River for the next 15 years.[171]

Despite this attention at both Savannah River and at Argonne, thorium breeder reactors did not really establish themselves in the 1950s, or afterwards. After 1955, the demand for thorium within the AEC research centers was so low that no new contracts were signed for the material for the next two years.[172] As it turned out, the thorium breeder reactors were never put into use, in large part because the supply of natural uranium turned out to be much greater than was imagined in the late 1940s and early 1950s. This simple fact also put the brake on breeder reactors that produced plutonium, which was thought to be a potential fuel for power reactors as late as 1976.[173] Throughout the 1950s, 1960s, and beyond, power reactors, just like production reactors, would rely on uranium fuel.

OTHER AEC POWER REACTOR RESEARCH

A reliance on uranium fuel did not put a damper on power-reactor research. In 1956, the AEC announced a Five Year Civilian Power Reactor Development program, which was an outgrowth of the various reactor programs pursued by Argonne in the early 1950s.[174] This program was designed to test five experimental reactors for use as civilian power reactors. Listed below, they were:

Reactor type	***Moderator***	***Fuel***
Pressurized water	light water	slightly enriched uranium
Boiling water	light water	natural and highly enriched uranium
Sodium graphite	sodium	slightly enriched uranium
Fast breeder	sodium	uranium–plutonium alloy
Homogenous	heavy water	highly enriched uranium in UO_2SO_4 solution.[175]

Out of these five, the main reactor types were quickly determined to be the water-moderated reactors, namely the pressurized- and boiling-water reactors.[176] One of the first boiling-water reactors, Borax III, was used to provide electricity to the town of Arco, Idaho, in July 1955. At that time, Arco became the first town in the United States to receive electricity generated by a reactor.[177] Even though it did not turn out to be economically viable, the Homogenous Reactor, also known as the Circulating Fuel Reactor, contained the fuel, target, and moderator all mixed together in a single solution. It was designed to save on fuel-element fabrication and much of the chemical processing that followed.[178]

The rising interest in power reactors led to the development of the first dual-purpose reactors, or reactors that served for both production and power. N Reactor at Hanford was a case in point. Designed as early as 1957, with construction beginning two years later, N Reactor began producing plutonium in 1964, and began providing electricity two years after that.[179]



Nuclear-Powered naval submarine training off the U.S. coast. Courtesy of SRS History Project.

U.S. NAVY'S POWER REACTOR PROGRAM

The greatest influence on the development of civilian power reactors, however, did not come from any of these AEC programs, but from the Navy's nuclear propulsion program that was already under way before the end of World War II. By the late 1940s, Hyman Rickover was in charge of this program and he pushed it relentlessly.[180] A student of nuclear technology at Oak Ridge, Rickover began designing nuclear reactors to power submarines and surface ships.[181] Part of the early submarine propulsion program was the construction of a small demonstration pressurized-water reactor or PWR.[182] This led to the Submarine Thermal Reactor (STR) and the Submarine Intermediate Reactor (SIR).[183] In 1951 came the construction of a land-based prototype of the reactor that would later go into the *USS Nautilus*.[184] The *Nautilus*, the first U.S. nuclear submarine, had its keel laid

in 1952 and was launched in January 1954.[185] It was followed the next year by the *USS Seawolf*.[186] Other subs and ships followed, until, in the early 1960s, the *Savannah* was launched as the world's first nuclear-powered merchant ship.

Although Rickover had an early interest in the thorium breeder reactor program, non-breeding pressurized-water reactors became the norm in the Navy's nuclear propulsion program.[187] It was this type of reactor that was used in the first civilian power reactor built in this country, and it became the norm for civilian reactors in the years that followed. When the first civilian power reactor was constructed at Shippingport, Pennsylvania, with Rickover's assistance, it was a pressurized-water, light-water-cooled reactor.[188]

SHIPPINGPORT AND THE RISE OF CIVILIAN POWER REACTORS

The Shippingport Power Reactor had its beginnings in December 1953, when the AEC invited private industry to respond to a proposal for a civilian-controlled pressurized-water reactor. In 1954, Duquesne Light Company was selected for the project, which was to be built at Shippingport, Pennsylvania. The reactor itself was to be designed and constructed by Westinghouse, under the supervision of the AEC Naval Reactors Division. Construction began before the end of the year, and the reactor was in operation by 1957 with a generating capacity of 60,000 KW. The Shippingport reactor used pressurized water, and was known as a Pressurized Water Reactor, or PWR.[189]

Shippingport used pressurized water in a light-water-cooled reactor in large part because that technology was better developed than the other concepts.[190] The technology had been proven in use by the Navy, which had long been interested in power reactors for ship and submarine propulsion. Following the success of the Shippingport project, most of the U.S. civilian power reactors that followed likewise favored pressurized water and a light-water moderator. During the heyday of the commercial nuclear industry in the 1960s and 1970s, the vast majority of power reactors were built to use light water as both coolant and moderator. About two-thirds of these used the pressurized-water system championed by Westinghouse; the rest used the boiling-water reactors favored by General Electric.[191]

Shippingport and the use of light-water moderators were pioneering efforts that would never have been duplicated if the government had not sought to promote civilian power reactors. First, was the issue of insurance. Few private companies wanted to tackle nuclear energy without some sort of guarantee of insurance in the case of catastrophic accident. In a 1957 amendment to the Atomic Energy Act of 1954, the government agreed to provide up to $500 million to cover possible claims. As a further incentive to private industry, the AEC also agreed to provide the requisite research and development, and agreed to waive or reduce charges for fuel use.[192]

The waiving of fuel costs was a crucial factor in the development of light-water-moderated civilian reactors in the United States. Light-water-moderated reactors are more efficient than heavy-water-moderated reactors only if the fuel is enriched uranium, usually around 2 to 6 percent uranium-235. (Heavy-water reactors are needed if the fuel is to be natural uranium.) The use of enriched uranium also allowed power reactors to be smaller. All of these factors allowed light-water power reactors to be built more cheaply than their heavy-water counterparts, at least in this country.[193]

The situation was different in Canada, where the nuclear industry elected to use heavy-water-moderated power reactors. The Canadians did not have the facilities to enrich uranium, and they did not want to become dependent on the U.S. in order to obtain it. Left with natural uranium, the Canadians soon specialized in the use of heavy-water-moderated power reactors.[194]

THE HEAVY WATER COMPONENTS TEST REACTOR (HWCTR)

Even though pressurized-water, light-water-moderated reactors quickly became the norm in the burgeoning civilian nuclear industry, the AEC was loath to give up on the possibility of heavy-water-moderated power reactors. In the mid-1950s, the AEC conceived of a program to further test the possibility of heavy-water power reactors, and as these plans crystalized in the late 1950s, it was clear that Savannah River Plant, the nation's premier heavy-water production reactor site, would be ideal as the test location. All of this led to the design and construction of the Heavy Water Components Test Reactor (HWCTR), better known as "Hector," a loose rendering of the acronym.

HWCTR was the culmination of AEC plans to test the potential of a heavy-water power reactor, and to see how it compared with the more accepted light-water power reactors. Specifically, its purpose was to test new fuel elements for a heavy-water power reactor, and provide additional information on the operation and use of such a reactor.[195] When the plan was first proposed by the AEC in 1956, the hypothetical test reactor was called the Power Components Reactor (PCR), and its purpose was to test the types of fuel elements that were being developed for power-reactor use.[196] The original plan was to use

Savannah River Plant News, Vol. IX, No. 13, July 28, 1961.

Placing of 96-Ton Reactor Vessel Is Milestone in Power Study

A major step in Savannah River's nuclear power study has been reached with the placing of the reactor pressure vessel inside the Heavy Water Components Test Reactor building.

The 96-ton vessel—heart of the HWCTR—had been shipped by rail from Alameda, Calif., where it was fabricated by Pacific Coast Engineering Co.

With the installation of the vessel, the HWCTR was declared 75 per cent completed. Startup is expected to be achieved in late 1961 or early 1962.

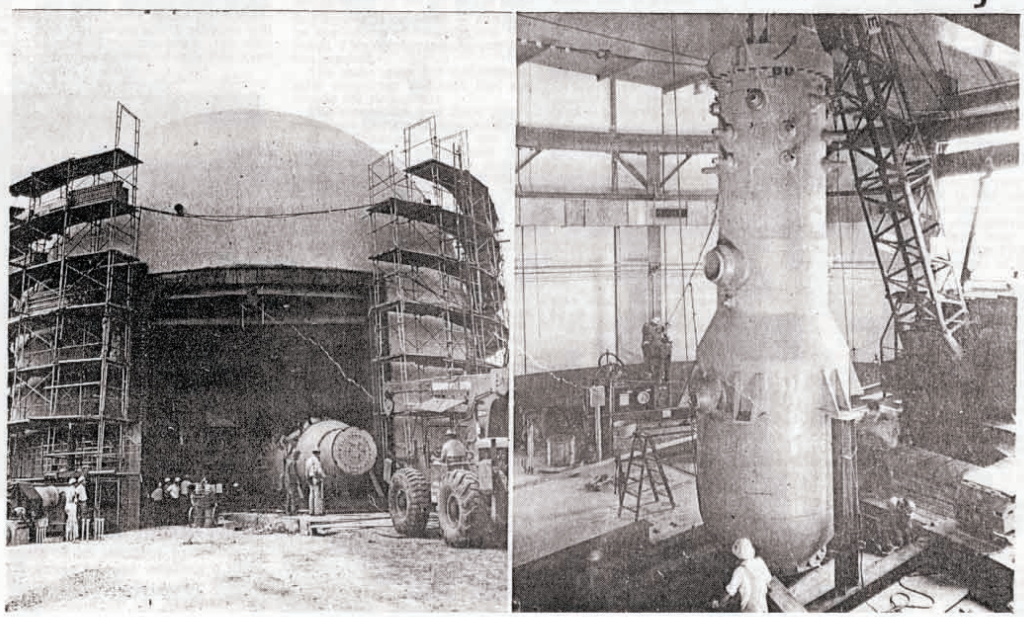
Construction of the $9,550,000 facility was begun in the spring of 1959.

The reactor vessel has an overall height of 29 feet 9 inches and a maximum outside shell diameter of 7 feet 11 inches. It was fabricated from plates of carbon steel 4-½ inches thick and all internal surfaces are clad with stainless steel to minimize corrosion. The vessel provides 12 test positions for ten-foot long natural uranium fuel elements under power reactor conditions.

The Heavy Components Test Reactor is an experimental pressurized heavy water reactor to permit testing of fuel elements and critical components as part of the studies of heavy water power reactors being conducted at the Savannah River Plant. The facilities being constructed include the reactor building, a control building, service facilities for power and water supply and service roads.

The reactor building is a containment structure 70 feet in dia-

(Continued on Page 6)



Pressure vessel is moved into containment structure, where workmen prepare to lower it into place.

natural uranium moderated with heavy water, and have a small test reactor in operation by 1962 with an electrical output of 100 MW. After early studies suggested that natural uranium reactors of such small size would not prove economical, the proposed power level was raised to 400 MW.[197]

By this time, in August 1956, the AEC had already turned over much of the work to Du Pont. Design work and construction plans were then carried out by Du Pont's Atomic Energy Division and Engineering Department, which submitted a proposal for a test program to the AEC's Savannah River Operations Office (SROO) in January 1957. In that proposal, Du Pont suggested that heavy-water power reactors could compete economically with traditional power plants and light-water power reactors only if they were larger than the 100- to 460-MW range. Plagued with high capital costs due to the use of heavy water, heavy-water power reactors would have to be large to maximize the savings on lower fuel costs. Despite this finding, Du Pont still recommended the construction of a small pilot plant at Savannah River, at a proposed cost of $15 million.[198]

In May 1957, the Savannah River Operations Office had allocated $16.5 million for the pilot plant, then still known as the Power Components Reactor. Two months later, AEC headquarters informed SROO that the allocation was too large, and that Du Pont should build a minimum-cost facility for the irradiation of heavy-water reactor fuel elements. This study was begun in August 1957. When the plans were re-submitted in early 1958, they called for a $6.4 million facility, with an additional $0.8 million allowance for heavy-water transfer charges.[199] At that time, the facility was proposed for construction in K Area, and was to irradiate 12 natural-uranium fuel assemblies with a heat output of 61 MW.[200]



Heavy Water Components Test Reactor (HWCTR), 1962. HWCTR was constructed to provide information about the operation of a projected power reactor that used heavy water as its coolant and moderator. Research at the $9 million dollar test reactor was carried out by American and Canadian scientists. On the homefront, fuel data from HWCTR was used in the operation of the Carolinas–Virginia Power Associates demonstration power reactor at Parr, near Columbia, South Carolina. Fuels for use in CANDU's large-scale reactor under construction at Douglas Point, Ontario, were tested in HWCTR. Courtesy of SRS Archives, negative 7759-2.

Additional design changes were made in the spring of 1958, the most significant of which was the addition of isolated coolant loops. It was also about this time that the name of the reactor was changed from Power Component Reactor to Heavy Water Component Test Reactor or HWCTR.[201] In November 1958, the new plans were approved by the AEC and authorized as Project S8-1086-Part I, which was folded into the larger contract between Du Pont and the AEC.[202] Almost immediately, the PDP was modified to begin study of the preliminary aspects of HWCTR.[203]

One of the last changes made was the program location. The first plans called for the test reactor to be sited in K Area, but in 1958 the AEC decided that this might compromise the security of the production reactors. The AEC requested another location, and Du Pont selected a site adjacent to Building TC-1 in the temporary construction headquarters area, now known as B Area.[204] The area around HWCTR would be designated the 700-U Area, with the reactor

building itself identified as Building 770-U.[205] According to the final scope of work issued in May 1959, reactor building 770-U would be a cylindrical structure with a hemispherical dome, 70 feet in diameter and 125 feet high. Almost half of that height, 60 feet, would be located below ground level. The building was to be gas-tight, with the pressure designed for 24 psig.[206]

Construction on HWCTR began in 1959, with Du Pont's AED serving as the primary contractor. Due to unexpected delays, the building was not completed until October 1961.[207] The reactor tank or "pressure vessel" inside the building was 30 feet high, with an inside diameter of 7 feet and a wall thickness of 4 inches. The tank could accommodate 12 large in-core test positions, up to 5 inches in diameter and 10 feet long. Maximum reactor power was pegged at about 70 MW. After a series of tests, HWCTR began power operation later in 1962.[208] During its two years of operation, Du Pont developed a computer program to help determine the range of heavy-water, power-reactor operations.[209]

The reactor was shut down in December 1964 and placed on six-month standby status.[210] It was never restarted. The operation of HWCTR led to a number of conclusions concerning the operation of heavy-water power reactors. It was determined that they worked best with the use of pressure-tube reactors, fueled with mechanically compacted tubes of slightly enriched uranium oxide. The best coolants were found to be liquid heavy water or organic liquid. It was also recommended that further design work be done on more powerful heavy-water power reactors in the 300- to 500-MW range.[211] Du Pont urged the construction of even larger heavy-water power reactors, some in the range of 3500 MW and even 8300 MW.[212] By this time, however, the AEC had largely decided to curtail its development of heavy-water-cooled and -moderated power reactors.[213]

Even though HWCTR and the heavy-water power reactors had demonstrated a good neutron economy and lower fuel costs, the savings were not enough to override the cost of the heavy water itself.[214] Besides, the civilian nuclear power industry had already shown a preference for light-water reactors, which could be constructed and operated at a lower cost. This was especially the case since the AEC supplied those reactors with enriched uranium fuel, an essential ingredient in the cost-effectiveness of light-water power reactors.[215] As a result, HWCTR had little direct impact on the civilian industry; with the exception of the Carolinas–Virginia Tube Reactor, near Columbia, South Carolina, few other private facilities in the United States chose to use heavy-water reactors.[216]

ISOTOPIC HEAT SOURCES AND THE FIRST TRANSPLUTONIUM PROGRAMS

Neutrino research and studies for civilian power reactors, were not the only non-weapons programs conducted at Savannah River during the 1950s and early 1960s. Work was also done to prepare isotopic heat sources for military outposts in the Arctic and for the space program. Work also began on the various transplutonium programs that were close to the heart of Glenn Seaborg, who became chairman of the AEC in 1961.

Developing heat sources for the military was certainly more specialized than developing civilian power reactors, but like the power-reactor work, this development dated back to the 1950s. This work began with cobalt-60, which was produced by the irradiation of

natural cobalt (cobalt-59). In May 1955, the first Savannah River Plant contract was signed for the production of cobalt-60, which was not only useful as a heat source, but also had application as a food irradiator, or sterilizer.[217] The first production program (1955–1958) made cobalt-60 with a specific activity of 50 Ci/GM. The second period of production (1959–1964) created cobalt-60 with 100 Ci/GM. The third program (1964–1967) generated material with 700 Ci/GM.[218]

Most of this cobalt-60 was used as a source of heat in isolated Arctic locations. As the DEW Line of early warning stations was established in Alaska, Canada, and Greenland in the 1950s to guard against a possible Soviet attack, cobalt-60 provided heat sources for those outposts at relatively low cost.[219] By the late 1950s and early 1960s, cobalt-60 was also used in the Food Process Development Irradiators that Curtiss–Wright manufactured for the Army.[220]

Nuclear Tests and the Rise of the Space Program, 1955–1960s

If the transition from production reactors to power reactors was slow, it was because the Cold War was hardly over. In fact, it expanded into space. The mid- to late-1950s was a time of increased nuclear testing, with detonations set off above the atmosphere in the wake of *Sputnik.*

By the mid-1950s, nuclear deterrence had become the front line of national defense. It was less costly than a large conventional force, and it dovetailed well with Dulles' policy of massive retaliation. The Soviets, of course, were not far behind. On November 22, 1955, they detonated their first two-stage, lithium-deuteride thermonuclear bomb, based on a Teller-Ulam configuration they had worked out on their own. That same year, Nikita Khrushchev consolidated his hold on the Soviet Union, and his rule was marked by a definite internal thaw, and by increased rhetorical attacks against the capitalist powers. Both the U.S. and the Soviet Union detonated many nuclear bombs.



Between 1955 and 1959, the United States detonated nuclear bombs in the course of operations Wigwam, Redwing, Plumb-bob, Teak, Orange, Argus, and Hardtack, among others. Most of these tests took place either in the Pacific Proving Grounds around Enewetak, or in Nevada.[235] Teak, however, was the first detonation in space, and it closely followed the national panic over *Sputnik*, the first satellite to orbit the earth.

Like the first Soviet A-bomb in 1949, the Soviet satellite *Sputnik* was not announced, but was quickly detected by radio in October 1957. Fearful that the nation had fallen behind the Soviets in the space race, Congress quickly passed legislation designed to catch up. *Sputnik* spurred both the U.S. space program and the rush to put nuclear bombs on rockets. The National Aeronautics and Space Administration (NASA), created in 1958, and the first Inter-Continental Ballistic Missiles.

There was an "unofficial" moratorium on atmospheric nuclear testing between 1959 and 1961, as the United States and the Soviet Union first sought ways to limit their burgeoning nuclear arsenals. During these negotiations, however, nuclear production continued unabated, as did most other kinds of military hardware. The growth of Curtis LeMay's Strategic Air Command was a case in point.

The agency that made all this possible was the Atomic Energy Commission, which, by the early 1960s, was a virtual state within a state. By the early 1960s, there were 14 production reactors—9 at Hanford and 5 at Savannah River. At the peak of production, these reactors produced around 7 tons of plutonium per year; by 1964, the U.S. alone had over 60 tons of plutonium—two-thirds of the total U.S. inventory as late as 1992. All of this was made by AEC contractors and academic employees, which comprised a work force that numbered

The rapid development of the space program in the late 1950s and early 1960s brought about an increased need for heat sources in outer space. The best heat source for the production of electricity in space proved to be plutonium-238, first produced as an isotopic heat source at Savannah River in 1958. Easily shielded, and with a relatively long half-life of 89 years, plutonium-238 proved to be a valuable asset for space exploration.[221]

The creation of plutonium-238 paved the way for the first transplutonium programs. Transplutonium Programs I and II, 1959–1963 and 1961–1964, respectively, were overlapping irradiation programs designed to make artificial elements heavier than plutonium. This included the so-called "heavy nuclides" like plutonium-242 and curium-244, which would lead up to the production of more distant isotopes like californium-252.[222] All of these elements were produced by adding one or more neutrons to the nucleus of an existing element, thereby bumping it up to a heavier isotope.[223]

Continued

around 170,000. The AEC staff, which oversaw this operation, numbered 7,000.

The greatest AEC construction costs during this period coincided with the construction of Savannah River. Both Oak Ridge and Hanford ballooned in size, as did the Argonne National Laboratory facility in Idaho. Other facilities like Rocky Flats were either created or enlarged. This wave of construction is represented by the huge increase in AEC capital investment during this period: from $1.4 billion in 1947, AEC facilities totaled almost $9 billion in 1955. During the period that followed, the late 1950s and early 1960s, most of the operating expenses went to the production of nuclear materials for the military. Out of an operating budget of $2 billion for fiscal year 1957, source materials, nuclear materials production, and weapons development and fabrication absorbed a total of $1.527 billion. Reactor development received $276 million. Other research programs got much less.

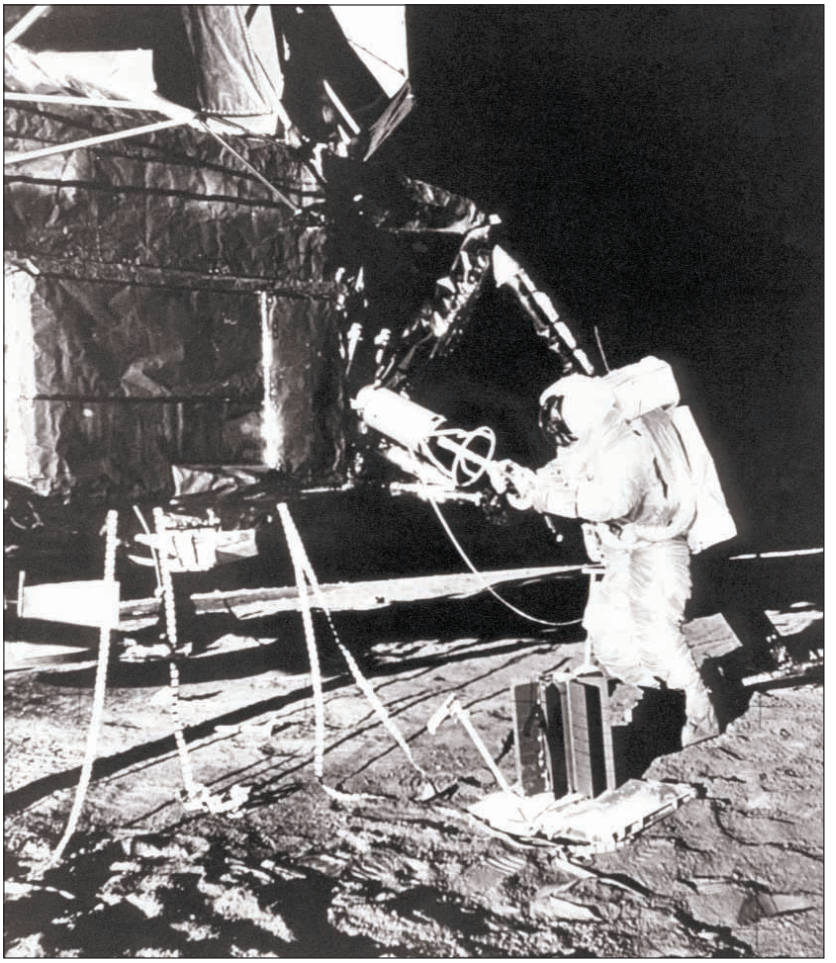
The informal moratorium on nuclear testing came to an end in 1961, shortly after the construction of the Berlin Wall. On October 30, 1961, the Soviets detonated a 57-megaton thermonuclear bomb in Siberia, the largest ever exploded by either the Soviet Union or the United States. This "monster bomb" ended the moratorium on atmospheric testing, and by 1962 the U.S. was detonating its own devices in the Pacific. All of this led to heightened tensions as the Cold War went into another warm round, this time between Khrushchev and the new American president, John Kennedy. The Cuban Missile Crisis in the fall of 1962 was in some respects the height of the Cold War, with both sides threatening massive retaliation over the issue of Soviet ground-to-ground missiles in Cuba.

In the wake of the Cuban Missile Crisis, both Kennedy and Khrushchev stepped back from the abyss. The following year, 1963, they signed the Limited Test Ban Treaty that prohibited further atmospheric testing by either the United States or the Soviet Union. Kennedy and his Secretary of Defense, Robert McNamara, had already pulled back from Dulles's policy of massive retaliation. As champions of the "flexible response," they made it a policy to entertain military responses more subtle and less threatening than that of a full-scale nuclear response. The new policy also paved the way for U.S. military involvement in Vietnam, an involvement that expanded exponentially after Kennedy's assassination in November 1963. When Johnson announced the first reduction in the production of nuclear materials in January 1964, he was only doing what Kennedy probably would have done had he still been president.

The Cold War, of course, was far from over. In 1963, the Americans and Soviets were negotiating the Limited Test Ban Treaty, and Vietnam, while not yet a major conflict, was certainly an intractable problem. On the international scene, Eisenhower's Atoms for Peace initiative had definitely stalled. David Lilienthal, describing its status in 1963, called it "still alive, but in a wheelchair." This, however, could only be applied to the international situation. Within the United States itself, Atoms for Peace took off in the late 1950s and early 1960s, and the Savannah River Site played a role in that development as well.

Sources: Lewis *et al.*, *A Systematic Study of Air Combat Command Cold War Material Culture; Volume I: Historic Context and Methodology for Assessment*, 30; U.S. Atomic Energy Commission, *Progress in Peaceful Uses of Atomic Energy July-December 1957*, 424-425; and David E. Lilienthal, "Change, Hope, and the Bomb," Stafford Little Lectures, Princeton University, February 13, 1963,11.

Transplutonium I and II represented the first involvement of Savannah River Plant in the AEC's overall transplutonium program, organized and engineered by the Transplutonium Program Committee. The first Savannah River Plant involvement began with the irradiation of plutonium-239 to make a kilogram of plutonium-242, in addition to another kilogram of mixed americium-234 and curium-244. These materials were then to be used as targets in the High Flux Isotope Reactor (HFIR), which was then only in the planning stages at Oak Ridge National Laboratory.[224]

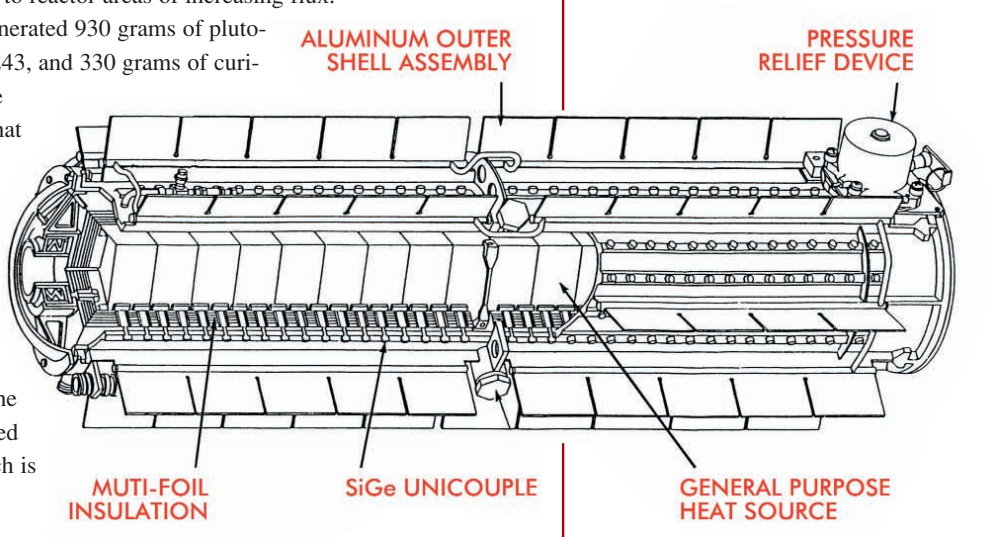


Deployment of the SNAP-27 RTG during the Apollo 12 moon mission, on November 19, 1969. Courtesy of NASA.

Plutonium-238 is the main component of the general purpose heat source that forms the central axis of the RTG. Similar generators have supplied electricity for navigation satellites at home to deep space probes that have continued to operate even after passing beyond the reaches of our solar system. The plutonium-238 usually used in the space program has typically been provided in the form of plutonium oxide, a ceramic material. This material is very stable, has a high melting point, and is chemically compatible with the material that its containers are usually made from, an iridium alloy. Source: Richard R. Furlong and Earl J. Wahlquist, "U.S. Space Missions Using Radioisotope Power Systems," *Nuclear News* 42. No. 4 (April 1999): 26.

In the early Savannah River Plant transplutonium programs, coextruded rods of plutonium–aluminum alloy, clad with aluminum, were prepared by the Metallurgy Development Division at Hanford. These rods were then irradiated for a long period at Savannah River to convert the plutonium-239 to plutonium-242, americium-243, and curium-244. This was done rather leisurely by what were called "incidental irradiations" in reactor loads primarily designed for other purposes. As the plutonium-239 was burned up, the targets were progressively moved to reactor areas of increasing flux.[225] Transplutonium Programs I and II generated 930 grams of plutonium-242, 300 grams of americium-243, and 330 grams of curium-244, laying the foundation for the much larger and longer irradiations that would follow after 1964.

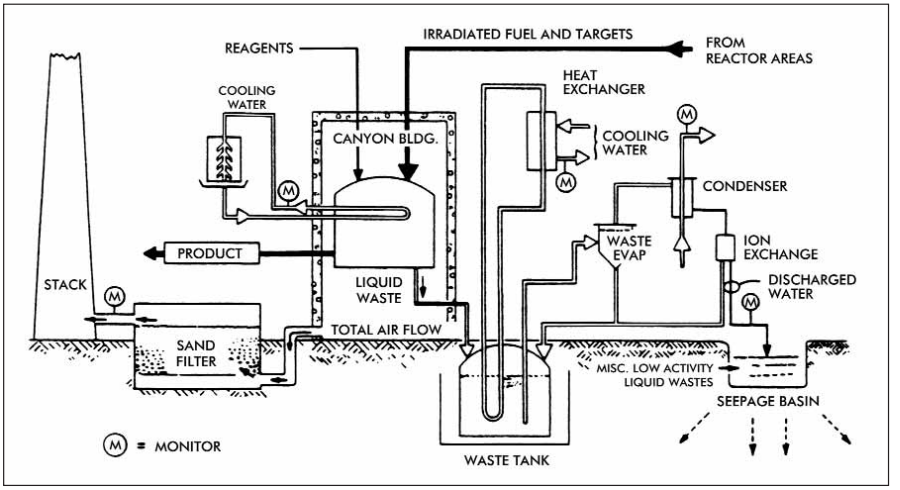
Some of these first transplutonium elements were used as heat sources, but the program later went far beyond that requirement. With the closure of R Reactor in 1964, and with a declining demand for weapons-grade nuclear materials in the years that followed, the way was paved for the transplutonium program, which is discussed in Chapter 16.



Radioisotope thermoelectric generator (RTG). The length is 44.5 in (113cm), the diameter is 16.8 in (42.7 cm), and the weight is 124 lb (56.2 kg). Source: Department of Energy.

14 Separations and Waste Management

Separations and waste were managed under the same department until the late 1970s, when a separate Waste Management department was created. Separations functions involved refining products from the reactors to meet customer specifications, while waste functions dealt with the treatment of the residue materials. Separations involved two primary operations: liquid extraction and gas extraction. Liquid extraction—used to purify plutonium, uranium, and various other elements—was housed within the enormous canyon buildings, one in the F Area and one in the H Area. In addition to the main processing facilities were the A- and B-Lines, where concentrated liquids were converted to solid forms. Gas extraction—for tritium purification—originally took place in F Area, then in H Area. By 1960, major modifications had greatly altered nearly all separations work.



Separations Process Systems. The purpose of separations was, as the term implies, to separate useful products from waste. Initially, separations activities included the storage of waste as well. This simplified diagram shows the major activities of liquid separations and waste processing. Source: *Waste Management Operations*, Document ERDA-1537 (Aiken, South Carolina: Savannah River Plant, September 1977), II-23.

THE PROBLEM OF PLUTONIUM PURIFICATION

Initial research into the separation of irradiated plutonium from uranium and fission products was headed by Glenn Seaborg at the University of Chicago's Metallurgical Laboratory during the Manhattan project. Seaborg's group developed a process for sepa-

rating plutonium by using lanthanum fluoride to bind with and precipitate the new element. Seaborg and his group also investigated ion exchange and solvent extraction, both of which were important at Savannah River.

Research at the Oak Ridge separations pilot plant and laboratories incorporated Du Pont chemists' experience and coordinated findings with Hanford and Los Alamos personnel. The work at Oak Ridge showed that bismuth phosphate was better suited to separation of plutonium from fission products, but that lanthanum fluoride was better suited to final concentration of the plutonium preparatory to conversion into metal. Problems with the bismuth phosphate process were that it did not recover uranium, which remained mixed with the process waste, and that it was slow. Although not ideal, the process was adequate for the emergency needs of wartime production, so it became the basis for the separations facilities at Hanford. However, what was suitable to meet war needs was less than ideal for the long term.[1]

Solvent extraction, as opposed to precipitation, is generally a much more efficient means of separation, and postwar investigations concentrated on this type of processing. The basic principle of solvent extraction is that certain solutions are immiscible—if mixed together then allowed to settle, the solutions will tend to separate into heavier and lighter layers, or phases. The chemistry of the phases can be adjusted so that select elements or molecules stay with one or the other phase when they separate. The process can also be operated continuously rather than in batches, as was done with precipitation. A solvent-extraction process that would separate both uranium and plutonium from fission products was developed at Argonne National Laboratory shortly after World War II. The process used an organic solution called hexone (methyl isobutyl ketone), and it was called Redox, for Reduction Oxide process. Pilot-scale development took place at Oak Ridge between 1945 and 1951, and operation of a full-scale Redox plant began at Hanford in 1952.[2]

Research toward the next improvement began in 1948 and was initially developed through about 1952. Called Purex,[3] the new process was better able to recover uranium than Redox, was more versatile, decreased fire hazards by incorporating less flammable solutions, lowered operating costs, and perhaps most importantly, reduced the amount of waste created.[4] The most important chemical in the Purex process was a compound (an organic solvent) called tri-n-butyl phosphate, also known as TBP.[5] The quality that made TBP of value was its ability to latch onto and release plutonium, uranium, and other elements with great selectivity. As related to nuclear materials processing, Purex generally referred to a countercurrent (two streams flowing in opposite directions) solvent-extraction process by which uranium and plutonium in a nitric acid phase were separated from other fission products

Genesis of the Idea

The initial concept of using TBP for plutonium separations can be attributed to Ray Fisher, who worked at Iowa State University's Ames Laboratory. In the mid- to late-1940s, Fisher attended a conference in Chicago that Warren Eister, an engineer in the Oak Ridge Chemical Technology Division, also attended. In 1992, Eister recalled a conversation the two had at the conference:

> After trying to impress Ray with our contributions to the Redox process… Fisher asked why we hadn't used tributyl phosphate (TBP) for the solvent instead of the hexone… since TBP was stable in nitric acid…. Our Chem Tech forces were devoted to Redox/hexone systems, and it was several years before TBP was seriously considered both for the recovery of uranium from the bismuth phosphate waste and for application at both Savannah River and Hanford for plutonium recovery.

Post-World War II efforts to improve plutonium purification involved, directly and indirectly, thousands of research personnel within a nationwide network of research facilities; it would thus be presumptuous to attribute the origin of a concept to a single individual or even a small group of researchers in such an environment. Charles Runion, Thomas Ellison, and Bill Lanham are noted to have been listed on the original patent for the process. Other persons may have also considered using TBP in speculative conversations. Although it may be that a conversation between Fisher and Eister marks the initial concept formation, credit for the idea should be shared between these persons and the many other scientists like them who collectively undertook the research and development efforts at the national laboratories and contractor facilities that turned the process into the important nuclear-materials processing technology used around the world today.

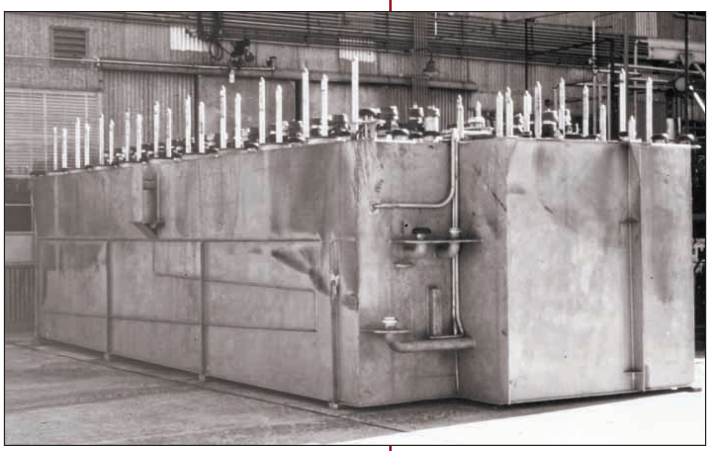
Source: R. L. Jolley, R. K. Genung, L. E. McNeese, and John E. Mrochek, compilers, *The ORNL Chemical Technology Division, 1950–1994* (Oak Ridge, Tennessee: Oak Ridge National Laboratory, October, 1994), 2–8.

and impurities by using TBP in an organic phase. The term could also be used to refer to operations that use these same chemical compounds to recover other materials, principally actinides.[6]



(Right) Savannah River Laboratory's Semiworks called TNX, 1951. Courtesy of SRS Archives, negative 6-157.

(Below) Mixer-settlers installed at Savannah River's TNX facility in 1960. Courtesy of SRS Archives, negative 6554-21.



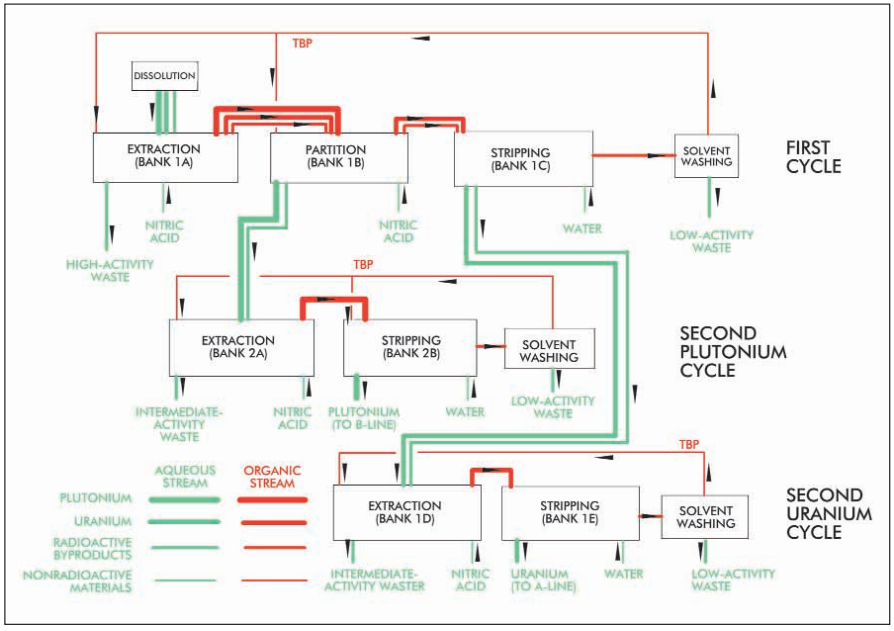
Development of the Purex process for plant-scale operations was undertaken at both Oak Ridge and Knolls Atomic Power Laboratory, and pilot facilities were operated at Oak Ridge. Although Oak Ridge was the focus of separations development at the time,[7] the Atomic Energy Commission had asked Knolls laboratory to construct an experimental facility called the Separation Process Research Unit (SPRU) to support Hanford separations process development, and this facility was used for Purex development as well. A tentative flow sheet for Purex had been worked out by October 1950, and by a year later much of the initial data needed to establish operational parameters had been provided by Knolls and Oak Ridge. To supplement data from those facilities, a semiworks facility called TNX (Building 678-G) was constructed at Savannah River. At TNX, experiments using mockups of the specific equipment to be installed at Savannah River were conducted.[8]

THE PROCESS STEPS

The initial process for plutonium and uranium separation at Savannah River involved five major steps: dissolution, head–end treatment, first–cycle, second–cycle uranium, and second–cycle plutonium. The last three steps comprised the Purex process *per se*. Most Purex plants have included head–end treatment, and dissolution is a necessary first step.[9]

Dissolution The first step in processing materials irradiated in the reactors was the conversion of the solid reactor assemblies to a liquid. Assemblies were placed in a dissolver, to which caustic solutions were added to remove the aluminum cladding. The resulting solution was transferred to the waste tanks. Nitric acid was then added to the dissolver and heated to aid dissolution of the assemblies.[10]

Head-End Treatment Not at first considered necessary, by the spring of 1951 process development research showed head-end treatment to be essential to effective Purex processing. The head-end treatment involved centrifuging the solution to remove zirconium and niobium fission products as well as solids from the solution sent from the dissolver.[11]

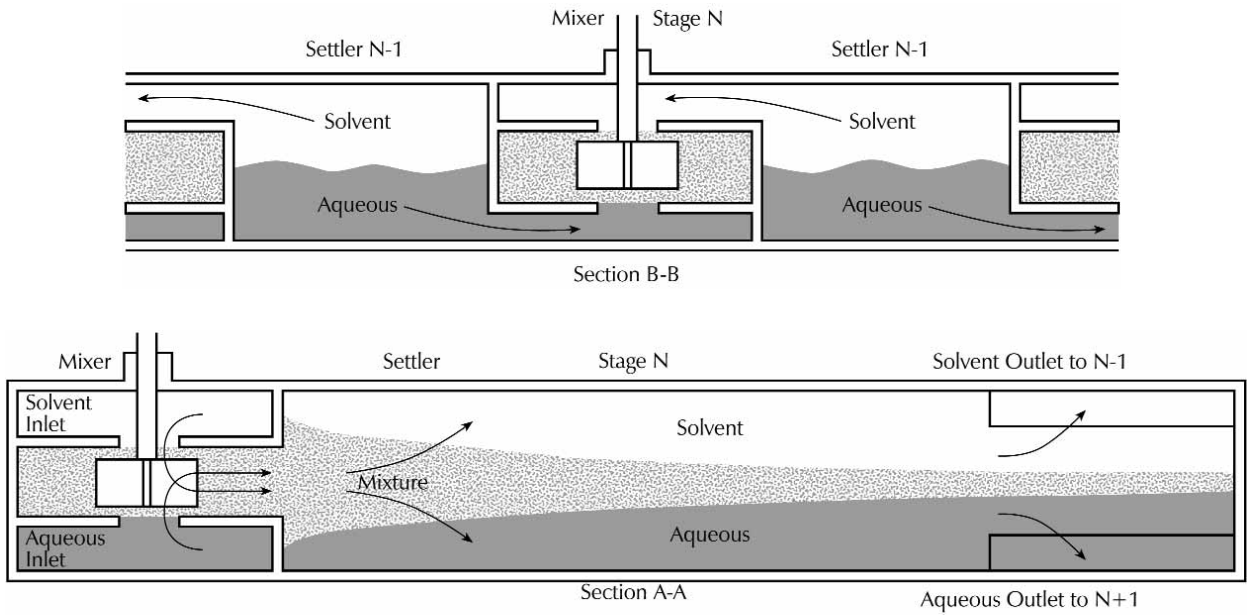


Purex incorporates three main steps: first cycle, where plutonium is separated from uranium; second–cycle plutonium, where the plutonium is purified; and second–cycle uranium, where the uranium is purified. Sources: W. P. Bebbington, The Reprocessing of Nuclear Fuels, *Scientific American* 235, no. 6 (December 1976): 32–33; J. L. Swanson, Purex Process Flowsheets, in *Applications of Tributyl Phosphate in Nuclear Fuel Reprocessing*, ed. Wallace W. Schulz, Leland L. Burger, and James D. Navratil, Science and Technology of Tributyl Phosphate, vol. 3, (Boca Raton, Florida: CRC Press, Inc., 1984), 57–59; and C. S. Schlea and A. S. Jennings, Behaviour of Actinides and Fission Products in Tri-n-butyl Phosphate and in Di-2-amyl 2-butylphosphonate Solvent Extraction Processes Using Short-residence Contactors, in *Solvent Extraction Chemistry of Metals*, ed. H. A. C. McKay, T. V. Healy, I. L. Jenkins, and A. Naylor (Toronto: Macmillan Publishing Company, Inc., 1965), 83–84.

First Cycle The Purex process began with the first cycle. In this step, uranium and plutonium were extracted from the liquid containing the fission products, then partitioned from each other for further processing. The first cycle took place in the hot canyon. The main equipment pieces were three mixer–settler banks developed by Knolls Atomic Power Laboratory and TNX.[12]

Prior to being sent to the first mixer–settler unit (Bank 1A), the solution containing plutonium and uranium was chemically adjusted to meet specifications for extraction.[13] In Bank 1A, a 16-stage mixer–settler unit, the aqueous and organic phases were brought into contact with each other to form extractable complexes with the TBP in the organic phase, then the two phases were allowed to separate, extracting the plutonium and uranium from the fission products, which stayed in the aqueous phase. The second step was performed in Bank 1B, where an adjustment of the solution chemistry and further mixing and settling caused the plutonium to be stripped from the organic phase to the aqueous but left the uranium in the aqueous, a step called "partitioning." And finally, in Bank 1C, the uranium was similarly stripped from the organic phase.[14]

Second–Cycle Plutonium The original second–cycle plutonium step used two 16-stage mixer-settlers, Banks 2A and 2B, to further purify the plutonium from the first cycle. The plutonium from the first cycle was oxidized to the tetravalent state for feed to the cycle. In Bank 2A, the plutonium was mixed into countercurrent aqueous and organic streams, where it would form complexes with the TBP and follow the organic stream, while most of the residual fission contaminants would stay with the aqueous stream. In Bank 2B, the plutonium was reduced to the trivalent state and again moved back to the aqueous phase. The aqueous stream carrying the plutonium was then sent to a holding tank, from which it was delivered to the B-Lines to be converted into metal.[15]



Line drawing of mixer-settlers. Mixer–settlers combine the aqueous and organic solutions in mixing chambers, then allow the two to separate into individual phases in settling chambers. Each pair of mixing and settling chambers is called a stage. The original mixer–settler units at Savannah River each contained 12 or 16 stages. Source: W. P. Bebbington, The Reprocessing of Nuclear Fuels, *Scientific American* 235, No. 6 (December 1976), 35.

Second–Cycle Uranium The second–cycle uranium step, which took place in Banks 1D and 1E, served a similar purpose as second–cycle plutonium, namely greater removal of fission byproducts and further extraction of any plutonium carried with the uranium through Bank 1B. The uranyl nitrate solution from Bank 1C was concentrated and adjusted as desired and fed to Bank 1D to undergo another series of mixing and settling.[16]

LIQUID TO METAL—THE B-LINE

Plutonium was converted from a liquid to a solid metallic form in a shape called a button in the canyon's B-Lines. The buttons were sent to other sites in the national weapons complex to be forged into final weapons components. The B-Lines were also known as the button lines, and some early descriptions used the term "isolation area."[17]

Du Pont personnel drew largely from experience at Los Alamos and Hanford in developing the button line process, and early descriptions of the Savannah River process closely resemble that used at Los Alamos.[18] But operations at these sites were basically at the pilot-plant scale; the Savannah River process needed to be a plant-scale, integrated means of converting plutonium to metal. Coupling, the procedure for concentrating the plutonium solution received from Purex operations and preparing it for conversion to metal, required a considerable development effort. Research for this step took place mainly at Knolls Atomic Power Laboratory and Oak Ridge.

Evaporation was the first choice for a means of concentrating the solution. But an explosion in an experimental evaporator at TNX caused the Du Pont engineers to abandon

Explosion and Change—Ion Coupling

Concentrating plutonium from the second cycle to prepare it for B-Line processing initially involved evaporating the excess nitric acid. The Blaw-Knox Construction Company designed an evaporator for experimental work in 1951, which was tested at Oak Ridge; research using a different design of evaporator was conducted at Knolls. By the end of March 1951, however, Du Pont's L. C. Peery (who was directing Du Pont work at Oak Ridge) had suggested that personnel at Oak Ridge might have a better method than evaporation—an ion–exchange process.

By mid-September, enough work had been done on the ion exchange process that it served as a definite rival to evaporation. On December 5, 1951, ion–exchange coupling was noted to have been "added to B-Line," although this may only have meant that consideration was given to installing either process or that the process would be installed later in the H Area. Oak Ridge personnel were to work on refining the process during 1952 and 1953, and evaporator research continued at TNX.



TNX explosion. Courtesy of SRS Archives, negative M-236.

On January 12, 1953, during the 4 to 12 shift, the TNX evaporator exploded. Investigation into the cause of the explosion found that distillate from the evaporator contained TBP and a kerosene-like diluent, which meant that part of the organic phase had been transferred to the evaporator with the aqueous phase from the experimental second cycle stream. Reaction of the TBP with other materials in the solution was determined to be the most likely cause of the explosion, and there was a chance that the same could happen in the canyons during plant operation.

By March 1953, sufficient data had been compiled to determine that the evaporation process was unsuitable for installation in the B-Lines, and the "[t]riple evaporation coupling process [was] eliminated from Building #221 B-Line." The coupling step would be provided by the ion-exchange process developed at Oak Ridge. Until this time, B-Line construction and equipment acquisition efforts appear to have proceeded under the assumption that evaporators would be installed. Manufacture of the evaporators was far enough along that the order could not be cancelled after the explosion, so the evaporators were received and placed in storage.

Sources: *Savannah River Plant Engineering and Design History, vol. 1, Text and Exhibits*, Document Number B-989-3-5 (Pittsburgh: Blaw-Knox Company, June 30, 1954), 140,143, and 150; R. M. Girdler, "Chicago Meeting—September 18–19, 1951, Separations Development Program," memorandum, October 3, 1951, Acc. 1957, Series IV, Box 45, Folder 7, 2, Hagley; F. S. Chambers to L. C. Peery, "Plutonium Isolation," April 5, 1951, Acc. 1957, Series IV, Box 44, Folder 5, 1, Hagley ; Girdler, "Chicago Meeting—September 18–19, 1951, Separations Development Program," 2. F. S. Chambers to Lombard Squires, "Separations Development Programs for Fiscal Year 1953," memorandum, March 24, 1952, Acc. 1957, Series IV, Box 46, Folder 1, 4, Hagley.; T. J. Colven, Jr., G. M. Nichols, and T. H. Siddall, *Interim Technical Report, TNX Evaporator Incident January 12, 1953*, Document Number DP-25 (Aiken, South Carolina: Savannah River Laboratory, May 15, 1953), 8, NTIS; *Savannah River Plant History, All Areas, August 1950 through June 1953* (Aiken, South Carolina: Savannah River Plant, ca. 1954), 5–25; and *Savannah River Plant Engineering and Design History*, vol. 3, *#200-F&H Areas*, Document Number DPE-972 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 77.

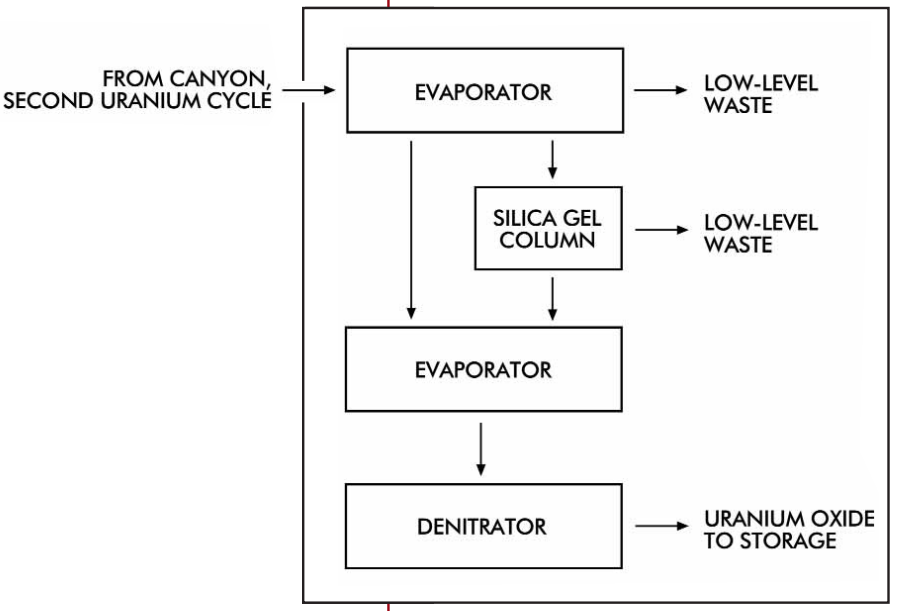
that process for a safer means of concentration under investigation at Oak Ridge, where cation exchange columns were being used. These were long tubes packed with a resin in the form of small beads that had exchangeable hydrogen ions. In dilute nitric acid, the resin beads would hold onto the positively charged plutonium, while in strong nitric acid they would release it. The plutonium from the Purex process was pumped to the fourth level of the canyon building; the valence was adjusted to provide plutonium ions that would be strongly attracted by the resin, then the solution was passed through the columns. Next, sulfuric acid was passed through the columns to remove uranium absorbed with the plutonium, then sulfamic and nitric acids were used to desorb the plutonium from the resin, giving a concentrated solution.[19]

The next B-Line steps were precipitation and filtration. In the precipitators, hydrogen peroxide was added, which reacted with the plutonium to form crystals of plutonium peroxide. After settling to the bottom of the precipitator as a sludge, the plutonium peroxide was filtered in a "filter boat" to produce a cake of plutonium peroxide. Still in the filter boat, this cake was transferred to a conveyor, the beginning of the "mechanical line."

In the mechanical line, the plutonium cake was dried by drawing air through the filter boat. The boat was then moved by conveyor to a furnace where it was heated as first air, then hydrogen fluoride and oxygen were passed through it to produce plutonium tetrafluoride. Calcium, and originally iodine, were added to the plutonium tetrafluoride at a mixing station, then the mixture was emptied into a "bomb," or pressure chamber, that contained a magnesium crucible.[20] The bomb was placed in a reduction furnace, the atmosphere in the bomb was replaced with helium, then the materials were heated to form metallic plutonium. The crucible was broken to free the button, which was cleaned, then packaged and sent to the storage vault.

Most B-Line operations were carried out in gloveboxes and cabinets. The cabinets, some nearly 50 feet in length, housed the various equipment and conveyors that transferred material from station to station. Operations that were not carried out mechanically were conducted by operators working through glove ports.[21]

The A-Line process consisted of four steps (three when the silica gel column was not needed for removal of fission products) and involved first, the concentration of uranium-containing liquid, then the conversion of the liquid to uranium oxide. Source: W. C. Perkins, W. S. Durant, and M. L. Hyder, *The Safety of UO_3 Production in the A-Line at the Savannah River Plant*, Document Number DP-1449 (Aiken, South Carolina: Savannah River Laboratory, (March 1977), 11 and 14-15.



RECYCLING URANIUM—A-LINE

The purpose of the A-Line was to process uranium-containing solution generated by the solvent extraction process for storage and reuse, either at Savannah River or at other facilities. The A-Line received uranyl nitrate solution from the second uranium cycle, then concentrated the solution and converted it into uranium oxide powder, a stable form for storage or shipment.

The solution containing uranium was sent from the canyon second-cycle uranium banks to a storage tank. From there it was fed to a continuous evaporator, which boiled off liquid (mainly water and nitric acid). If necessary, this concentrated solution was then passed through a silica-gel column to remove radioactive contaminants. The second stage of evaporation continued the process of concentrating the solution; these evaporators were more specifically called hydrate evaporators. The final stage of denitration was carried out in pot-type denitrators that could process about a ton of uranium oxide each. In the denitrators, the solution became noticeably more viscous as it was heated, eventually acquiring the consistency of dough. At this stage, the mixture had to be continuously agitated so it would not harden into one large mass. With continued agitation and removal of moisture, the dough became a powder. After cooling it was vacuumed out and then pulverized and blended, and finally packed into steel drums lined with resin for storage or shipment elsewhere.[22]

TRITIUM

The extraction and purification of tritium was an entirely different process from that used for extracting and purifying plutonium. Not only did the process involve working with gas instead of liquid, it involved working with an isotope of hydrogen, the smallest and most difficult chemical element to contain.

The tritium purification process for Savannah River can trace its origins to development work by General Electric for tritium extraction facilities at Hanford (one installed, and a second under development by November 1950), and to early experience in tritium separations at Los Alamos. The Hanford equipment setups were known as M-Lines. M-Line tritium was sent to Los Alamos for further purification in their thermal diffusion column. The tritium facility eventually installed at Savannah River combined both these steps.[23]

Development work on the process was an on-again, off-again affair due to uncertainties about the nation's need for tritium.[24] At one point, the line being manufactured for Hanford was to be installed at Savannah River, but an improved and better-integrated process was developed instead. General Electric built a prototype that was installed at Knolls to provide process and operations data for the full-scale line. By the end of 1951, the Atomic Energy Commission requested that only a minimal tritium separations facility be built at Savannah River, designed to make later expansion easy.[25]

Although the Atomic Energy Commission again changed its plan for the Savannah River tritium facility in early 1953, this change did not affect the initial tritium process developed for the F Area. The 1953 decision called for a new, larger, and much improved tritium extraction facility to be built in H Area. The minimal facility was constructed in F Area (Building 232) according to General Electric designs. The process lines built by Consolidated Vacuum Corporation; installation began in early 1954.[26]

THE PROCESS STEPS

The F-Area tritium extraction process included five main steps: extraction (including receipt of the assemblies, drying, and decanning), primary separation, stripping, isotope

separation, and packaging. All but the initial processing steps took place in stainless steel hoods.



The irradiated assemblies were lifted from the cask cars by remote-lifting mechanisms. Courtesy of SRS Archives, negative DPSPF-41138-2.

Irradiated lithium–aluminum assemblies were shipped from the reactors to F Area by truck in shielded casks. A monorail hoist was used to move the cask into an air lock and onto a transfer car driven by a detachable car called a "mule." The mule and transfer car, after being monitored for gamma radiation, moved along tracks to a storage area, where the transfer car was secured with latches and the mule taken away. The assemblies were removed from the casks by remote lifting mechanisms and master–slave manipulators, then dried in heated air, as were the crucibles into which the slugs would be placed. This removed moisture, and, in the case of the crucibles, also released gases absorbed during prior extraction cycles. Finally, the outer aluminum coverings that encased the elements were cut lengthwise by a decanning machine, and the slugs were added to the crucible. The crucible containing the irradiated elements was then placed into a hood and evacuated, then heated to release the gases from the slugs.[27]

The gases released by the slugs were removed from the crucibles by mercury diffusion pumps and Sprengel pumps, then drawn through palladium diffusers. Each original diffuser contained four palladium membranes that were maintained at varying temperatures. The palladium membranes would remove about 95% of the hydrogen (as tritium, deuterium, and protium) from the gas that passed through them.

The waste gases from the diffusers still contained approximately 5% hydrogen, which was removed by a process called stripping. The gases were passed through a bed of palladium powder and silica sand heated to 100º C, which absorbed almost all the remaining hydrogen. Gases thus stripped that had a tritium content of 0.1% or less were released to the atmosphere. After gas from two charges was passed through the stripper bed, the bed was heated slightly to release the hydrogen, which was returned to the palladium diffuser.

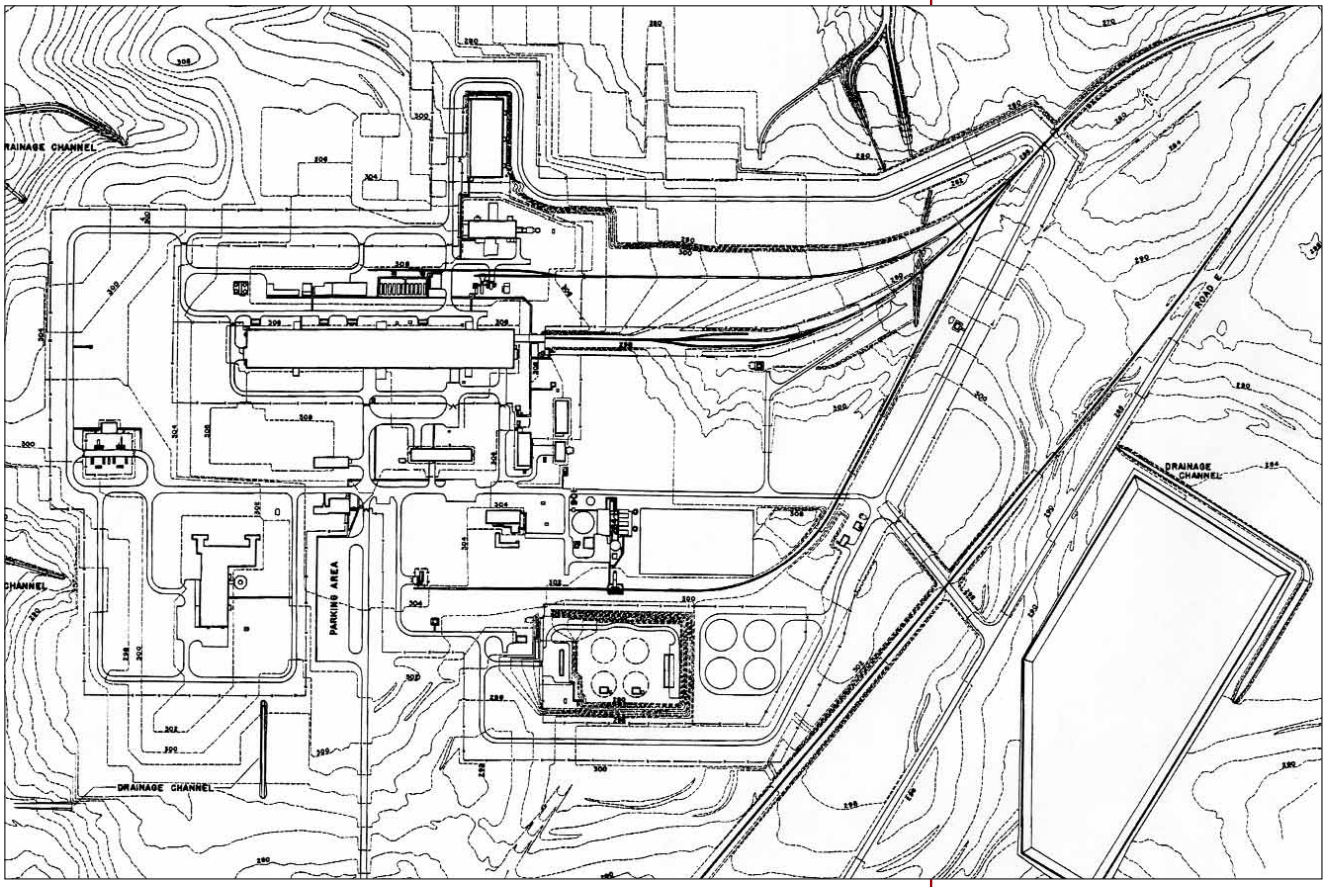
Tritium was separated from the other hydrogen isotopes by a process called thermal diffusion, which was accomplished by a simple 24-foot-long stainless steel column set vertically, with a water jacket surrounding its exterior and a heated molybdenum wire running lengthwise through its center. The mixture of hydrogen isotopes was fed at a controlled rate to the column near its center. The lighter protium and deuterium atoms would tend to concentrate in a rising stream near the hot wire, and the heavier tritium atoms would tend to move downward near the cool outer wall. The protium and deuterium were continuously drawn off at the top of the column, and tritium—of a purity of 99% or higher—was drawn at the bottom. The tritium was then placed in containers and sent to the vault building in F Area, where it remained until shipped off the site.[28]

The design of the separations facilities at Savannah River drew from a wide range of sources: from Du Pont's past experience in the chemical industry, from World War II and post-World War II experiences at Hanford, and from the knowledge and understanding then being accumulated at the fledgling national laboratories system. The canyons built at Hanford during World War II, for using the bismuth phosphate process to extract plutonium, served as a design basis for the Savannah River canyons. The engineers and architects contributing to the designs came from Du Pont; the Blaw-Knox Construction Company, which was the initial general subcontractor for architect–engineer services in this area; American Machine and Foundry Company and Gibbs and Hill, both responsible for special equipment design work; the Schutte-Koerting Company; the Penberthy Injector Company; and the Allstates Engineering Company. Initial plans for Savannah River called for only one separations area, but by the end of 1950 Du Pont had specific instructions to plan on two separations plants (F and H Areas) and consider a possible third plant, identified as X Area.[29]

As first conceived, F and H Areas had similar plutonium separation facilities, but the plutonium shapes would be manufactured in F Area only, and all A-Line operations would be located there as well. The F Area contained four primary process-related buildings: the

H AREA

Basic Information Map, 1956. The original layout for the H Area. The most important facilities are the canyon building, the new tritium Manufacturing Building, fan house, canyon stack, and the sand filters. Source: Basic Information Maps, 200-H Area, 1956.



canyon, which housed Purex and B-Line operations; the A-Line associated with the canyon; the Manufacturing Building, where tritium was extracted, purified, and packaged; and the Metallurgical Building, where the plutonium was to be fabricated into weapons components—something that never occurred. H Area was to contain only the basic production buildings, but included space for more complete facilities if future production demands warranted their construction. Both areas were to have their own support facilities for the generation of process steam, water and air supply, and filtration, and for materials storage—but only one area analytical laboratory was to be built, located in F Area.[30]

The design of the facilities incorporated some standard chemical industrial features such as central control panels and remote operation capabilities. Special design considerations included: shielding, segregation of the process steps by the radioactivity of the materials being processed, ventilation, the manner of servicing the equipment, the nature of the waste and means of treating it, the number and placement of sampling stations, the degree of automation, the type and organization of equipment (including using gravity flow as opposed to pumping solutions), the control of fissile materials to avoid criticalities, and contamination control (from washing contaminated clothing to preventing radioactive solutions from backing up into process piping intended for inactive solutions).[31]

> The dangers of working with radioactive elements and Du Pont's safety culture made it imperative that worker safety be a major factor driving design. "It was basic that every possible precaution should be taken to guard personnel against exposure to radiation beyond established tolerances. In the #100 and #200 Areas, this was accomplished through the use of both concrete and metal shielding around critical areas, by the use of remote handling equipment to manipulate the in-process materials, and by radiation monitoring and alarm systems."[32]

Another aspect of area design was the relation between the canyons and the waste tank areas. The canyons were designed to use gravity to discharge wastes, so the canyons had to be set on the highest ground in the area. Initially, a single waste-storage area was to serve both F and H areas, but providing the proper slope for transfer piping was problematic, so separate waste facilities were provided for each. Once the locations of the canyons and waste areas were established, the other buildings and facilities could be placed "from the standpoint of economy and their relationship to the over-all process."[33] Buildings that supported canyon operations—such as the chemical feed tanks, the canyon stacks, the fan houses, the sand filters, and the F Area A-Line and laboratory—were placed adjacent to the canyons. The tritium-extraction facilities and the Metallurgical Building were less closely associated with canyon operations and so could be placed where suitable ground was located. The Product Storage Vault was placed in an inconspicuous corner of the F Area to give as little indication of the importance of its contents as possible.[34]

As originally designed, the F and H areas had about 50 buildings each, for which over 300 acres of land were graded and more than a quarter of a million yards of concrete were poured. Construction work began in June 1951 with the initial grading and setup of temporary facilities in F Area. The same activities began in H Area in September.

> Among the factors that extended the major construction period [for F Area] were the low priority of completion of the 200-F Area with respect to force, materials and equipment. This was particularly true of pipefitters, electricians, and the mechanical crafts. Since the 200 Areas performed the last operating phase in the manufacturing process, overall scheduling placed the 200 Areas as the last to go into operation, and the 400, 300/700, and two of the 100 Areas were given priority over them.[35]

The majority of the F Area construction had been completed by the end of December 1954, and most of H Area was completed by the following spring.[36]

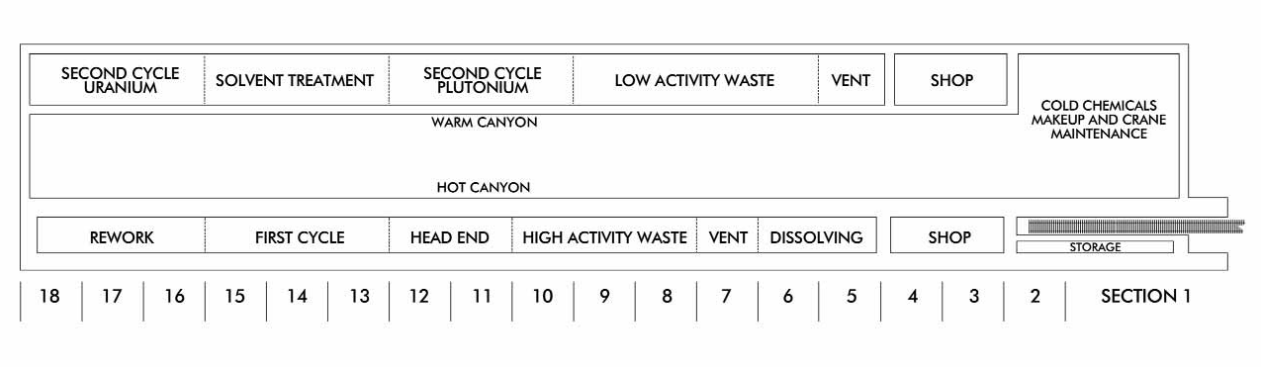
CANYONS AND B-LINES

Many canyon features were based on Hanford Building 221-T, the Cell Building.[37] The Savannah River canyons were approximately four stories tall, situated partially below grade, and enclosed two open processing areas that ran almost the length of the buildings. These areas were called canyons and gave the informal name to the buildings.[38] At Hanford, the most radioactive solutions were dealt with in the Cell Building, and work with the less radioactive solutions were conducted in the Bulk Reduction Building. These two Hanford buildings became the hot and warm canyons in the Savannah River canyons. And the interior division into cells at Hanford's canyons was eliminated in South Carolina in favor of continuous open process areas. At Savannah River, the hot and warm canyons were situated on either side of a central section that included control rooms, feed tanks, equipment, and piping for non-radioactive solutions. Processing flowed from south to north in the hot canyon, then to the appropriate warm canyon equipment and to either the A-Line or the B-Line.[39]

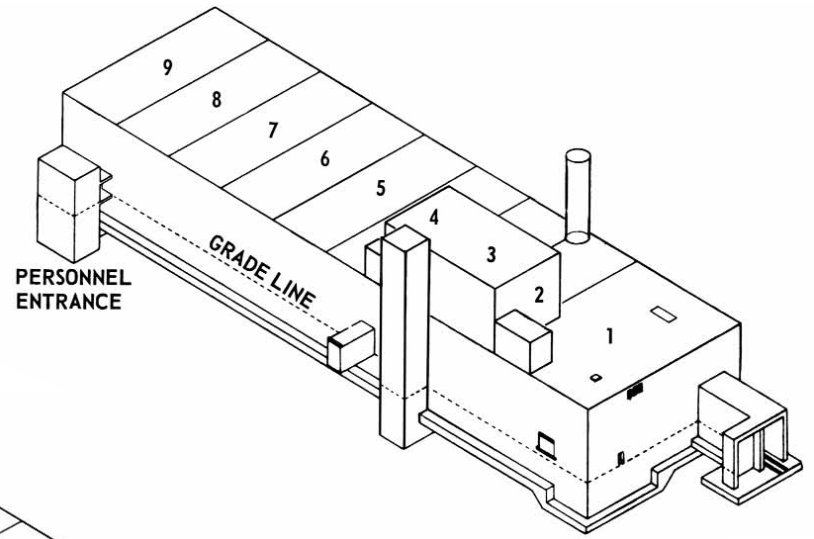
> Cellular construction was discarded and one continuous canyon building was proposed. Further study of this design led to doubling back half of the single canyon [Hanford's Cell Building had one row of process cells] and placing the two halves side by side, with common facilities for each incorporated in one general area serving both. A number of layouts based on this plan, and some application of model work by Blaw-Knox, assisted in establishing an efficient design.[40]

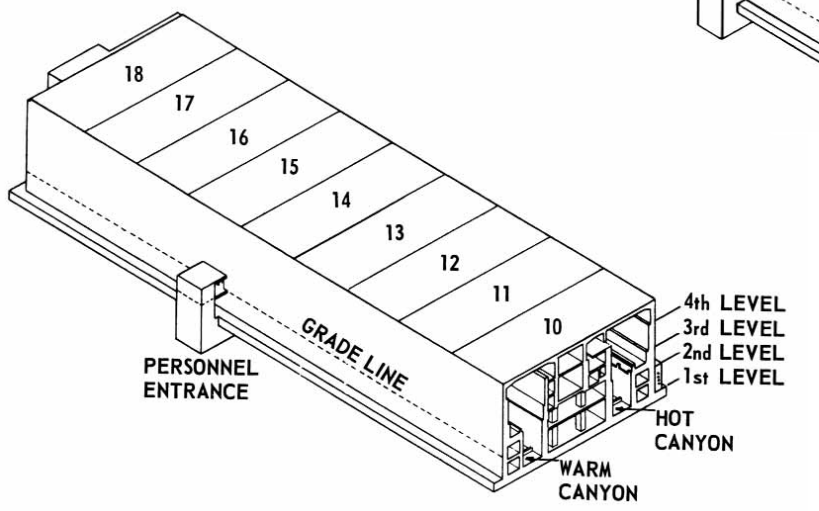
The most important design criterion for the buildings was to incorporate remote operation, which offered a means of better limiting radiation exposure to operations personnel. This meant that all processes were controlled from behind thick concrete walls; irradiated reactor elements entered the separations process by a remotely operated crane, and equipment was exchanged via the same crane. The goal was to keep exposures at no more than 1/1000 rem per hour in operating areas, and at no more than 6/1000 rem per hour in areas less frequently occupied.[41]

Processing Areas in the Savannah River Canyons



The 221 buildings were divided into hot and warm canyons that ran nearly the length of the buildings, situated on either side of personnel and equipment areas. Source: *Savannah River Plant Engineering and Design History, vol. 3, #200-F&H Areas* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 31, 33, 35, and 37.





Source: Adapted from [Don A. Orth], "SRP Experience in Storing and Processing of Irradiated Fuel to Recover Plutonium and Uranium," typescript (ca. 1976), 12, personal files of Donald A. Orth, Aiken, South Carolina.

At the end of the design process, F canyon was a Class I building almost three football fields in length that housed two processing canyons. The building was divided into 18 sections, initially of equal size, extending across its width. Just prior to the freezing of the design, the length of Section 1 was increased to allow additional room for movement of materials and equipment into and out of the canyon; the other sections were equal in length. For the purpose of locating equipment, each section was divided into four square modules (basically equipment stations—these were not divided by walls). The north wall of the building was designed so that it could be easily removed if the building needed to be expanded.[42]

Initially, the designs for the two canyon buildings were nearly identical, but experience gained during the construction and early operation of the F-Area canyon provided the means for design improvements, cost reductions, and equipment installation and layout modifications in H Area.[43] Construction of the F-Area canyon began at the end of June 1951, and the canyon equipment was installed by the end of October 1953. The building was complete enough to turn over to operations in early April 1954.[44] The H-Area canyon construction began in late September 1951. During construction, continuing development work was undertaken to increase processing capabilities. By March 1955, when the building was turned over to operations, adjustments had been proposed or made to the head-end equipment, high-activity waste equipment and process, the solvent recovery system, and other equipment pieces and process steps, "all of which should improve continuity of operation."[45]

Standardization of design was essential to each canyon's future efficiency as a remotely-controlled facility and for future maintenance. Flexibility was equally important:

> Building #221-F basic design criteria called for remotely operated and maintained processing equipment to insure a proven, safe and efficient way to produce decontaminated plutonium solutions and decontaminated uranyl nitrate solutions. In order to meet this design requirement basic criteria of safety, reliability, simplicity, interchangeability, standardization, and flexibility were adopted. These principles of design were applied to both building and equipment and particularly to the canyon equipment, piping, and other facilities required for materials handling and remote maintenance. In fact, emphasis was placed on structural flexibility and the principle that the building should not be designed for any specific piece of equipment. An example of this is the flexibility afforded by the uniform wall sections and embedded piping in the canyons. This design facilitates the rearrangement or relocation of equipment or operations in the future.[46]

TRITIUM

Just as the development of the tritium process for Savannah River was an on-again, off-again affair, so was the design of the physical plant.[47] Blaw-Knox initially proposed a

Piping the Canyons

One of the more demanding portions of construction in the canyons was the precision to which the process piping had to be installed. Through these pipes, chemicals were supplied to and transferred between the processing equipment. The piping system needed to allow relatively easy equipment removal and replacement. To accomplish this, banks of piping were set in the canyon walls, and trunnions were provided to precisely locate equipment within the canyon modules. Jumpers then provided the means of connecting the equipment to the piping. The embedded pipes had to be located accurately so replacement jumpers could be made in the future without entering the canyons to take measurements. To locate the pipes, beams were set up along the canyon walls and jigs used to align the pipes to a tolerance of no more than one ten-thousandth of an inch. Once the concrete was poured, variances were recorded on as-built drawings for future reference. Variances from one module to another do not exceed one-sixteenth of an inch.

Sources: *Savannah River Plant Construction History, vol. 3, Construction 100–R P L K & C and 200-F & H Areas* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 206; and LeVerne P. Fernandez, "Savannah River Site Canyons—Nimble Behemoths of the Atomic Age," in *50 Years of Excellence*, 134.

choice of L- and T-shaped two-story buildings of Class I construction as most suitable to the processes to be housed. In October 1951, the work was stopped due to a reduction in the production requirements of the Atomic Energy Commission, giving engineers at Knolls an opportunity to study the feasibility of the integrated process then planned for installation at Savannah River. Du Pont expected the work to be on hold for approximately six months, but near the end of the year the Atomic Energy Commission requested that the design work resume. In mid-December Blaw-Knox began working on the design again.[48] Although the specifications for the building had been modified, the process equipment being designed was not altered by this change. By early 1952, General Electric had turned over a proposed equipment setup to Du Pont, and this was the design used for the equipment installed in the F Area Manufacturing Building.[49]

Late in 1952, the Atomic Energy Commission increased its emphasis on tritium production, and by January 1953, the projected schedules were impacting the design of the tritium facility once again. Plans were made to extend the F Area Manufacturing Building to add additional capacity, and by the end of February, a new Manufacturing Building with two process lines was added to the project. In March, it was determined that the new building would be located in the H Area and that its capacity would be double that of the facility in F Area.[50]



Building 232-F, the first tritium facility at Savannah River, 1953. Much smaller than the tritium separations building in H Area, Building 232-F operated only a few years and can be viewed as a pilot plant for the vastly improved H Area tritium facility. Courtesy of SRS Archives, negative DPSPF 2-604.

Increased pressure to complete the F Area building delayed work on the new tritium facility. Extensive and time-consuming modifications were needed to improve the efficiency of the process, but time constraints limited the amount of improvements that could realistically be made, so the equipment setup was based on that which was planned for F Area. By the end of July, Allstates Engineering Company and Voorhees, Walker, Foley & Smith were nearing completion of the building design, and the specific H Area location for the facility had been determined.[51] The new L-shaped Manufacturing Building enclosed more than twice the floor space of its counterpart in F Area and incorporated Class I reinforcement for the process area. Although not noted in the history of the design of this building, it is likely that the early L-shaped building plans for F Area served as a design basis. Before the building was completed, the commission again reduced its tritium requirements; as a result, the H Area building was completed, but no equipment was installed.[52]

Construction of 232-F began in early January 1953, and the building was turned over to operations at the end of June the following year. Excavation for the larger tritium facility in H Area began in January 1954, and the following month it was given priority over all other construction in the area. Although the later change in production schedules decreased the urgency for the facility, construction still proceeded apace, and the building was turned over to operations in February 1955.[53]

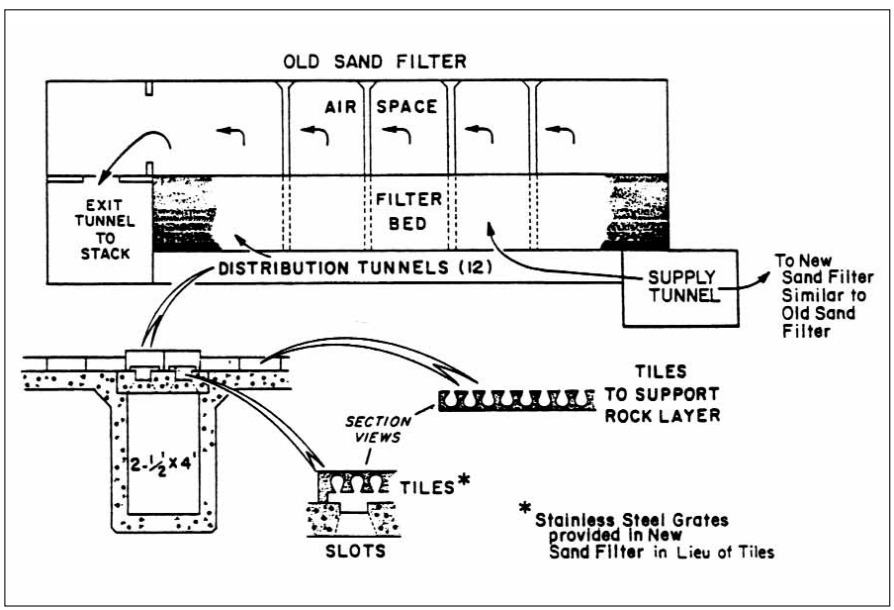
The design basis for the equipment in the A-Line facility was the Mallinckrodt Chemical Works plant in St. Louis, Missouri. For the sake of economy of construction and operations, the line was not housed in the canyon but in a separate building that could be built with less shielding and would require fewer access restrictions.[54] In April 1952, design responsibility for the A-Line was transferred from Blaw-Knox to the Lummus Company, which adopted a three-story Blaw-Knox design and added a fourth-level penthouse and a basement.[55] The interior surfaces were also designed to minimize dust collection by limiting shelves, ledges, and other details where dust could settle.[56]



A-Line facility, November 1953. The H Area did not have an A-Line facility because the one in F Area was considered sufficient to handle all processing. Courtesy of SRS Archives, negative DPSPF 2-602-8.

Among the more elegantly simple structures at Savannah River were the sand filters, items that have provided surprising performance over the years. These were important components in the canyon ventilation system, used to remove radioactive particulate matter from the air before it passed through the exhaust fans and out the stack. The design of the sand filters was derived from operational data and experience from smaller units at Hanford. With the assistance of C. E. Lapple of Ohio State University, who was hired as a consultant for the filter development, the specifications for the Hanford filters were modified to create units suitable to the needs at Savannah River.[57]

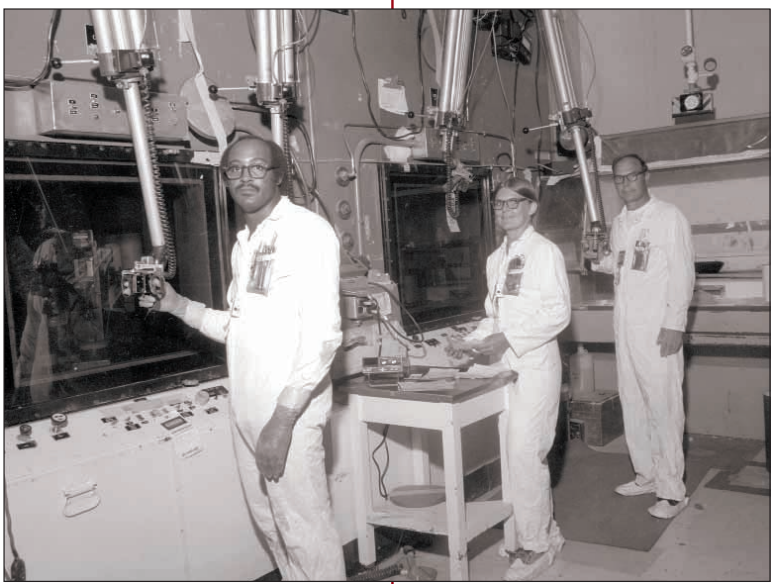
Acidity in the filter matrix eventually resulted in the erosion of the concrete support structure, which resulted in a loss of filter material and a short release of activity. The holes in the concrete grate were blocked and normal performance was restored. However, these failures prompted consideration of replacement filters. Two new filters were constructed with steel grates as supports, as opposed to the concrete grates on the original filters. The new filters were placed in operation in parallel with the original filters, which continue to give satisfactory service.[58] "The variability in naturally-occurring sands makes the design of a filter more complex than simply creating a pile of sand."[59]



Process air entered the sand filters through a tunnel from the canyon building, then passed out to the Fan House, and from there was vented to the stack. Once in the filter structure, the air was distributed underneath the filter bed by small distribution tunnels covered by slotted concrete covers, above which were set die-formed clay tiles. Above the tiles, were seven layers of graded gravel and sand that removed radioactive contaminants. A bypass tunnel allowed the air to be routed around the sand filter if needed. Source: *Waste Management Operations*, Document ERDA-1537 (Aiken, South Carolina: Savannah River Plant, September 1977), II-31.

A separations laboratory for analyzing products and operations in the 200 Areas was constructed in F Area. The laboratory was designated the Control Laboratory. As with the other laboratories around Savannah River, the Separations Control Laboratory assisted the other process-control laboratories and the main Savannah River Laboratory when needed.

The fundamental requirement for the design of the laboratory was versatility, since the methods of analyzing and assessing operations in the areas were not fully known at the time of design and would be subject to change during the operational lives of the separations facilities. The Control Laboratory was a one-story building with a basement, and was divided into four sections for metallurgical control related to operations in Building 235-F, Purex process control, A-Line process control, and other assistance to plant operations. Areas for handling plutonium analysis were segregated from the areas where low-level analysis was conducted by the arrangement of the change room and shower facilities. Work surfaces were designed to be easily decontaminated, and complex exposed surfaces where dust could collect were avoided—process piping, ductwork, and lighting were concealed behind hung ceilings. Construction of the laboratory began in October 1951, and the building was turned over to operations in early 1954.[60]



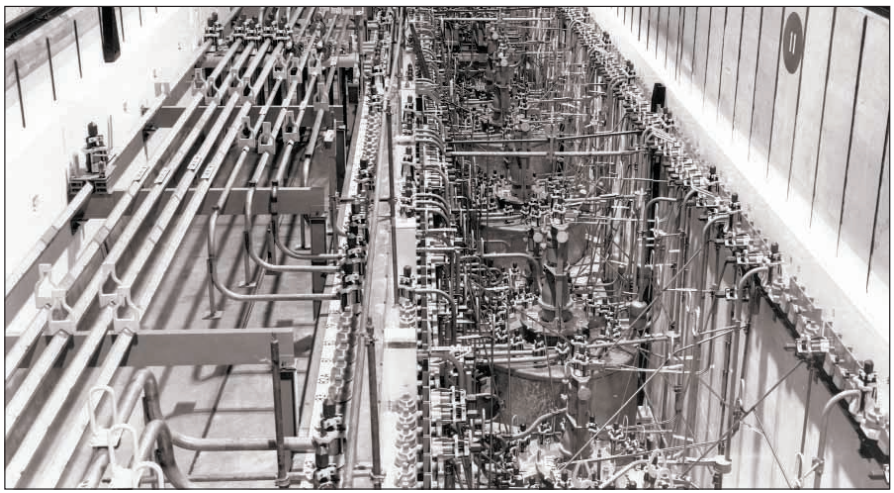
772-F Laboratory. Willie Simmons, Karen Felder, and Jim Johnson, Technical Assistants, in front of shielded analytical cells in 772-F Laboratory, 1978. Simmons and Johnson are remotely performing analysis and tests on radioactive samples. They are protected from the radiation by high-density concrete and a specially designed window that provides additional shielding. Courtesy of SRS Archives, negative DPSPF 27375.

The Mockup Building in the F Area served as the main shop for the fabrication and test assembly of equipment, and for the routine maintenance and inspection work for the separations areas. The original Mockup Building included two bays running the length of the building. In the high bay were machine and metalworking equipment and the test assembly facilities. Other shop facilities, offices, and personnel areas were located in the low bay. The design was based on a similar building at Hanford.[61]

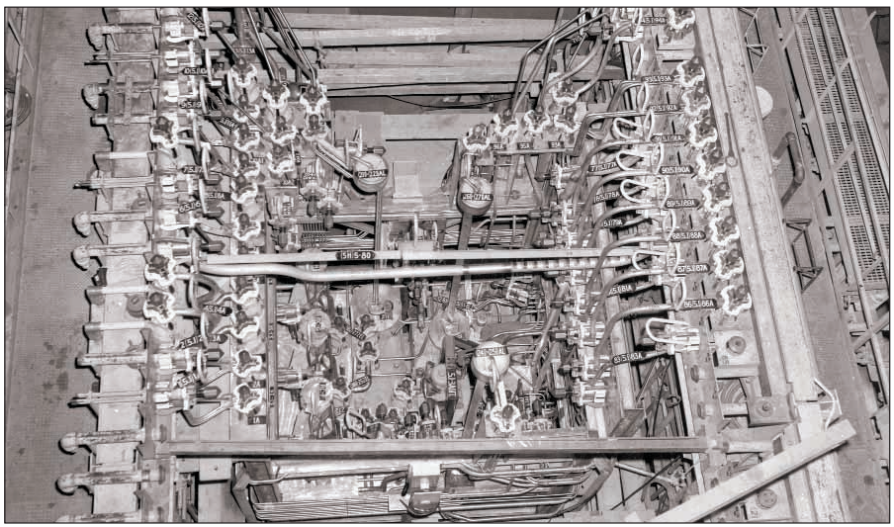
> The mockup of all pieces of equipment that would be remotely operated and maintained in the 200 Areas was accomplished in Building 717-F. The personnel responsible for the mockup operations "received component parts of equipment… [which they] cleaned, inspected, identified and assembled into precise units. These units were then prefitted to other related units until a complete operating assembly was created. An 'As Built' record was made to record all pertinent dimensions of the assembly for reference in future fabrication. After this work had been done, the functional parts were placed in moisture-proof, weather-sealed bags in preparation for storage until they were required in the areas."[62]

The primary design consideration was that the mockup facility exactly duplicate the process equipment areas of the hot and warm canyons. Replacement jumpers and equip-

ment, manufactured after operations began, would not fit if the canyon equipment stations were not precisely duplicated. The Mockup Building was used during construction for the mockup of equipment for the reactor areas as well.[63]



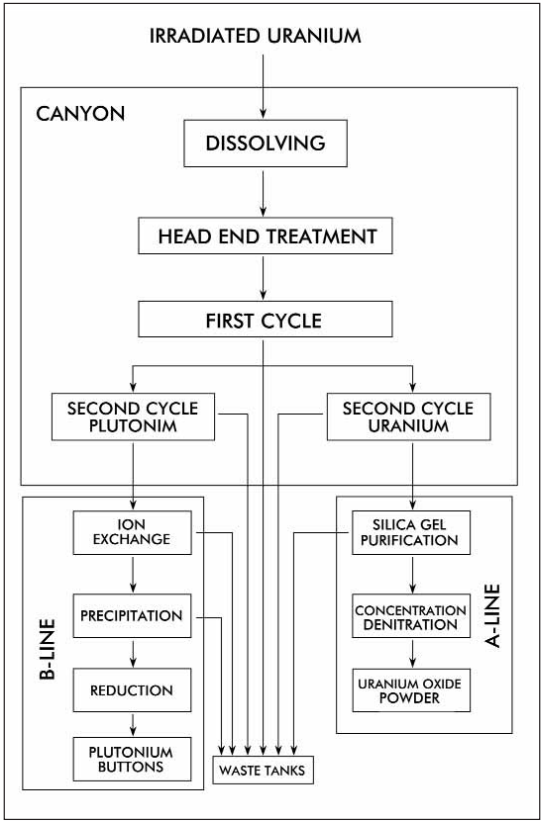
> The mock-up facilities in the high bay are patterned exactly after the layout in the canyons of the #221 Buildings, including the slope of the floor, pipe nozzle locations and the equipment positioning guides. This made it possible, while the #221 Buildings were under construction, and in a clean location convenient to tools and material, to fit and assemble all canyon equipment and pipe jumper assemblies and to take measurements with the assurance that all equipment could be installed or replaced in the #221 Buildings by remote operations. After start-up, all new installations and replacements of process equipment will be 'mocked up' in this building.[64]



Interior views of canyon and comparison with canyon frame in Mockup Building. Courtesy of SRS Archives, negatives DPSPF 11568 and 7224-15.

One final building of interest was the patrol headquarters. During normal operations, the building served as the control point for personnel and vehicular movement into and out of the F Area. But in the event the main patrol headquarters for Savannah River became inoperable, F Area's patrol headquarters would become the emergency control center for the entire Savannah River plant. Disaster control facilities were located in the building, as were Army Teletype transmission and other communications equipment. The emergency control portion of the building was constructed according to Class I standards and was protected against gamma radiation by shielding in the walls and roof.[65]

(Opposite Page) 1. H Area powerhouse employees, 1957. George Stewart, Doug Hortin, Bob Felton, Joe Hall, (rear) Charlie Rice and Luke Cain, negative 4002-4. 2. Ray McJunkin plotting a standard calibration curve using atomic absorption spectrometer, negative DPSPF 27375-10. 3. Swimming Pool Area, Harold Harmon operating agitator for decontamination, 1975, negative 27226-75. 4. Shielded locomotive for moving cask into canyon, K. R. Taylor climbs aboard, 1978, negative 27226-78. 5. 221-F Control Room, left to right, O. L. Dobson, Jr., T. E. Philbeck, V. L. Rhoden, E. E. Haynes, H. E. Wright, and J. S. Bullington, 1963, negative 27226-63. 6. Hot Gang Valve Corridor, 1979. Left to right, L. E. Gattman, K. R. Taylor, and M. Davis, Jr. Negative 27226-79.



Originally, operations in both F and H areas followed this general scheme. All A-Line operations took place in the F Area. Source: Adapted from *Savannah River Plant Engineering and Design History, Vol. III, #200-F&H Areas* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 23.

OPERATIONS

Liquid Separations

Operation of facilities in the separations areas, to approximately 1965, can be characterized as having been guided by two overarching and related efforts—to increase throughput, and to refine procedures. Improvements to the H Area canyon, based on experiences gained in F Area, enabled Savannah River to continue to meet production requirements while the F Area canyon was shut down from 1957 to 1959 for the installation of larger equipment and other modifications. The larger equipment, however, caused problems that had not been anticipated; adjustments to the equipment and the processes were made during the ensuing years, to work out a method of operation for plutonium separation, that remained virtually the same throughout the remainder of the operations history of the F Area canyon. Changes in tritium production requirements during the mid- to late 1950s made it necessary for the reactors to be loaded with enriched uranium. Special equipment and procedures were needed to separate enriched uranium, and this mission was undertaken in the H Area.[66]

The first irradiated material entered the F Area canyon in November 1954, and the canyon was able to operate at its designed capacity of about three tons of uranium per day. Throughput was increased slightly during the early months of 1955 as operators gained experience with the process and made small adjustments in the canyons and the B-Line facilities. The increased throughput made modifications to the A-Line necessary; a single-story addition and basement were built onto the south end.[67]

What Holds Separations Together


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The H Area canyon went into operation in July 1955. Due to the improvements based on F Area's experience, the designed process rate of uranium per day accomplished in F Area was more than doubled in H Area operations. The need for even greater throughput, based on predictions for increased reactor operations, was imminent, and the combined button production capacity (two lines in F Area and one in H Area) was expected to be exceeded within two years.[68]

The conversion projects, explained in more detail below, were the focus of activities during the 1957 to 1960 period. As these projects were completed, participation in the Atomic Energy Commission peaceful uses programs expanded. Problems to 1965 included the contamination of the cranes in both areas (a recurring problem); corrosion in the canyon stacks, that resulted in releases of radioactive materials; a solution leak, that resulted in the plutonium contamination of a ventilation tunnel in the F Area canyon; malfunctioning gang valves in the canyons, that resulted in contamination of the routinely occupied gang valve corridors; the release of radioiodine from the canyon stacks; and a fire in the F Area primary recovery column. New technologies were also brought into the canyons during this period. In 1962, tests were begun on a closed-circuit television system for the canyons. And in the summer of 1965, the applicability of computers to separations process control began being studied.[69]

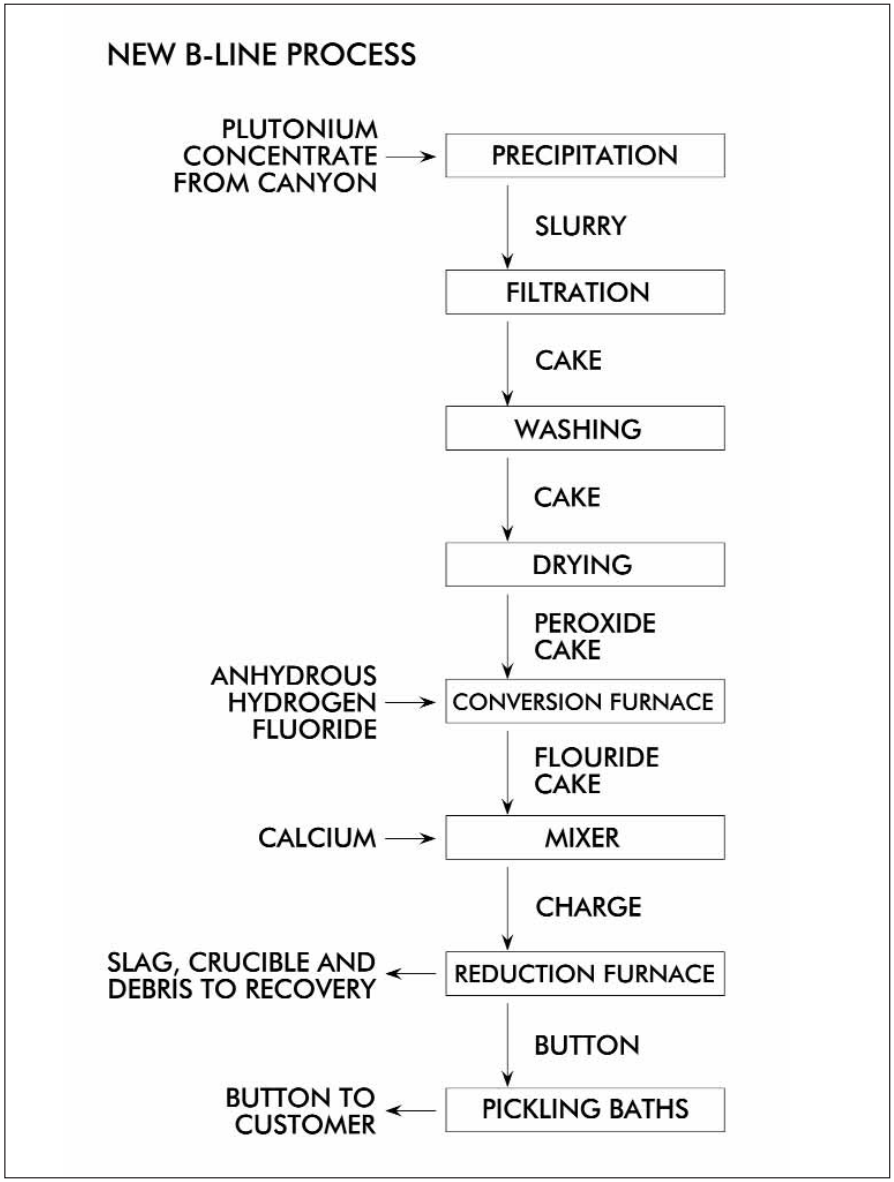
F Area Increased Throughput In 1957, the F Area canyon was shut down for a major renovation that would eventually increase throughput to nearly five times its initial capacity. Design work for the change began in early 1956, when new mixer–settlers, evaporators, and hold tanks were developed. As in the original design phase, pulse columns were considered in lieu of mixer–settlers, and means of securing columns were installed in the hot canyon, but mixer–settlers were again chosen because they could be more economically developed.[70]

The modifications included the B-Line facility as well. A trifluoride precipitation process, rather than the original peroxide process, was adopted because it was faster and more economical to operate. New criticality safe vessels were designed for handling large amounts of concentrated plutonium solution, and improved equipment designs were incorporated. To alleviate crowding, a new facility was constructed on the roof of the canyon.[71]

The increased throughput project involved removing most of the tanks and mixer-settlers and replacing them with the largest units that would fit in the canyon modules.[72] Some tanks were specially shaped to fit across two modules. The new, substantially larger mixer-settlers for F Area were called Jumbos. The units were developed at Savannah River's TNX facility and replaced the 1A, 1B, 1C, 1D, and 1E banks. The installation of the Jumbos and the other modifications related to the increased throughput project were completed in early 1959, and the F Area Purex facility went back into operation on March 19, 1959.[73]

Although there were great expectations for the Jumbos, they caused major problems and have been described as a mistake, that would have to be corrected for the next seven years. The problems began appearing almost immediately—plutonium began accumulating in Bank 1B, and excessive fission byproducts were following the plutonium through Bank 1A. By the summer of 1959, degradation of the solvent was expected to be at least part of the cause. Corrections involved extensive research and experimentation on the part of the laboratory, operations personnel, and Works Technical for several years. The solutions included ceasing the use of the decanters below the mixer–settlers, improving the

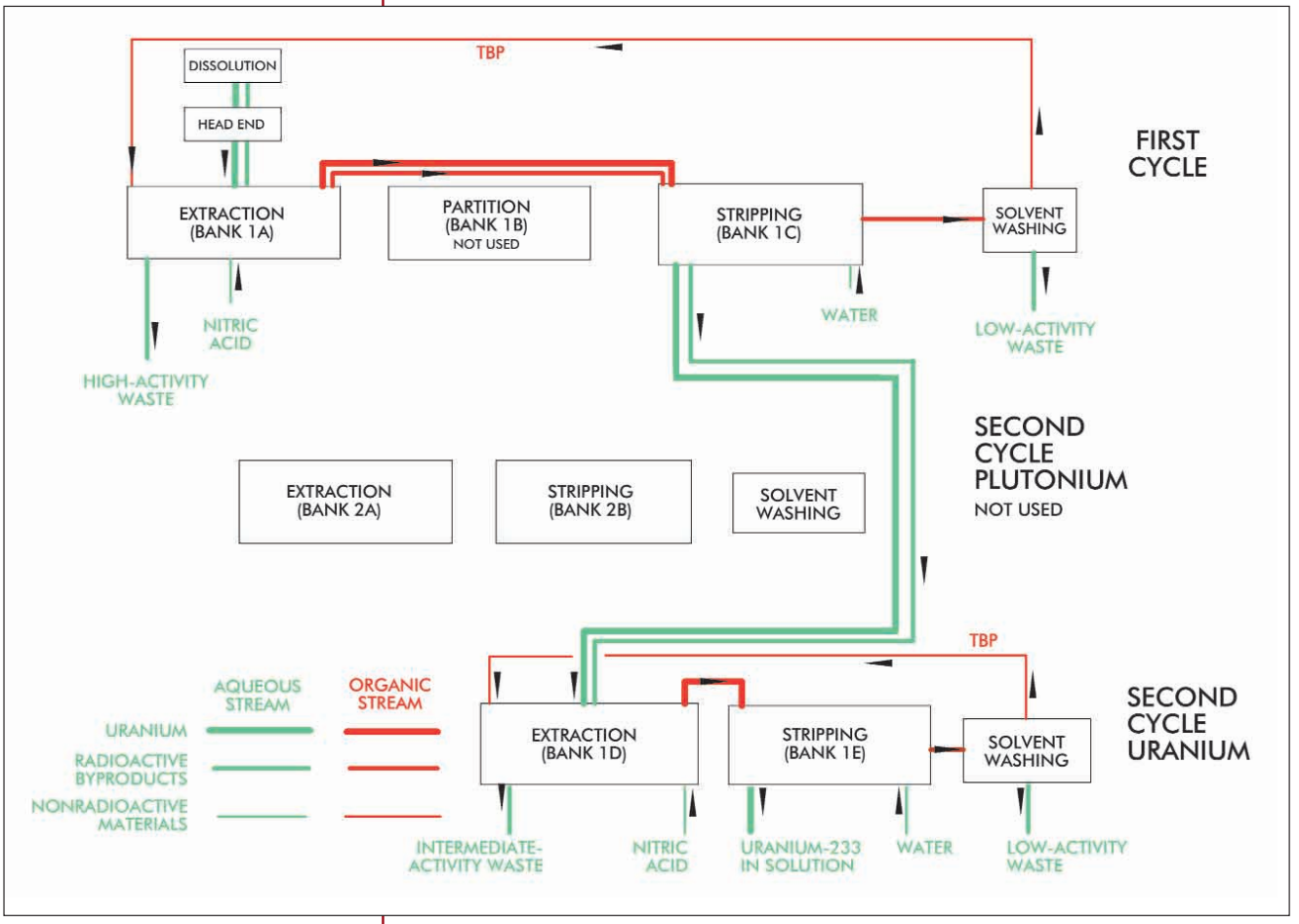
solvent recovery process, changing the solvent, and installing centrifugal contactors in the Bank 1A.[74]



The process used in the new B-Line in the F Area. Source: Adapted from E. W. Mainland, Donald A. Orth, E. L. Field, and J. H. Radke, Production of Plutonium Metal, *Industrial and Engineering Chemistry* 53, no. 9 (September 1961): 686–687.

While the canyon was shut down for the increased throughput project, significant changes to the B-Line were also undertaken. The rationalization for this modification was carefully developed by the personnel involved in getting it accomplished. The original B-Line was crowded and not well laid out. Safety issues were noted during a July 1958 safety review.[75] A plutonium trifluoride precipitation method was developed that offered a means of providing an integrated facility with new coupling, recovery, and metal production line.[76] The new coupling and precipitation systems featured slab-shaped tanks for increased nuclear safety in handling concentrated plutonium solutions. The metal line had

segregated maintenance areas that controlled contamination when individual equipment pieces needed attention. The new B-Line went into operation at the end of April 1959.[77]



The HM process was similar to the Purex process except that no second–cycle plutonium steps were required. Source: Adapted from D. G. Karraker, *Solvent Extraction of Enriched Uranium in Conventional Purex Equipment*, Document DP-481 (Aiken, South Carolina: Savannah River Laboratory, June 1960), 5.

H Area, Processing Enriched Uranium As soon as the F Area canyon was back in operation, the H Area canyon was shut down for conversion to processing enriched uranium. The new process drew from processes worked out at Oak Ridge and elsewhere, but still used TBP and was essentially a variation on Purex, except that no plutonium was extracted. The name HM process, as it was called, was probably derived from "H Modified." The conversion was only made possible by the upgrade in F Area to a level of throughput sufficient to process enough plutonium to meet Atomic Energy Commission schedules for production. If F Area had not been able to meet production schedules alone, the construction of a new facility for the separation and purification of the uranium-235 reactor components would have been necessary. Operations in H canyon were halted in February 1959 for the modifications, which took only a few months. The canyon began operations again in May, and in general, production was satisfactory.[78]

Separations Diversification In 1959, the Savannah River mission was expanded to include the production of plutonium-238, as a power source for use in space vehicles. The program entailed first, the separation of neptunium-237 (neptunium was a byproduct of

plutonium production that prior to this had been sent to waste storage), then its fabrication into reactor targets, and irradiation to plutonium-238. The plutonium-238 was purified and initially shipped offsite, then later was converted to a solid and formed into heat sources at Savannah River. The primary recovery column was installed in F Canyon to absorb neptunium from the waste stream. The column contained a resin that absorbed both neptunium and any plutonium-239 that had followed the waste stream.[79]

Since the H Canyon had been converted to process only uranium, the second-cycle plutonium equipment was no longer being used. This was converted to decontaminate neptunium. After being partitioned from the enriched uranium in the first cycle extraction step, the neptunium was then sent to the equipment originally installed for the second-plutonium-cycle purification, where it was decontaminated with a TBP-based process. New equipment was also installed to recover neptunium and plutonium-238 from irradiated neptunium reactor targets.[80]

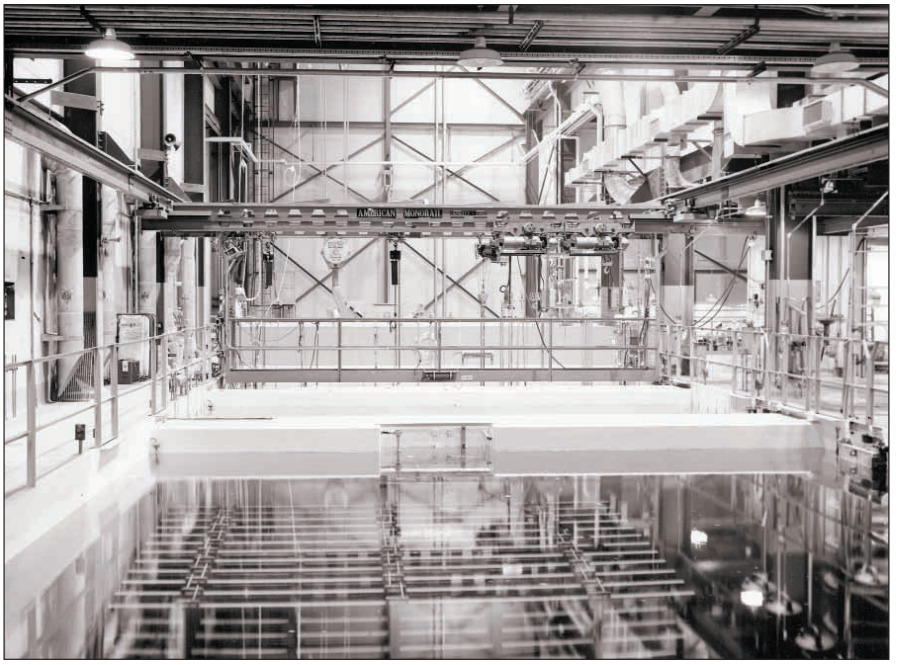
Much of the equipment was mounted on steel structures called "frames," each of which could be placed as a unit into a canyon module. One frame was installed in the F Canyon to purify neptunium from the primary recovery column, and two were placed in the H Canyon for purification of the neptunium from the second cycle and all processing of the irradiated neptunium targets. The first irradiated neptunium targets were processed in the H Area frames in March 1961. The first facility to convert neptunium to a solid was installed in the H Area B-Line by the end of 1961. The oxide produced in the B-Line was fabricated into reactor components in a facility in F Area that had been converted to this purpose in 1960.[81] In 1963, the Plutonium Fabrication Facility was constructed in the H Area B-Line to convert the plutonium-238 into an oxide, and produce heat sources onsite for the National Aeronautics and Space Administration, a continuing activity there for the next two decades.[82]



E. B. Jones and Frank Loudermilk operating glove boxes on F Area's Np Line, 1978. Courtesy of SRS Archives, negative 27204-54.

Separations programs involving other elements were undertaken in both F and H Canyons between 1961 and approximately 1975. These involved the recovery and purification of several isotopes of uranium, plutonium, americium, curium, europium, and other elements, primarily for research purposes. Major programs included campaigns to recover uranium-233, beginning in March 1964; Thorex campaigns for the recovery of thorium along with uranium-233, beginning in September 1965; and a variety of projects related to the production of transplutonium elements, beginning in 1962. That year, cabinets and equipment in Building 235 were decontaminated in preparation for the fabrication of plutonium-242 targets for irradiation to create transplutonium isotopes. The following year, a glove box line was installed in the building, for the manufacture of plutonium–aluminum billets with higher than normal content of plutonium-240. In 1965, the Curium-I campaign began in the F Canyon and B-Line, recovering plutonium-240, americium-243, and curium-244. There were also four programs to recover plutonium, that had a higher than normal content of plutonium-240 in the F Canyon, to be fabricated into billets in 235-F for the Curium-II campaign. A transplutonium campaign in the H Canyon and B-Line ran in late 1964 and early 1965,

recovering plutonium-241, -242, americium-243, and curium-244. These were converted to oxides in the B-Line facilities, and the highest-quality plutonium-242 was shipped to Oak Ridge for irradiation in their High Flux Irradiation Reactor.[83]



Receiving Basin for Offsite Fuels (RBOF), 1963. Courtesy of SRS Archives, negative DPSTF 1-07531.

> Beginning in 1960, SRP played an increasing role in reprocessing uranium used as fuel in reactors at other sites. Much of this activity arose from the "Atoms for Peace" plan initiated by President Eisenhower in 1953…. Under the program, uranium was made available from AEC stocks for use as fuel in experimental power reactors and for research reactors at universities and AEC laboratories. A general condition imposed was that the uranium should come back to the AEC when no longer needed or for reprocessing…. SRP was designated as the principal recipient of these experimental fuel elements, which were diverse in dimensions, types of cladding and nature of the fuel cores. To handle these, a new facility, the Receiving Basin for Offsite Fuels (RBOF), was built.[84]

Another way that operations diversified in the separations areas was with the storage and processing of offsite reactor elements. In 1961, construction began on the Receiving Basin for Offsite Fuels located in H Area. In 1964, Savannah River was authorized to begin receiving and processing assemblies from other sites.[85] The plant began receiving uranium-235 fuel from universities and other countries that year. These materials remained in storage until they could be processed in the H and F Canyons.

TRITIUM OPERATIONS

The F Area tritium facility went into operation in October 1955. As operating experience was gained, throughput quickly increased. By January 1956, the amount of material being placed in the furnace for a single melt had been raised to five times design specifications, causing only slight difficulties in the operation of the diffusion column. The throughput for the column was more than doubled during the initial months. Revisions to the F Area equipment in the fall of 1956 approximately doubled the capacity of tritium processing there. But the operations history of 232-F was short—the final charge was processed on October 6, 1958.[86] The new tritium facility in the H Area had made 232-F superfluous. Tritium demands waxed and waned, but at the end of 1955 demand was expected to remain high:

> The original purpose [of the Savannah River facilities] was the production of plutonium, together with the maximum tritium producible with natural uranium as the fuel. Almost immediately, emphasis shifted to maximum plutonium production. Soon interest in tritium revived and about two years ago, it appeared that the plant would by now be primarily a tritium producer. Again, as a result of new information, tritium dropped out of the picture. Instead, it was believed that U-233 producible from thorium, might be the major product. This interest waned and although some U-233 has been produced, it is no longer in the production forecast. Instead, interest in tritium has revived more bullishly than ever before and it is again estimated that the plant capacity will be largely assigned to this product in 1958. It is our belief that this time, tritium is in the production program to stay, but at what level, time alone will tell.[87]

H Area's New Tritium Facility By the end of 1955, new appropriations had been made to cover resumption of the installation of two process lines in the H Area tritium facility, and by late 1956, the work there was considered to be urgent. During 1957, construction of the second line was begun. The first line operated throughout 1958, then was shut down in December. The second line had begun operating in August, and by December its capacity was proven to be sufficient to meet production requirements of the time.[88]

Construction of the tritium packaging facility began in April 1956, and in August 1957, the building was turned over to operations. Many problems, especially with leaks and reservoir stems, had to be overcome, but by the end of the year operations were encountering no major problems. The completion of this facility allowed the tritium to be loaded in the actual weapons components rather than shipped to another site for that procedure.[89]



The H Area tritium facility, just after completion. No equipment was installed in the building, when first completed. After initial experience was gained in the F Area facility, improved equipment and processes here would make the F Area facility obsolete. Courtesy of SRS Archives, negative 2-762-12.

> [I]n 1957, a new task was assigned to SRP—the loading of tritium into 'reservoirs' that would be actual components of thermonuclear weapons. This was the closest SRP ever came to justifying the name widely applied to the plant by the local population: 'The Bomb Plant'![90]

Savannah River began receiving reservoirs from thermonuclear warheads in August 1958. The tritium was discharged from the reservoirs, and fed to the process stream to be purified, primarily for the removal of helium-3. At this time, the reservoirs were not reusable, so they were sent offsite as waste, an expensive necessity because the reservoirs were costly to produce. In 1969, Savannah River would bring on line an important new facility in H Area, the Reclamation Building, that would allow reservoirs of various modified designs to be recycled. An addition to H Area's Manufacturing Building was begun in 1960, in which was installed a third process line that could handle the long tubular elements, then being irradiated in the reactors for the production of tritium. The line went into operation in September of the following year. In 1964, construction began on the Helium Recovery Building, where helium-3 was recovered and returned reservoirs were tested. The building went into operation in 1965.[91]

1962, Savannah River provided special tritium loadings for a nuclear test that shows the quick turnaround capabilities of the tritium facility. The orders for the specially loaded reservoirs were received only 72 hours before the test was to take place; the reservoirs were delivered on schedule.

Source: Orientation to Board of Directors—12/17/1962, Document Number DPW-71-170-3, December 17, 1962, Acc. 1957, Series IV, Box 48, Folder 17, 1, Hagley.

At the end of this period, tritium production was at an all-time high and expected to increase. "A record number of tritium boosters were loaded and shipped during 1965. SRP has the only facilities in the AEC for loading the critically important tritium boosters for nuclear weapons. Increased facilities at SRP are under way and will be in production in 1966."[92]

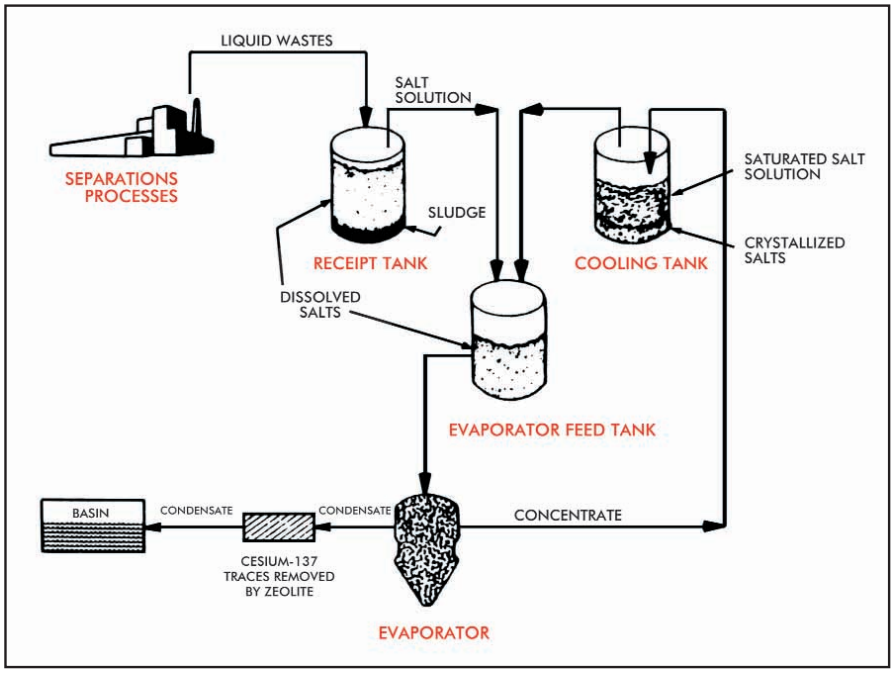
Wastes Defined

High-level wastes are defined, as the term implies, by the level of their radioactivity. Nearly all the radioactivity of these wastes is generated by the decay of short-lived radioactive products. These are also called high-heat wastes because they give off heat at a rate of between 0.5 and 5 Btu per hour per gallon. Low-level wastes are generally less than one percent as active as high-level wastes, but are still too radioactive to be released to the environment. Transuranic waste is a special type of waste that primarily gives off alpha radiation. These wastes are kept separate because they contain isotopes of elements heavier than uranium that may need to be retrieved in the future.

Source: Claude B. Goodlett, Evaporation and Storage of Liquid Radioactive Waste, in *50 Years of Excellence, 207; and An Evaluation of the Concept of Storing Radioactive Wastes in Bedrock Below the Savannah River Plant Site* (Washington, DC: National Academy of Sciences, 1972), 55.

WASTE

The types of waste generated at Savannah River could be generally divided into liquid and solid wastes, and broadly classified as high-level, low-level, and transuranic waste. Liquid wastes comprised the majority by volume and radioactivity. These were stored in large tanks in the Separations Areas. Solid wastes included contaminated clothing, process and experimental equipment, some contaminated materials from offsite, and the like. These have been stored in the site burial grounds and most are classified as low-level and transuranic wastes, and have long half-lives.



Liquid radioactive wastes were first sent to a receipt, or aging, tank, where solids were allowed to settle and short-lived fission products to decay. In the beginning years, this was about all the activity in the waste areas. As more was learned about the behavior of the wastes, steps were taken to reduce volume. Beginning in 1960, the clear solution in the waste tanks was sent to evaporators to be concentrated, greatly reducing the volume of waste in storage at Savannah River. Source: Adapted from *Management of Radioactive Waste at the Savannah River Plant* (Washington, DC: Department of Energy, April 1976), 7.

DESIGN AND CONSTRUCTION

Originally, a single waste tank group was to serve both Separations Areas, but transfer-piping requirements made that option impractical.[93] Three important factors influenced the location of the tanks: proximity to the canyon buildings, elevation (for gravity flow to the tanks), and topography. The tanks needed to be close to the canyons, yet in areas that would allow room for more tanks to be installed in the future. Use of gravity flow meant that intervening terrain between the canyons and the tanks needed to be economical to excavate to provide the proper slope for the piping. The flow of leaks from the tank area was also considered from the standpoints of both operations and environmental safety.

> [P]erhaps most important, it was desirable to so place the tanks that any contaminated leakage would seep, into a stream flowing into the river below the plant main pump house intakes. Actually, the design of the tanks made dangerous leaks highly improbable but the remote possibility of a catastrophe was taken into consideration in their location. In such an event, any released wastes will flow into Four Mile Creek and into the river down stream from the pump houses.[94]

The tanks were designed jointly by Blaw-Knox and Du Pont, modeled on the World War II-era tanks at Hanford. The requirement at Savannah River that the tanks be blast-resistant and the higher radioactivity of the solutions to be stored at Savannah River, as well as geologic and groundwater conditions, determined the nature of the modifications to the Hanford tanks.[95]

> The storage of liquid waste in these underground tanks is only regarded as a semi-permanent storage since the ever present hazard of a large earthquake could be a major disaster. Incorporation of the fission products in an unleachable concrete has been considered as one method of permanent storage…. Considerable development will be required, however, in order to make an unleachable concrete.[96]



F Area Type I Tanks. Courtesy of SRS Archives, negative 6098-11.

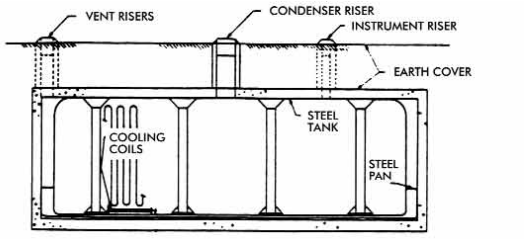
An extensive study to determine the most practical means of meeting design requirements determined that the cylindrical tanks, each with a capacity of hundreds of thousands of gallons, should be encased in concrete. The F Area originally had more tanks than H Area; this disparity resulted from their individual development history. H Area's complement of tanks would be doubled in 1955. Each tank was buried after being set in a "saucer" designed to collect potential leaks. Squat in configuration, the tanks were roughly three times wider than their height. Interior columns were built to support the tank roof. Half the tanks in each area initially had cooling coils (intended for storage of high-level wastes, while the non-cooled tanks were for low-level wastes). In 1955, all tanks were equipped with cooling coils.[97] These tanks were considered to be sufficient to hold the waste produced during the first six years of operation. F Area had more tanks because that area was expected to see more operations activity and because wastes from the plant's laboratories were to be stored there also. Excavation for the F Area waste tanks began in June 1951, and the first slab was poured in August. The tanks were handed over to operations, beginning in the summer of 1954. In the H Area, excavation began in early 1952, and operations began accepting the tanks in early 1955.[98]

In addition to the liquid wastes, provision was needed for the safe storage of solid waste. These ranged from irradiated aluminum housing tubes used in reactor assemblies to contaminated canyon equipment, protective clothing, and instrumentation. A large enclosed burial ground was established for this purpose in proximity to the Separations areas.[99]

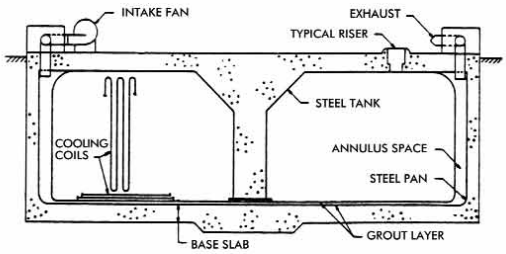


H Area Tank Farm, 1980. Courtesy of SRS Archives, negative DPSPF 30174-1.

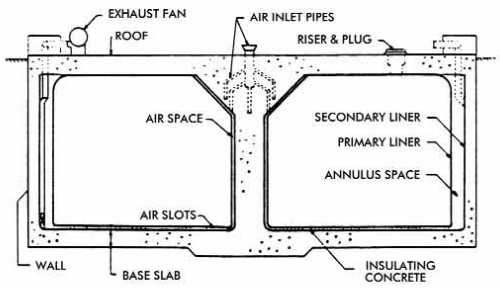
Waste Tank Types and Chronology



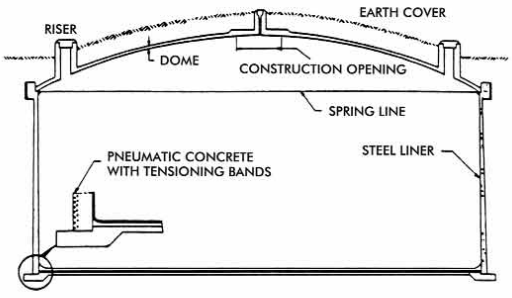
TYPE I



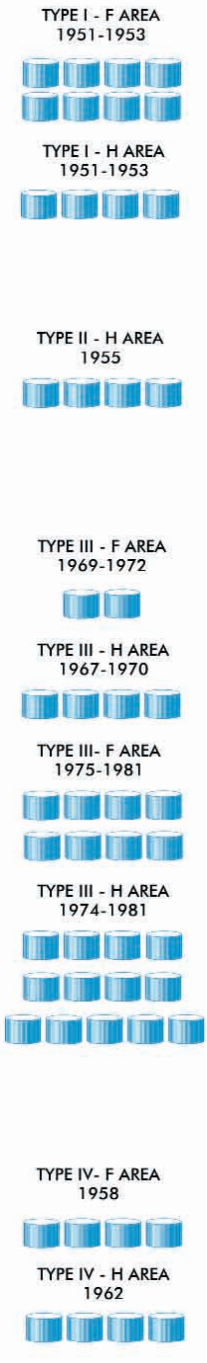
TYPE II



TYPE III



TYPE IV



The first liquid waste storage tanks at Savannah River became known as Type I tanks. One of the most critical aspects of construction was the care that had to be taken in making and inspecting the welds of the plates that comprised the tanks. The Pittsburgh Testing Laboratory spent nearly a year and a half x-raying welds to assess quality. Between February 1952 and August 1953, approximately 50,000 feet of welded seams were checked by the laboratory.

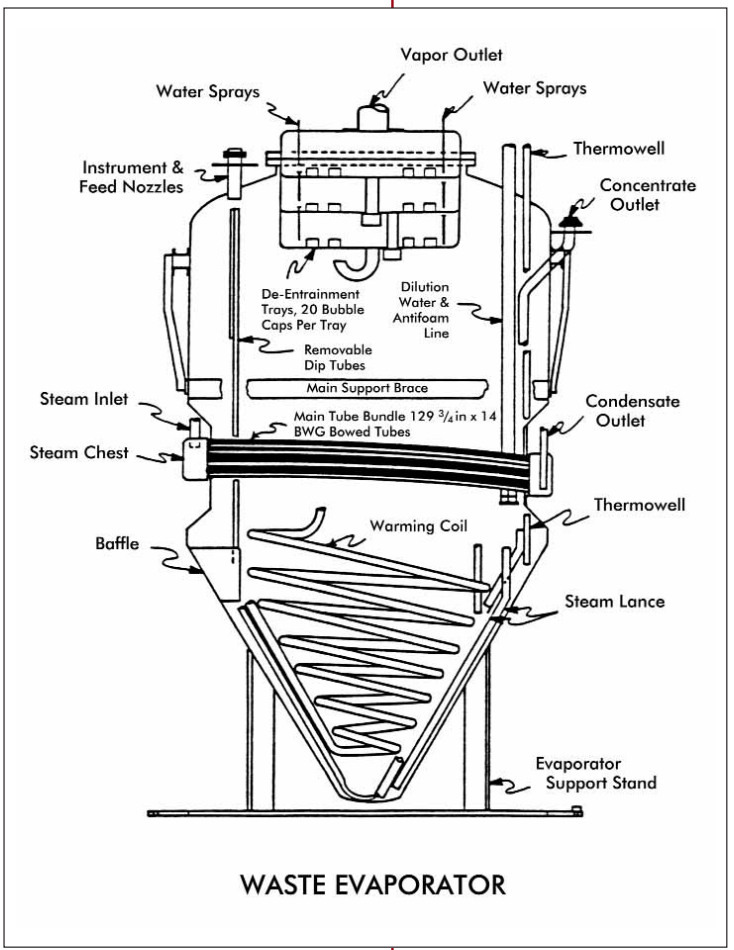
Type II liquid-waste storage tanks were constructed in the H Area. The modified design was prompted by construction experience gained building the first tanks, by new data concerning waste behavior from Hanford, and from research at the Savannah River Laboratory.

The Type IV tanks were more economical than Type I and II. They were used to store wastes that generated less heat. These tanks were simpler than the early types, and so were cheaper to design and build. Source: *An Evaluation of the Concept of Storing Radioactive Wastes in Bedrock Below the Savannah River Plant Site* (Washington, DC: National Academy of Sciences, 1972), 56–57.

OPERATIONS

The first radioactive waste was sent to the tanks soon after 221-F began operating. These wastes were adjusted with sodium hydroxide to slightly alkaline pH levels so they would be less corrosive. The alklaine conditions precipitated radioactive elements out of the solution to form a sludge on the tank bottoms. The radioactive element remaining in the solution was primarily cesium.[100] The sludge could later be stored permanently in a more stable form, but it would be several decades before this would actually be done.

As projected production schedules increased for H Area, a need for four more tanks was seen almost immediately. Designated Type II tanks, these were slightly larger than the Type I units. The design was based on reevaluations of the economies of construction, experience building the Type I tanks, and new data from Hanford's Redox operations and the Savannah River Laboratory. The Type II tanks were designed for sludge of a higher temperature, the tank bottoms were set above groundwater level, and the upper extent of the liquid in storage was to remain at or below grade. Only a single center column was used for support to allow the tank bottom to expand and contract more freely. Like the Type I tanks, these also had a five-foot-high catch pan and were enclosed in concrete.[101]

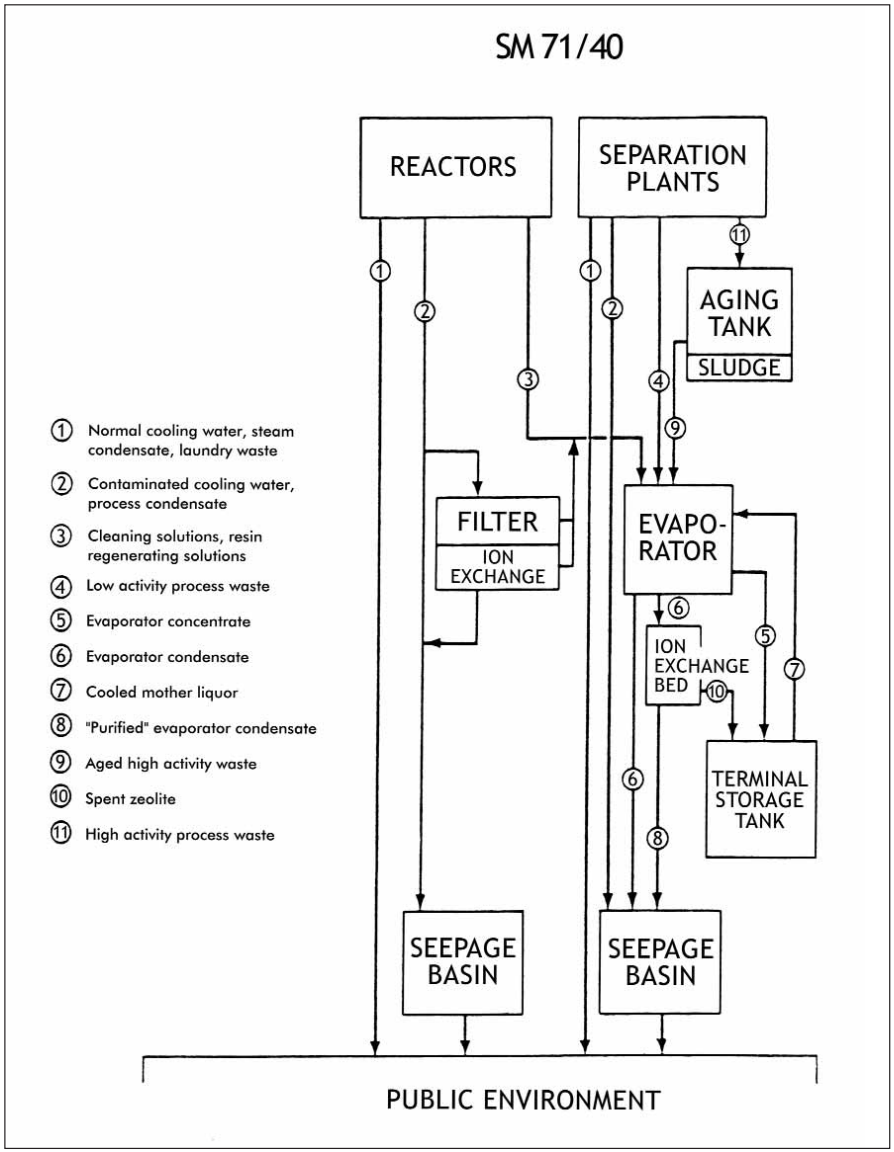


Cross-section of Savannah River waste evaporator. Source: J. E. Haywood and T. H. Killian, Overview of Savannah River Plant Waste Management Operations, in *Waste Management* '87, ed. Roy G. Post, vol. 2 (Tucson: University of Arizona, 1987), 52.

Complete filling of the first waste tank by June 1955 encouraged efforts to reduce the volume of liquid wastes.[102] Soon, treatments in the waste areas began significantly reducing the volume. High-activity waste evaporators were installed first in F Area in 1960, then in H Area in 1963 to concentrate wastes, and a system of aging and concentrating the liquid was worked out. The process involved storing high-heat waste in a cooled tank until fission products with shorter half-lives settled out as sludge and decayed. The sludge was to be converted to a stable solid form when an appropriate process for doing so was developed. After sufficient aging, the only important radioactive component of the liquid was the long-lived and relatively cool cesium-137. This liquid could be concentrated in the evaporators. Single-wall Type IV tanks were designed without cooling coils for the storage of the aged liquid. Four tanks of this type were constructed in F Area in 1958, and four more were built in H Area in 1962. Although such tanks seemed justifiable at the time, leaks in some of the other tanks showed that the Type IV tanks did not offer enough protection from potential leakage to warrant expanded use, so no more of these were built. None of the Type IV tanks, however, has leaked.[103]

Several of the waste tanks began leaking shortly after operations began. A Type I tank in the H Area, the first to have been filled there, began leaking high-activity waste during the summer of 1957. By the end of October it had lost approximately 16,000 gallons.

Leaks in a Type II tank in the H Area were discovered in May 1959, and a third tank (Type I) was discovered to be leaking two months later. One of the worst incidents of leakage



Shown are the routes that waste, produced by operations at Savannah River, followed to the environment and to storage tanks during the early years of operation. Source: R. M. Girdler, Handling of Low- and Medium-Level Liquid Waste at the Savannah River Plant, in *Practices in the Treatment of Low- and Intermediate-Level Radioactive Wastes, Proceedings of the Symposium on Practices in the Treatment of Low- and Intermediate-Level Radioactive Wastes* (Vienna: International Atomic Energy Agency, 1966), 481.

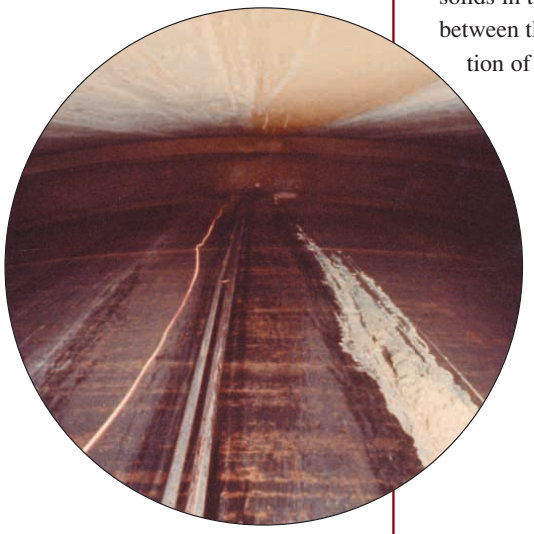
began about November 1959, in another H Area Type II tank. Leakage from this tank increased dramatically to about three and one-half gallons per minute in the fall of 1960; the flow—all of which came from cracks near welds—was lessened by removing some of the liquid from the tank to lower the pressure.[104]

These four leaking tanks in H Area (no leaks had yet been detected in the F Area) prompted Du Pont's Atomic Energy Division to request an extensive investigation of the causes. The resulting report found that stress corrosion cracking caused at least one of the tanks to leak and probably caused all the leaks; and determined that repair of the tanks was not feasible. A portion of the tank experiencing the worst leaks was cut out for test-



(Right) Periscopes were used to inspect the walls of waste tanks for leaks. Source: R. M. Girdler, *Leaks in Radioactive-Waste Tanks*, Document DP-990 (Aiken, South Carolina: Savannah River Laboratory, December 1965), 17. Courtesy of SRS Archives, negative 7555-1.

(Below) Waste Tank Leak Site. Photograph taken from the annular cavity between the outer tank wall and the inner concrete enclosure wall. Source: *Waste Management Operations,* Document ERDA-1537 (Aiken, South Carolina: Savannah River Plant, September 1977), II-107–II-108. Courtesy of SRS Archives, negative 23205-1.



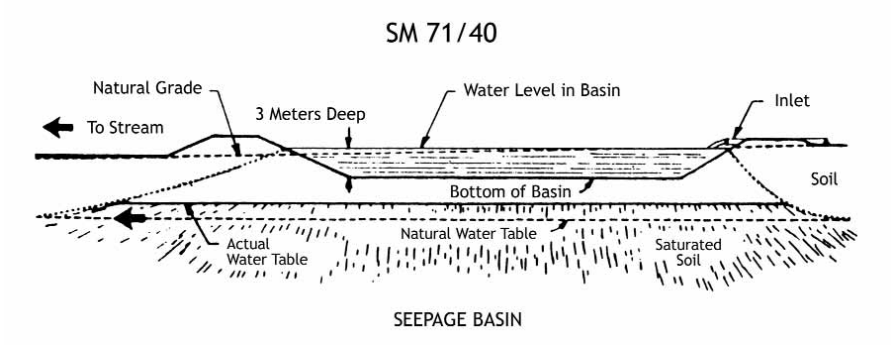
ing, the results of which indicated the hazardous material process wastes held in that tank were particularly aggressive at initiating stress-corrosion cracking. It was suggested that all future tanks be fully stressed relieved during construction by heating to 1100º Fahrenheit. All of these leaks eventually sealed themselves through the deposition of solids in the small openings, a process aided by the circulation of heated air in the space between the tank wall and concrete enclosure to encourage evaporation and the accumulation of the solids.[105]

> When the supernate from stored waste is evaporated, the residue is thereby saturated with salts at a temperature of about 100° C above ambient, and upon encountering a cool surface such as the wall of a tank, it immediately deposits a layer of salt. Thus, any tank that has received evaporator tailings in amount[s] sufficient to bring the salt content above saturation at ambient temperature (and we propose to put all tanks in this condition) is self-sealing against cracks. The sealing action is simply a matter of change in solubility with temperature, there being necessarily a temperature differential between the interior and the exterior of the tank. The sealing action has no relation to the composition of material outside the wall…. Thus, the evaporated waste, partially solidified in tanks, appears to be immobilized.[106]

Very low-level liquid waste was sent to seepage basins and allowed to soak into the ground. By design, seepage basins were about ten feet above the natural water table, located as far as practical from streams, and constructed in soil permeable enough to allow adequate seepage, but dense enough to give radioactive elements time to decay. The soil also needed to have good absorptive characteristics for radioactive isotopes, an attribute aided by higher clay content. Liquid from the seepage basins was expected to take several

years to reach the local river systems, and most of the radioactive isotopes would have decayed by then.[107]

The original burial ground, now known as the Old Burial Ground, was used from 1952 until 1974. During those years, solid waste was placed in approximately 160 trench-



Cross-section of a typical seepage basin at Savannah River. Source: Robert M. Girdler, Handling of Low- and Medium-Level Liquid Waste at the Savannah River Plant, in *Practices in the Treatment of Low- and Intermediate-Level Radioactive Wastes* (Vienna: International Atomic Energy Agency, 1966), 483.

es, segregated according to type and level of activity. In addition to being radioactive, some burial ground wastes contained mercury, lead, cadmium, solvents, and other hazardous substances. Up until 1965, transuranic waste was placed in bags and boxes and buried like other solid contaminated wastes. After 1965 these wastes were segregated by level of activity, and some were placed in retrievable concrete containers. Savannah River was one of the first sites in the weapons complex to store these wastes in a way that they could be recovered—the federal government did not define procedures specifically for



H-Area Seepage Basin. Courtesy of SRS Archives, negative 36633-6.

handling transuranic waste until about ten years later. Seepage tests were conducted, during the early years of operation, to determine rates of the spread of contamination from the materials that would be buried there, and routine monitoring for contamination has been ongoing part of operations.[108]

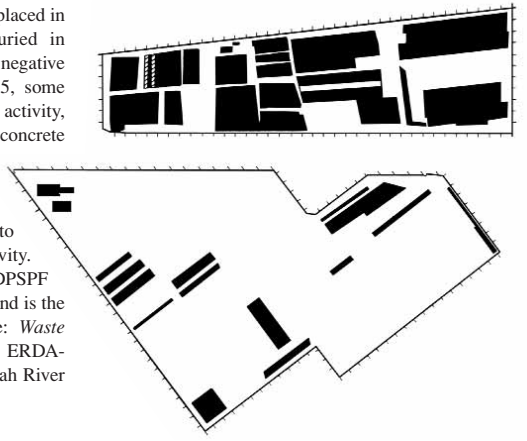
Diluted TBP that had degraded during operations and was no longer useable, was fairly free of radioactivity, so this was sent to the burial ground instead of the waste tanks. There, it was held temporarily in 18 storage tanks (installed between 1955 and 1962), then

BURIAL GROUNDS





1. Low-level radioactive wastes were placed in plastic or cardboard boxes and buried in trenches. Courtesy of SRS Archives, negative DPSTF – 1-11937-8. 2. After 1965, some wastes were segregated by level of activity, and some were placed in retrievable concrete containers, 1976. Courtesy of SRS Archives, negative DPSTF-1 13093-10. 3. Wastes in the burial ground were segregated according to the type of waste and level of activity. Courtesy of SRS Archives, negative DPSPF 28321-1. (Map) The Old Burial Ground is the lower area shown in drawing. Source: *Waste Management Operations*, Document ERDA-1537 (Aiken, South Carolina: Savannah River Plant, September 1977), II-119.





burned in a large open pan, dispersing combustion products to the atmosphere and leaving only residues to be buried. Radioactivity released to the atmosphere by this practice was minimal; the main radioactive contaminant in the TBP solution was ruthenium, which remained in the burn pan as residue.[109]

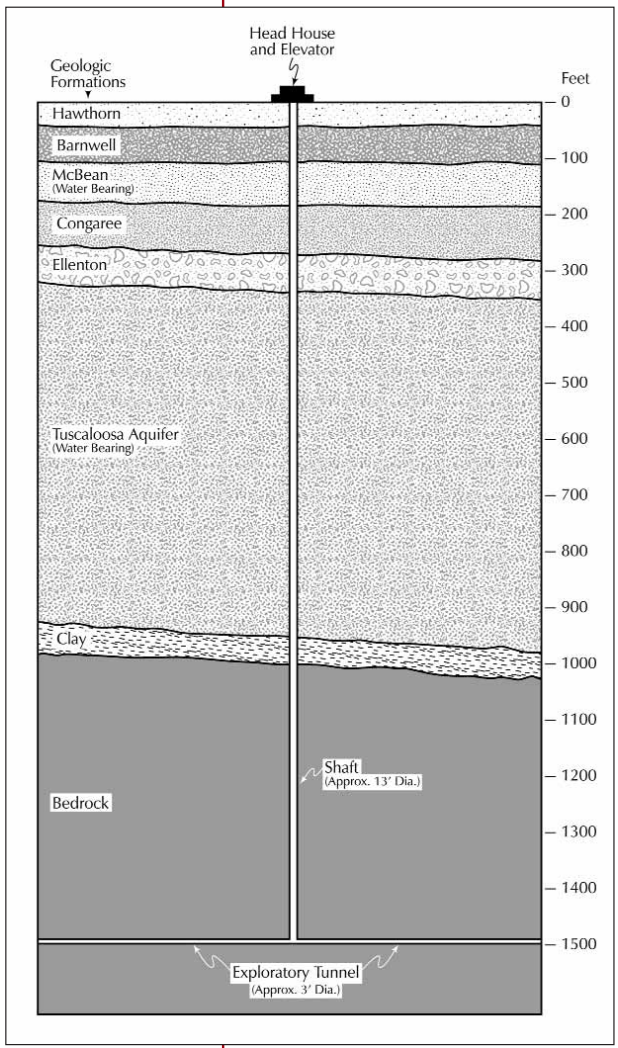
Seeking a Means of Permanent Storage As mentioned previously, the storage of high-level waste in steel tanks was considered only a temporary solution to handling process wastes at Savannah River. More permanent solutions were being sought even during initial design and construction. Conversion to a solid of some type was the primary approach to permanent storage. Investigations ranged from pumping solution underground to conversion to solid cakes that could be dumped into the oceans.[110]

One early potential solution that received a great deal of attention was storage in deep underground vaults beneath the plant. A mine shaft over 1000 feet deep was to be dug, then storage chambers would be excavated into granite bedrock underlying the area. Consideration was given to pumping wastes directly into these tunnels. By 1957, the idea was temporarily abandoned because of findings related to the permeability of the formations beneath the plant.[111]

The bedrock storage idea was revived in the late 1950s. A proposal was submitted to the Atomic Energy Commission in 1958, and brought to the attention of the National Academy of Sciences in 1960. The academy recommended that test borings be taken to see if the proposal was feasible, and this work began in 1961. Investigations continued for several years, and the concept was not abandoned until the 1970s. One problem was that the shaft to the storage tunnels would pass through the Tuscaloosa Aquifer for several hundred feet.[112]

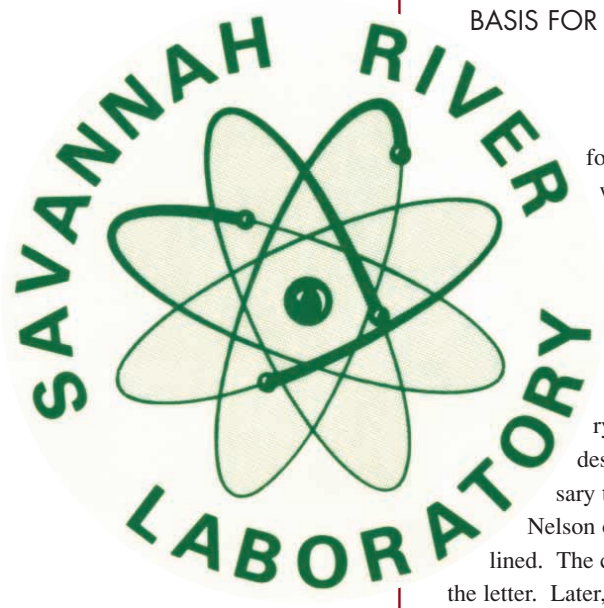
Another means of permanent storage was developed around the unusual properties of sulfur. Savannah River Laboratory research indicated wastes could be combined with molten sulfur, then placed in containers and allowed to solidify, creating a solid that was very resistant to leaching and possible release of radioactive materials. This process was considered to produce a product similar to glass, but at a significant savings of processing and handling costs.[113]

Vitrification, however, was the approach that was eventually adopted as the best method of stabilizing the wastes, and Savannah River's Defense Waste Processing Facility was constructed to vitrify wastes. The properties of different varieties of glass were studied at many of the Atomic Energy Commission laboratories. The most important research at Savannah River began in the 1970s, when the basic decisions and equipment designs were developed.[114]



The storage of radioactive waste in bedrock underlying the plant would have required an access shaft possibly 1500 feet deep. Source: *An Evaluation of the Concept of Storing Radioactive Wastes in Bedrock Below the Savannah River Plant Site* (Washington, DC: National Academy of Sciences, 1972), 10.

15 Savannah River Laboratory



"SRL is one of the best-equipped laboratories in the world. It is big enough so you can cut a swath in it; it is small enough so you won't get lost."

Source: *Nucleonics of Tomorrow in the Making Here Today Savannah River Laboratory*, E. I. Du Pont de Nemours and Company, Explosive Department, Atomic Energy Division, Technical Division, Savannah River Laboratory, Aiken, South Carolina; not dated.

BASIS FOR THE LABORATORY

The top secret letter of August 1950, setting forth the scope of work for Savannah River, stated that "new research and development facilities will be included at the main site or elsewhere to the extent required to support the work. Such facilities will be provided for the solution of process improvement and process development problems which may arise in connection with the work."[1] The nature of this "support" was later defined in more detail. In the summer of 1951, Du Pont's R. M. Evans wrote a long letter to Curtis Nelson, explaining the firm's ideas on the general division of responsibilities between Atomic Energy Commission laboratory facilities at the national level and those at Savannah River. He also described what Du Pont considered the minimum laboratory facilities necessary to support the plant's mission.[2] Since there were no initial objections from Nelson or others at the AEC, laboratory designs were developed as Evans had outlined. The commission also approved the designs for two pilot facilities described in the letter. Later, however, when the plans for the main technical laboratory were submitted, the Commission rejected them and asked that the laboratory space be reduced by half. Du Pont's reply, authored by Evans, voiced strong opposition to this reduction, and was ultimately persuasive. After further consideration, the Commission not only granted approval of the plans as originally submitted, but stated that Evans' justification of the laboratory had helped the Commission better define its own policy concerning other facilities nationwide.[3]

As Evans had explained in his reply:

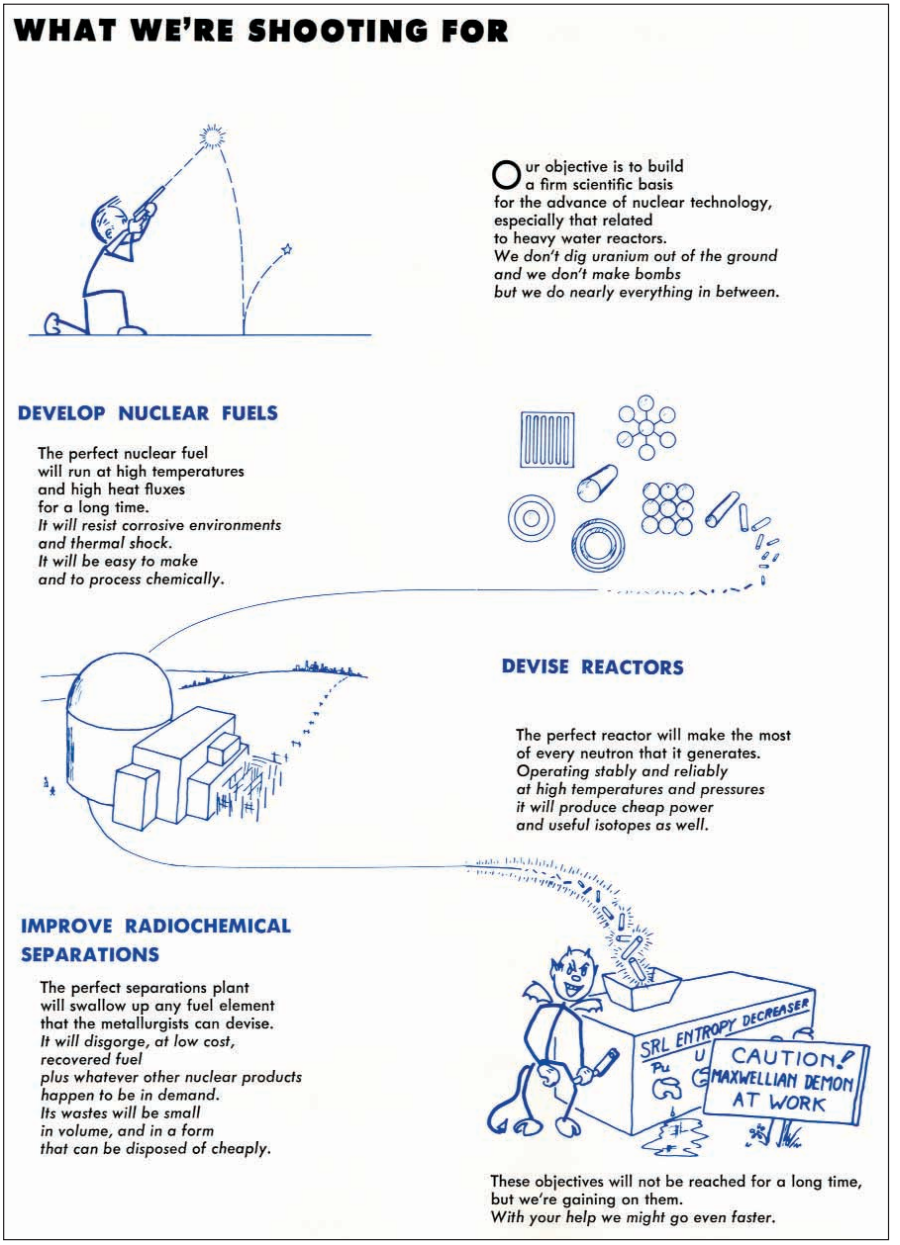
> We were on record with the Commission in 1949 recommending contractor responsibility for the solution of local technical problems, with a degree of self-sufficiency in force and facilities adequate to permit the solution of these problems to avoid the wastefulness of duplication in, or poor coordination of, process development work. We feel that an aggressive research and development program for process improvement is justified for the bene-

> fit of the Savannah River Plant, and that it can most effectively be realized as our responsibility. It should be administered with employees under our direction and closely integrated with the plant operation in which the opportunity for improvements is apparent in proper perspective. We would hesitate to assume responsibility for the research and development program under other conditions as we would consider we had inadequate control of priority, reduction to plant practice, or cost.
>
> As has been covered in previous correspondence and discussion, this does not mean that other AEC facilities will not have important functions in support of the Savannah River Plant. However, these should be in the field of fundamental research, more radical departures from Savannah River practices which may ultimately be taken over at the site for reduction to practice, and in specified fields which are applicable to Commission activities broadly.[4]

Although Evans' argument was built around what would be an economical and efficient division of responsibility between local and national laboratories, other influences also swayed Du Pont's conviction in this matter. The company wanted to attract competent scientists for work at the site; both to carry out its military production missions and to keep an eye on potential commercial developments related to nuclear energy. Evans convinced the Atomic Energy Commission that the laboratory was the minimum required, but it should be noted that the Savannah River Laboratory soon became Du Pont's second largest research facility.[5]

The company was not wholly self-serving in this matter. To some degree, changes in the nature of scientific research simply required this level of effort. As one researcher stated, "World War II created a new chemical community in which the distinctions between academic or pure science and industrial or applied science became increasingly blurred…. After [World War II], Du Pont and other chemical companies put increasing emphasis on doing their own science…. The pace of research in areas of interest to corporations had quickened, and universities did not have the resources to keep up. To redress this imbalance, companies gave more money to support academic research and postgraduate education. But companies relied on internal scientific research for future profits."[6]

The original mission of the laboratory was described as "the analytical control of purchased chemicals, manufacturing processes and finished products, and the procurement and assignment of non-technical laboratory personnel for the Technical Division," as well as the operation of pilot plants.[7] The initial undertakings were generally associated with solving plant startup problems, with a later shift to production efficiency and the development of new production processes as directed by the Atomic Energy Commission.[8] With time, programs expanded in scope and diversity—"nuclear technology as practiced at Savannah River encompass [ed] almost all of the physical sciences, mathematics, biology, and most branches of engineering."[9] Although the laboratory was not designated one of the national laboratories, in part because it was thought doing so might divert its work too far from local production-related work, the laboratory was an important component of the national network of atomic energy research facilities.[10]



Laboratory goals explained in recruitment brochure. Source: *Nucleonics of Tomorrow in the Making Here Today Savannah River Laboratory*, E. I. Du Pont de Nemours and Company, Explosive Department, Atomic Energy Division–Technical Division, Savannah River Laboratory, Aiken, South Carolina; not dated.

(Opposite Page) Technical Area Development between startup and the close of the Cold War. (Top) Source: 1956 Basic Information Map. (Bottom) Source: 1989 Basic Information Map.

In the national infrastructure that has comprised the nuclear weapons production complex, research and development is conducted at two levels: national and local. In general, the national laboratories support the overall nuclear weapons program, while the local laboratories are geared toward improvements related to site-specific missions. Local laboratories may take on broad national programs, if they have the technical personnel and experience suited to a particular research topic.[11]

The first dedicated atomic device research facility was "Site Y," established at Los Alamos, New Mexico. Many laboratories at universities, private laboratories, and military

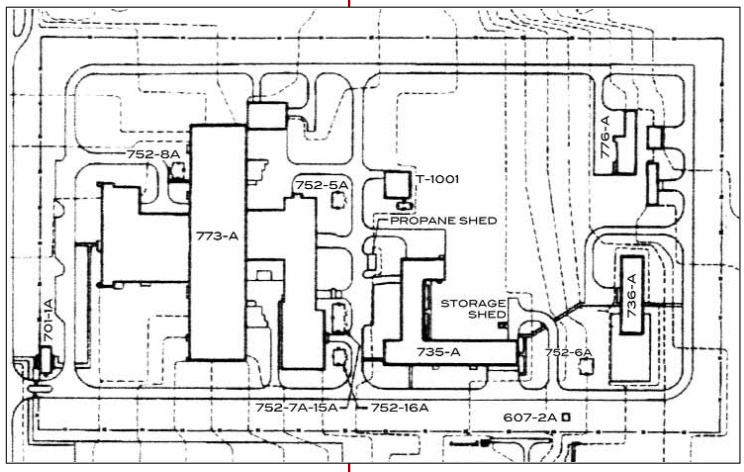
installations aided the Los Alamos scientists in their early work, and it was out of this loose association of research facilities that the system of designated national laboratories evolved. Los Alamos National Laboratory's primary mission was the "theoretical design of the nuclear components of nuclear weapons."[12] Sandia Laboratory was formed at Sandia Base in November 1949 from Los Alamos' Ordnance Engineering Z Division. Its primary mission was the design of non-nuclear components for atomic weapons. Lawrence Livermore National Laboratory, set up in 1952 in Livermore, California, focussed on the development of thermonuclear weapons.

GENERAL ORGANIZATION AND FACILITIES

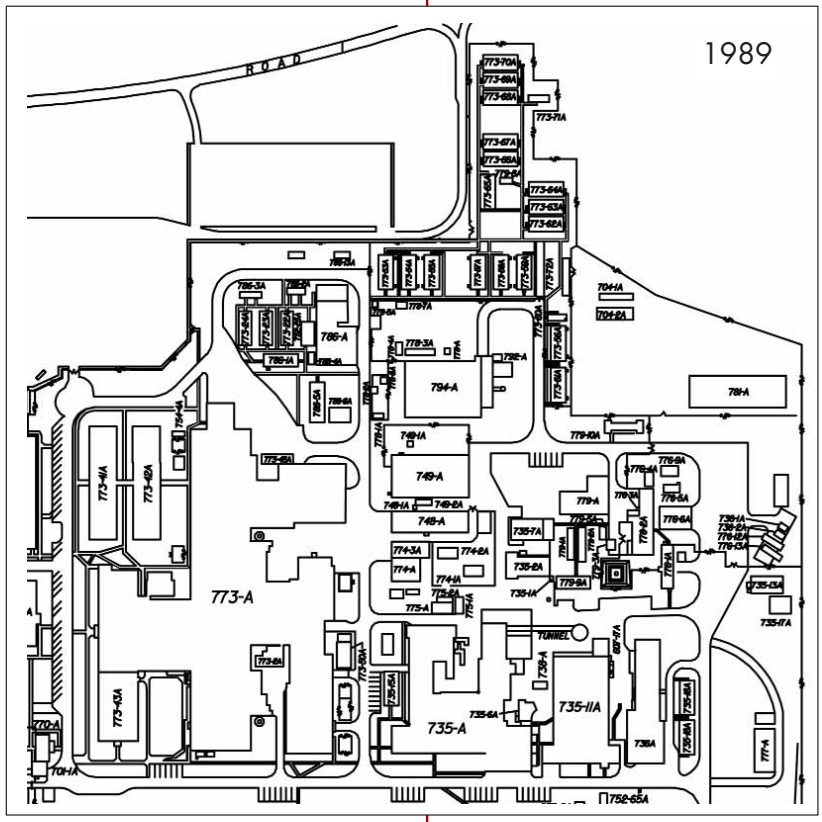
The original Savannah River Laboratory, now named the Savannah River Technology Center, initially included five primary facilities. Building 773-A served as the main laboratory and housed primary administrative functions and much of the process development and experimental research areas. Nearby was the Waste Disposal Facility (Building 776-A), set up to handle the waste created by the laboratory. The Pile Physics Laboratory, located in the manufacturing area or 300 Area in Building 777-M, contained various experimental reactors used for various lattice and reactivity experiments. The last two facilities were semi-works laboratories: CMX and TNX, located in Buildings 679-G and 678-G, respectively. CMX was originally set up to determine the treatment needed for the cooling water that would circulate through the reactor heat exchangers. TNX was used for determining operational data for various separations equipment.[13]

In addition to these original facilities, there were various additions to the laboratory in later years. These included the Health Physics Laboratory in Building 735-A and the Equipment Engineering Laboratory and shops, located in Building 723-A.[14] The latter became a part of the Savannah River Laboratory organization after the Equipment Engineering Division was transferred to SRL. Other temporary laboratories were set up over time to perform specialized work. Early examples of these facilities were the Fluid Pressure Bonding Laboratory in Building T-1001 (one of the early Temporary Construction administration buildings), and a mockup of a reactor tank in Building 677-G. A

1956



1989



portion of Building 677-G was converted to a gas-processing laboratory in 1956 to conduct tritium-related studies.[15]

In addition, small labs were established in outer areas to help with process control. Laboratories of this nature were located in the D and F Areas, such as Buildings 772-D and 772-F. Although they were called laboratories, the assay labs were not part of the formal laboratory structure. Since their work related to day-to-day operations, these labs were considered part of—and managed under—plant operations.

Under Du Pont, the management of the laboratory system was considered separate from operations, but the relationship between the two administrative organizations—the Savannah River Plant and the Savannah River Laboratory—was close. The laboratory was integrated into the site-wide safety programs, but health physics concerns in the laboratory facilities were initially handled by a separate organization. Plant and laboratory personnel were paid as part of the same organization to allow easier personnel transfer between the two.[16]

The management of the laboratory was based on that of Du Pont's Organic Chemicals Department and it incorporated elements of the nylon model. A Steering Committee, comprised of management personnel from the Technical Division and other interested directors in Wilmington, along with local managers, was set up to establish laboratory programs, control costs, coordinate subcontract work with outside entities, and represent the laboratory in relations with the Atomic Energy Commission.[17] Oversight of the Savannah River Laboratory management was provided by the Technical Division in Wilmington, which reported to the director of the Atomic Energy Division. Savannah River Laboratory was initially composed of 10 divisions: Theoretical Physics, Experimental Physics, Applied Physics, Pile Engineering, Pile Materials, Separations Chemistry, Separations Engineering, Analytical Chemistry, Laboratory Services, and Technical Information Service.

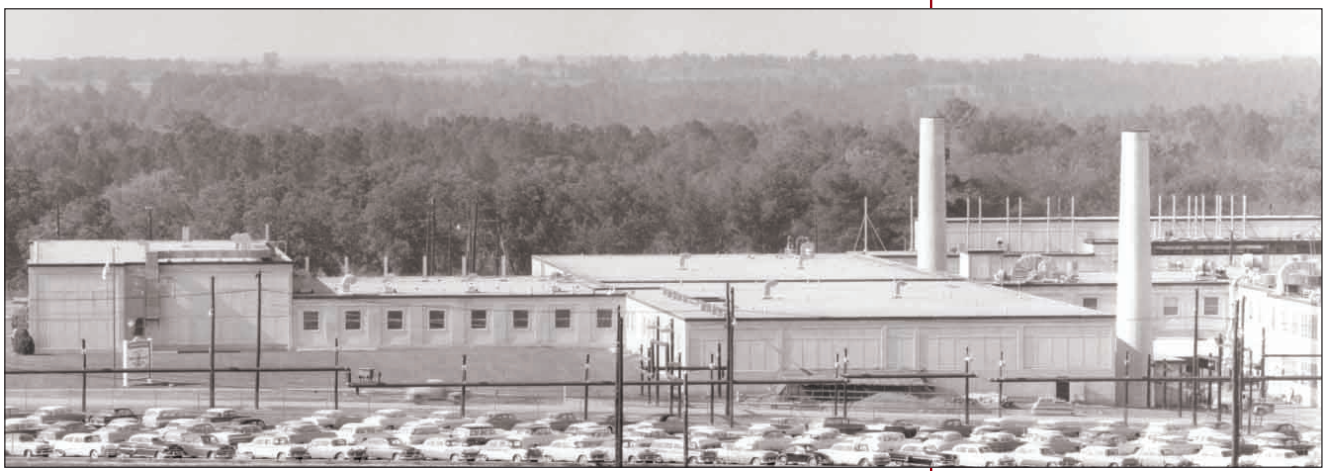


Original facade of Savannah River Laboratory, 1974. Courtesy of SRS Archives, negative DPSTF 1-12640.

MAIN LABORATORY

Construction of the main laboratory, located in Building 773-A, began in November 1951 and was completed in February 1953.[18] The main laboratory was comprised of a front wing, with administrative functions and services, along with change areas and laboratory space for non-radioactive work. The central portion of the laboratory had two rows of laboratory spaces separated by a utility corridor; personnel corridors were located on

the opposite sides of the rows of laboratories. This portion of the building was designed for handling radioactive materials, and was outfitted for chemistry, metallurgy, and other types of experimental work. A rear wing of the building contained storage, workshops, and instrument development facilities. Another rear wing, heavily shielded, was used for work with highly radioactive materials. The ends of these wings were constructed to allow for future building extension, if needed.[19]



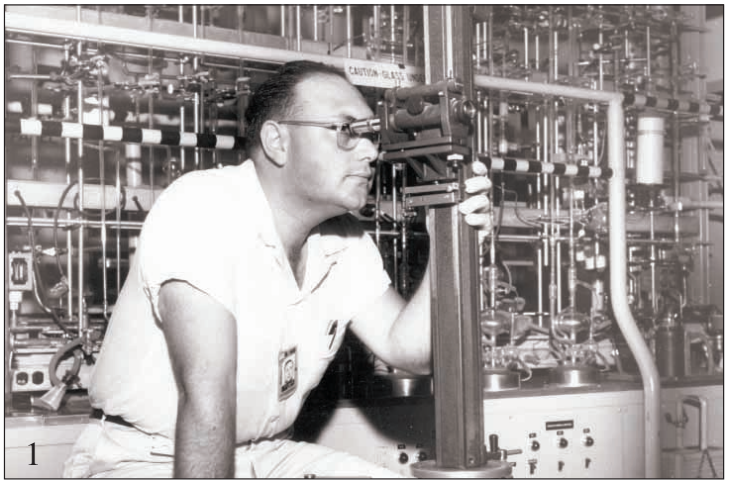
South elevation of Main Laboratory, 773-A, showing wings. Courtesy of SRS Archives, negative DPSTF-1-299-302.

The purpose of the main laboratory building was to house laboratory management, all related technical information services and personnel—including a print shop and a vault for document storage—as well as laboratory space for most of the technical work undertaken at the site. The laboratory space included a large metallurgical fabrication facility (soon dubbed the "Fab Lab"), machine shops, and three "High–Level Caves."[20] The High–Level Caves were heavily shielded areas where workers could use master-slave manipulators to work on highly radioactive materials. The High–Level Caves began operation in December of 1953, and were an essential component of the main laboratory.[21]

Over the years, the laboratory has been expanded many times. New high- and intermediate-level caves were needed for separations studies shortly after operations began. In 1956, planning began for the addition of five six-foot-square high-level caves and one double this size, as well as two smaller intermediate-level caves for a miniature mixer-settler setup.[22] Other facilities were added as well. One of these was the Isotopes Process Development Laboratory, used to place radioisotopes in capsules for later use in reactors as either sources or targets.[23]

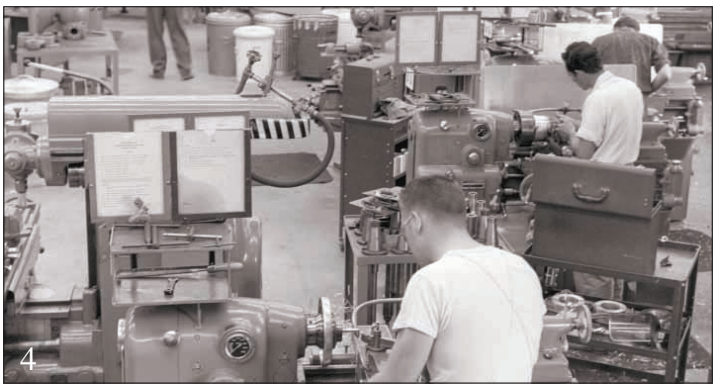
One of the more unusual features of the main laboratory building was the Glass Shop, established for the manufacture of glass bottles, pipettes, and unique glass apparatuses that could not be found on the open market. Because of the secret nature of much of the work done at the Laboratory, it was deemed necessary to bring glass blowing skills directly to the plant. A foreman, who was also a qualified glass blower, ran the Glass Shop, which began operations in August of 1953. Most other personnel were hired locally and trained on site. In the two years of 1956–1957, the Glass Shop turned out 2,474 work orders, half of which were for the Laboratory, the plant itself receiving the other half. Both the number of work requests and the allocation of the glasswork appeared to be typical for the early years of the Laboratory.[24]

Laboratory Perspectives


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THE PILE PHYSICS LABORATORY

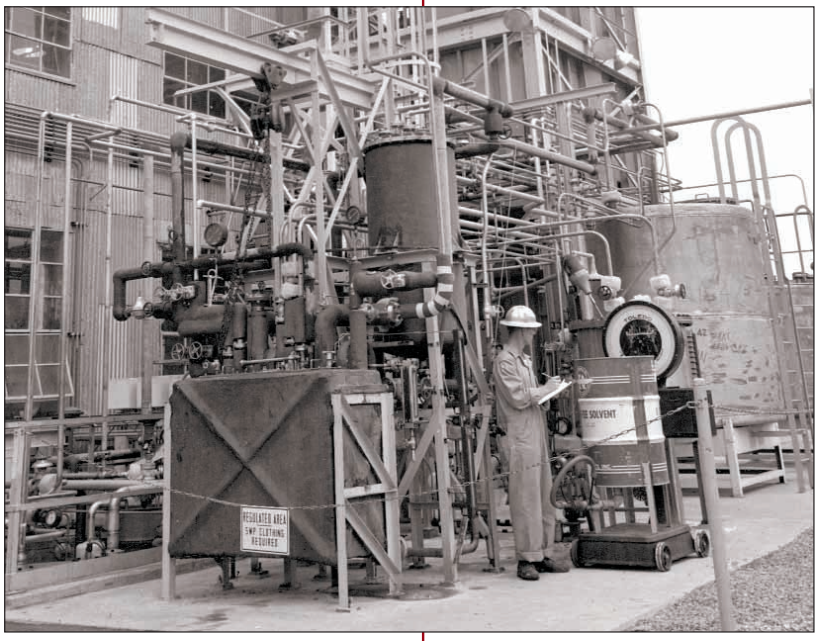
Construction of the Pile Physics Laboratory, Building 777-M, began in early 1952, and it was finished in the latter part of 1953. The building was originally designed to contain two experimental reactors. One of these was the Process Development Pile or PDP, a nuclear mockup of the site's production reactors. The other was a small unit designated the Standard Pile or SP, suitable for calibration purposes and for supplying neutrons for experimental purposes. The Subcritical Experiment or SE, a tank filled with D_2O, was closely coupled to the SP reactor. Many of the physics parameters of the SRP lattices could be determined in this facility using relatively little fuel.[25] After decades of service, the reactors in 777-M were effectively shut down in the 1980s, after most of their functions had been assumed by new computer codes and new computers.[26] The function and history of these experimental reactors is covered in the reactor chapter.

(Opposite Page) 1. Monitoring, courtesy of SRS Archives, negative 5222-17. 2. Five glassblowers were employed in the Technical Division in 1955, designing and producing laboratory tubes, flasks, beakers and pumps. Glassblowers such as Harold Marks, Tommy Tudor and Randy Searle delivered custom designs. Courtesy of SRS Archives, negative 3360-4-45. 3. G.E. Minor and J. T. Sales weighing down uranium in Fabrication Laboratory, 1978. Courtesy of SRS Archives, negative DPSTF –1-13826-34. 4. SRL shop scene, 1956. Courtesy of SRS Archives, negative 3360-47. 5. Interior view of laboratory. Courtesy of SRS Archives, negative DPSPF 12398. 6. Interior laboratory view. Courtesy of SRS Archives, negative 5233-5.

THE PILOT PLANTS

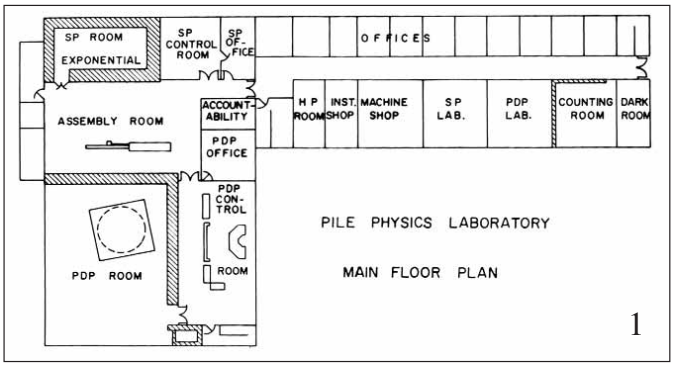
Early on, "it was recognized that several mechanical and chemical problems, as well as certain other process information, would require development and confirmation through the medium of pilot plant or semi-works operation before firm design could be established. It was felt necessary to test certain equipment and operating variables for the 200 Areas, and the entire design of the water cooling for the 100 Areas required substantiating from the point of view of flow patterns, corrosion, erosion, and heat transfer."[27] The CMX and TNX pilot facilities were established to perform these initial tasks prior to the completion of construction. Both CMX and TNX were located in what is known today as T Area, near the far-western perimeter of the site, adjacent to the Savannah River. The location was chosen so that experiments could be carried out without interfering with construction work in the production areas, and because services such as water and electricity could be readily obtained.[28]

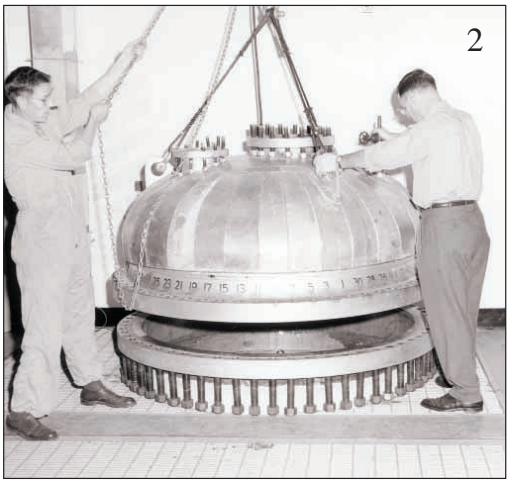
John Reed weighs chemicals in preparation of one of the feed materials for test equipment at TNX. Courtesy of SRS Archives, DPSPF-3-20.

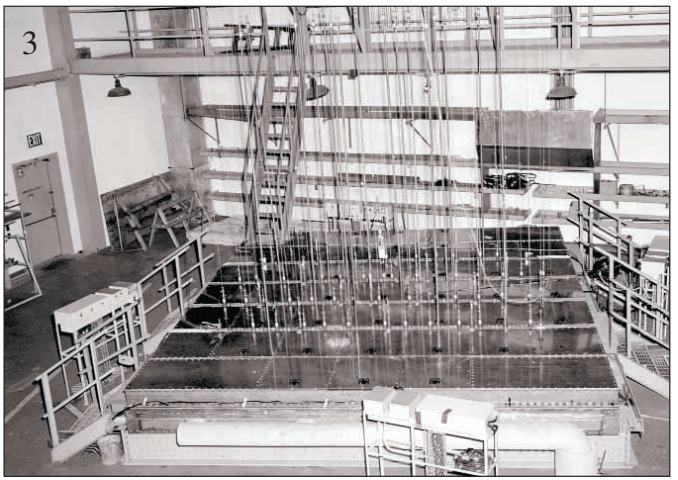


CMX construction began in April 1951, and the facility was turned over to operations in September of the same year.[29] It originally included equipment for water treatment and for hydraulic testing, several sets of heat exchangers (including a prototype of the original reactor heat exchangers), pumping and heating equipment, and equipment needed for conducting health physics experiments.[30] CMX was also called the Corrosion Laboratory and was similar to a laboratory built for a like purpose at Hanford.[31] Like the main laboratory, CMX was designed for future expansion, if necessary.[32]

One of the first tasks for CMX personnel was to determine the minimum treatment needed for the cooling water that had to be run through





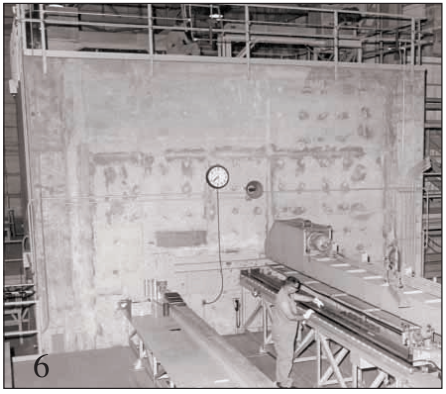


1. Pile Physics Laboratory floor plan. This facility housed three test reactors used by SRL researchers. The reactors are placed under the high-hat area of the building. Courtesy of SRS Archives, negative DPSTF-83. 2. Pressurized Subcritical Experiment (SE) test reactor in Pile Physics Laboratory that was used to measure nuclear parameters at high pressures and high temperatures. When built, it was the first of its kind. Courtesy of SRS Archives. The Standard Pile (SP) was designed and constructed by the General Electric Company and was similar to the Thermal Test Reactor at Knolls Atomic Power Laboratory. (Not shown). 3. Fuel elements are placed in the Process Development Pile (PDP), a zero-power test reactor used for physics research. Courtesy of SRS Archives, negatives DPSTF 1-2613, 1-2536. 4. PDP control room. Courtesy of SRS Archives, negative DPSPF-8929-13.





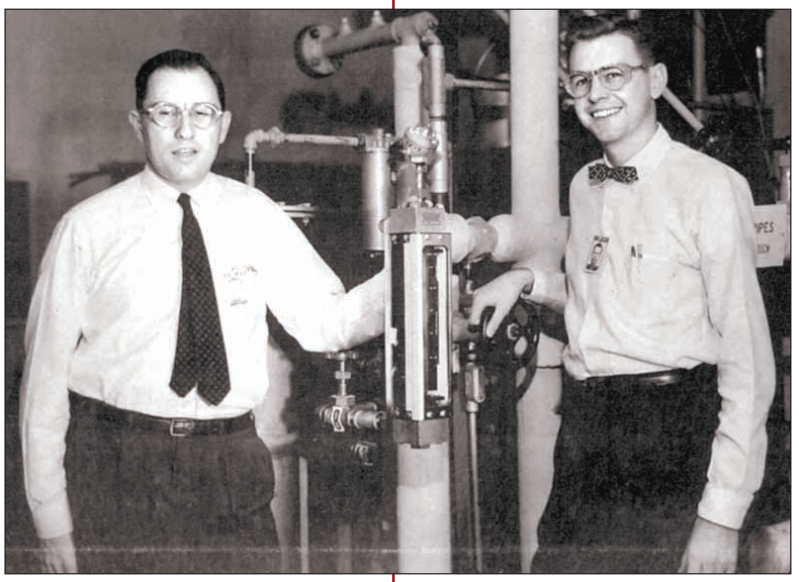
5. Graphite Test Pile control room in 305-M. Courtesy of SRS Archives, negative 2023. 6. Face of Graphite Test Pile, Courtesy of SRS Archives, negative 38887-1. 7. Interior of Heavy Water Components Test Reactor. Courtesy of SRS Archives, negative DPSTF-6027. 8. Aerial of Heavy Water Components Test Reactor (HWCTR). This test reactor facility was decommissioned in 1997. Courtesy of SRS Archives, negative 7885-G.







the reactor heat exchangers. This water was to be pumped from the Savannah River to the heat exchangers of the production reactors. There, it would absorb heat from the reactor's heavy water coolant, before being returned to the river. At R Reactor, the first reactor construction site, a treatment plant was built to process this cooling river water at a rate of about 90,000 gallons per minute. The treatment plant was designed to preserve cooling efficiency by removing minerals that could have accumulated within the heat exchangers. The work at CMX determined that this treatment was not required, since sands and silts in the river water acted as abrasives, scouring surfaces where minerals would accumulate. Based on these findings, the construction of these treatment plants was eliminated from the other reactor areas, greatly reducing construction and operations costs.[33]



Otto Morris and Al Peters in CMX Facility circa 1960.

By the mid-1960s, CMX was studying hydrodynamic properties of reactor assemblies and components.[34] These included vibration wear problems that could cause failure of reactor assembly components and release of radioactive contaminants into the heavy-water moderator. Reducing vibration through flow testing of the various types of assemblies was a long-term effort at CMX.[35] The tests that led to the abandonment of flat fuel elements, like Mark III, were undertaken at CMX.[36] Coolant–flow instability caused by heated reactor assemblies was also studied, contributing to determinations of reactor power limits.[37] In the late 1960s, the reactors were loaded with assemblies configured to provide very high neutron intensities. These loadings, part of the High Neutron Flux and Transplutonium programs, involved fewer assemblies, which were placed in the center of the tank. The entire reactor coolant flow was distributed to the smaller number of assemblies so individual assembly flows were unusually high. When the flow was increased to the levels determined necessary, the flow rate through the individual assemblies began oscillating. A full-scale reactor plenum was built at CMX to investigate these oscillations, resulting in a redesign of the coolant inlet for the assemblies.[38] In the years that followed, the CMX facility was used with less frequency as the various production processes were basically perfected. The facility was finally closed in 1983, when all remaining functions were moved to the main laboratory.[39]

The function of TNX was to test equipment before installation in the Separations Areas (F and H Areas), and to conduct research related to the operation of that equipment. Equipment, related to both chemical processing and waste storage was tested here, using solutions with no more than minimal radiation (such as that in natural uranium). The initial work primarily concerned scaling up experimental mixer-settlers to plant-operations scale, but other equipment such as evaporators, centrifuges, decanters, jets, vessel agitators, and gang-valves were also tested to provide operational parameters and explore potential improvements.[40] Trial applications of proposed process refinements, new processes, and new equipment were also important functions of the facility throughout its history.[41]

TNX construction began in May 1951, and was completed by the following fall. Laboratory appointments were moved into the building in the middle of October 1951 for the four chemists and three analysts then working there. The original equipment included two banks of mixer–settlers (prototypes for those to be installed in the canyons), an evaporator, and necessary pumps and tanks. By the middle of November, the first uranium had been introduced into the equipment and tanks, and pilot runs began December 10.[42] Additional equipment was installed during the months following completion of the building, and the replacement evaporator was moved outside the building after the first evaporator exploded in January 1953.[43]

Development of the jumbo mixer–settlers for the "F Area increased-throughput project" was undertaken in the mid-1950s. This work involved the construction of two, six-stage prototypes—one an enlarged version of the mixer–settlers in the canyons; the other, a new design called a turbine contactor—the best features of which were combined into the design that was used.[44] By 1955, an extensive program to determine operations parameters and performance of equipment for the HM process was underway in TNX, and other equipment setups had been installed for work on a thermal diffusion column for tritium purification.[45] Slightly later, the centrifugal mixer-settler units were also refined and underwent demonstration tests at TNX.[46]





Aerial views of CMX/TNX, 1981 (Above) and 1989 (Left), showing expansion during research and development for Defense Waste Processing Facility. Courtesy of SRS Archives, negatives 30141-6, 89-202.

(Opposite Page) 1. Bob Towell and John Walker measure heat transfer coefficients of "burnout." Courtesy of SRS Archives. 2. C. F. Forest performing metallographic and physical testing of reactor fuel and/or target elements, 1958. Courtesy of SRS Archives, negative DPSPF-5222-14. 3. Dr. Elizabeth Baumann, one of the site's first professional women, conducts analytical chemistry research in special areas of electrochemistry such as application of ion-specific electrodes to characterization and analysis of chemical systems. Courtesy of SRS Archives, negative 5222-11. 4. Gloved-box experimental work on proposed processes for recovering plutonium scrap. Courtesy of SRS Archives, negative 5222-11. 5. Laboratory technicians involved in testing water quality (for power department) or assaying raw materials prior to acceptance for process use. Courtesy of SRS Archives, negative DPSPF-7009-1. 6. Remote manipulation in High Level Caves. Courtesy of SRS Archives, negative 5469-1.

Other programs were undertaken at TNX, and some of these are listed here. One was the development of the complex frame systems for separating and purifying neptunium-237 and plutonium-238. Another was the development of the electrolytic dissolver for processing power reactor fuels such as those clad with zirconium and stainless steel. Others included the refinement of procedures to extract and purify tritium; various studies including the exploration of the reactions of metal nitrates with molten sulfur; the diffusion of gases in metals; the kinetics of aqueous and organic phase reactions; advanced methods for decontaminating process equipment; and evaluating the hazards of storing radioactive wastes in underground caverns.[47]

In 1978, a large addition was added to the TNX building to house equipment related to the vitrification of high-level radioactive wastes. The main equipment pieces were a calciner and a prototype glass melter.[48] The original melter operated more than two years until it was shut down in 1982, replaced by a melter of an improved design. These small melters were used to demonstrate various components of the vitrification system and to determine operational life span. The first large demonstration glass melter for the Defense Waste Processing Facility was started in 1982, and during the year, more than 130,000 pounds of glass were produced.[49]

Although built as a pilot plant for the initial separations and waste facilities at Savannah River, the TNX facility did not become extraneous once construction was completed. Rather, with the continual attention to process and equipment improvement, and with the addition of new missions at Savannah River, TNX has continued to serve as a pilot plant for operations in the F and H Areas, providing essential services in the scaling up of laboratory developments to plant scale.



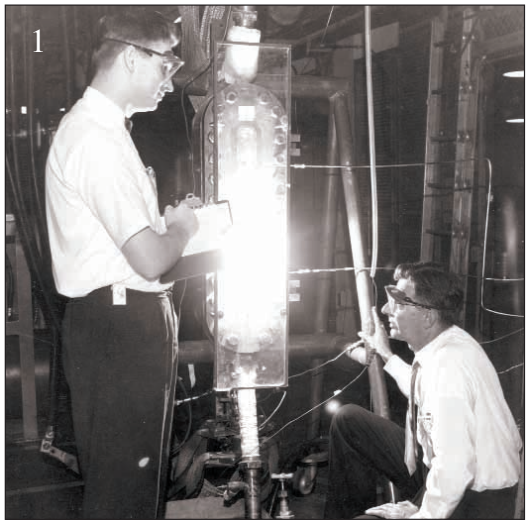
Savannah River Plant Management, Plant, and Laboratory, 1959. Photograph taken in front of Main Administration building, 703-A. Courtesy of SRS Archives, negative 5767-4.

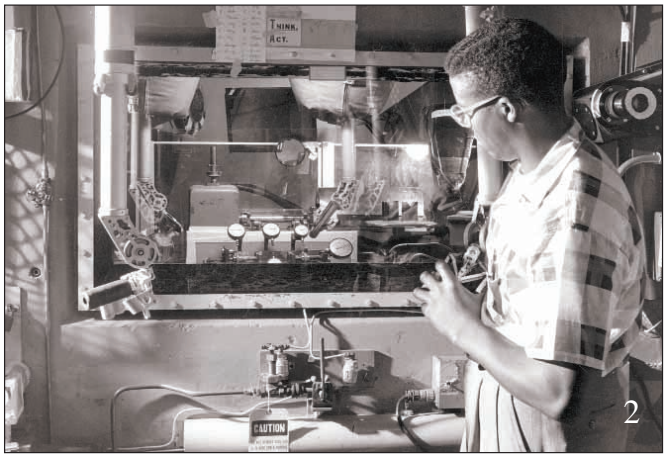
PERSONNEL

The personnel who worked in the Savannah River Laboratory were both scientists and engineers. "Science" generally includes experimental investigation and theoretical explanation, while "engineering" is the application of such scientific endeavors to practical ends. Production facilities, organized around practical principles of efficiency and product output, generally hire engineers rather than scientists, but Savannah River was not just a production facility. Successful startup of the production facilities required research in areas that still lacked well-understood theoretical explanation, such as reactor physics and radioisotope separations. An early issue of the plant newspaper noted that Savannah River was opening "new technological frontiers," and that the site was symbolic of "the beginning of a new civilization." Plant engineers and scientists, it went on to say, were "in the heart of the technological world… [And thus able to contribute] toward building that civilization."[50]

The original group to work in the laboratory was described by the first laboratory director, Milton Wahl, as "a very young organization… both with respect to age and experience." Most did not have experience at other Du Pont facilities. In July 1953, only 33 of

1950s Views of the Laboratory













the 173 persons in the laboratory had worked for Du Pont outside the Atomic Energy Division. Sixty had received some training at the other Atomic Energy Commission sites during the construction of the Savannah River facilities, and 68 reported directly to the site as new hires.[51] By December of 1955, when the plant and the laboratory were fully operational, there were a total of 571 employees at SRL, a number that would more or less be stable for a number of years. Of that number, 104 were engineers, 76 were chemists, 41 were physicists, 9 were metallurgists or metallurgical engineers, 3 were mathematicians, 11 were foremen, 11 were technical information specialists, and another 16 performed administrative functions.[52]

By 1957, laboratory personnel had been drawn from every commercial department in Du Pont. They were also drawn from 149 universities as new hires.[53] In the early 1960s, as laboratory projects diversified to include more peaceful atomic work, such as the Transplutonium programs, technical personnel included chemists, physicists, metallurgists, and mechanical, chemical, and electrical engineers. In 1962, 64 members of the laboratory staff had doctorates, while another 54 had masters' degrees.[54] Recruiting brochures noted that SRL compared favorably with Du Pont's largest and most diversified laboratories. Capital investment in buildings and equipment reached $45 million by 1960. Thus, each scientist had at their disposal an average of $200,000 worth of facilities.[55]

Many of the early SRL scientists and engineers had been involved at Hanford or had worked for Du Pont at some other Manhattan Project installation. Early laboratory superintendent Randy Fenninger had worked at Kankakee Ordnance Works, the Clinton Laboratory, and Hanford. And area supervisors Don Ebenhack, George O'Connor, and Rudy Piech had combined experience at the Kankakee, Indiana and Oklahoma ordnance works; at the Hanford and Dana plants, as well as with the University of Chicago Metallurgical Project; Oak Ridge; and the Aberdeen Proving Grounds.[56] Milton Wahl had worked at Hanford and served as a liaison between Du Pont and the Argonne National Laboratory.[57] C. W. J. Wende, an early assistant laboratory director serving under Wahl, was also at Hanford. Wende remained at Hanford after Du Pont left, working under the new contractor, General Electric. He returned to Du Pont shortly after the company accepted the Savannah River project.[58] R. I. Martens, who came to Du Pont in 1943 from the University of Chicago Metallurgical Laboratory, worked at Hanford, Argonne, and at Oak Ridge before coming to Savannah River.[59] In later years, technical personnel grew to include computer and environmental scientists. By 1980, with the increased workload, the laboratory employed nearly 1,000 persons,[60] and topped that number in 1982 and 1983,[61] partly as a result of the L Reactor Restart program, but primarily as research and development was underway for the Defense Waste Processing Facility.

LABORATORY ACCOMPLISHMENTS

The first priority of the Laboratory system was to gather data needed for startup and to support initial process development. By 1956, the laboratory had largely accomplished these initial objectives, and was being redirected toward improving the various processes required in the production of plutonium and tritium, the main missions of Savannah River. This was a tall order, since it meant nothing less than providing the main support for the industrial-scale operation of the plant. Neither the heavy-water reactors, nor the Purex

separations process had ever been operated before on such a huge scale, and the challenges to make these facilities work—much less make improvements to the systems—were daunting.[62]

Because the Laboratory was not set up to do pure research, but rather assist the plant in its various operations, the history of the Laboratory parallels that of the plant itself, and can be divided into similar periods. The first, spanning from the 1950s to around 1964, concentrated on the original mission of Savannah River, namely the production of plutonium and tritium for nuclear weapons. This was followed by a period of greater experimentation, beginning with the Heavy Water Components Test Reactor (HWCTR) in the early 1960s, and coming to full development with the Transplutonium programs that ran from 1964 to 1970. This in turn was followed by the further improvements to the production of plutonium and tritium that occurred in the 1960s and 1970s. This not only included improvements to the basic equipment and components, but also the development of new technologies to help streamline the process, such as computers. Finally, in the 1970s and 1980s, came the rise of new laboratory missions that began to supplant the old mission that was dedicated to production. These new missions were in full swing when Du Pont left the facility in 1989. Just a few years later, under Westinghouse, the Savannah River Laboratory was renamed the Savannah River Technology Center, in full recognition that the old laboratory system was to serve a new purpose.

Although this chapter discusses some of the major achievements of the Laboratory, work was not confined to these topics—the laboratory was involved in almost all improvements to site equipment and procedures. All developments discussed in the operations chapters are at least partly associated with work in the laboratory. The most important laboratory contributions are intimately associated with all of those discussed in the operations chapters. In the early years, those contributions supported, and continually improved, production equipment and procedures.

HIGHLIGHTS OF THE EARLY WORK, 1950s–1964

The early water–purification experiments performed in the CMX facility and discussed above, were just the beginnings of Laboratory work done in support of reactor operations at Savannah River. The Laboratory worked in full concert with the plant to improve production in the reactors long after they began operations in 1953 through 1955. One of the early achievements of the Laboratory was the creation of the "partial-length reactor control rods," commonly referred to as "half rods." Conceived by C. W. J. Wende, half rods allowed the reactors to increase power by as much as 30 percent. The use of these rods was also important to the xenon studies done with the Process Development Pile (PDP). Conducted in 1956–1957, these studies were absolutely essential to understand, and counteract, the effects of xenon oscillations that became troublesome when the reactors began their power ascensions. The xenon studies led to recognition of the need for greater vertical flux monitoring and control within the reactors, and led to improvements in instrument response and half-rod management within the reactor.[63]

The Laboratory was just as intimately involved with fuel and target improvements. The fabrication laboratory, or "Fab Lab," did some of the earliest work on possible replacements for the Mark I solid slugs that first went into the reactors. This led to the

creation of the first replacement for the Mark I, aluminum-clad plates that went into the Mark III assembly. While this concept did not prove successful, subsequent work on fuel and target tubes proved rewarding. Laboratory personnel, working in the High Level

"Du Hush"—A Savannah River Fable

Charles W. J. Wende, identified as the "doggerel laureate of Hanford," by atomic energy pioneer John Wheeler, was a leading force in the development of the Savannah River Laboratory. He came to the plant from Hanford and would remain a vital part of the laboratory until his retirement. In addition to his significant achievements in process development, he also left a legacy of prose that touched on everything plant-related from how to write a progress report to how to make "ethyl precipitate." His Savannah River verses and stories have been carefully archived by the many who had worked with him and enjoyed his whimsical writing style and comic perspective.



(Above) Charles W. J. Wende, Savannah River Laboratory. Courtesy of J.Walter Joseph.

There was Something of a Ceremony on the day when the First Kilogram of Du-Hush was delivered. The Engineering Department sent an Orator who showed a beautiful Movie, in five-color, four-dimensional, stereophonic Cinerama, that told how the Miracle was accomplished. Then the Orator made a Speech that told how His Department saved Three Times as much Money as the whole Job was supposed to Cost in the First Place. Everybody wondered if the Orator figured Stresses with the same kind of Arithmetic that he used to figure Savings, but nobody was Unhappy because the Job, after all, was a Howling Success. The Reactors, the Crab Grass, and the Charley Horses would Get What Was Coming To Them, but Good.

The Ceremony was very fine indeed, but the Physicist, the Chemist, the Engineer, and the Metallurgist weren't there. It had suddenly occurred to them that, with a Double Carom Shot of Dineutrons off of Isopontium, with Seaborgium in the Side Pocket, they might be able to make Protonemoursium. Theoretically, as everybody knows, this is just dandy for making Philosopher's Stones. So the Boys had forgotten all about Du-Hush and were Off in Full Cry.

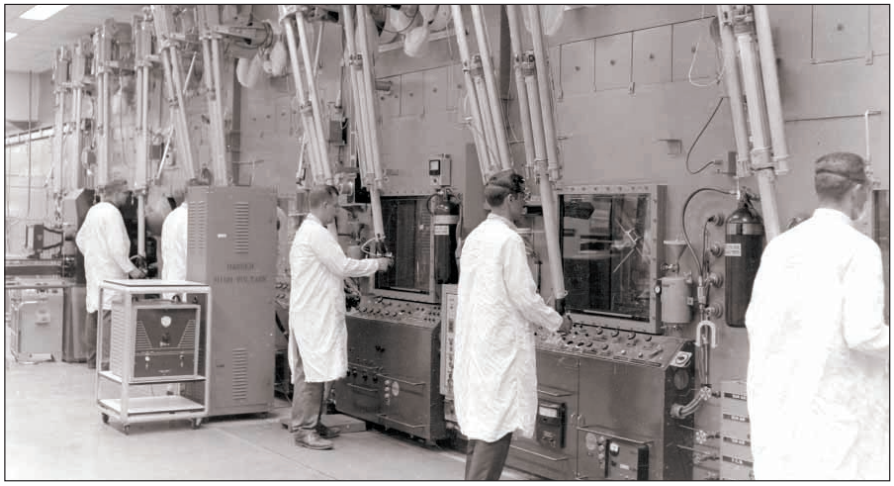
As they disappeared into the Remote Vastnesses of the Laboratory, all that you could hear was the Plaintive Voice of the Boss, shouting, "When are you guys gonna Write Up a REPORT on this Job?"

Tally-Ho and View Halloo! If you want any more of the inside lowdown on this fabulous Laboratory, you'll have to join the Fun & Games.

C. W. J. Wende

Source: Fable, courtesy of the SRS History Project; John Archibald Wheeler, *Geons, Black Holes & Quantum Foam: A Life in Physics* (New York: W. W. Norton & Co., 1998), 170.

Caves and with groups in other nuclear facilities around the country, pioneered the first successful tubular assemblies, essential for the optimum production of tritium. This led to the development of enriched-uranium alloy fuel tubes, used in conjunction with lithium–



"From the time the construction of High Level Caves was complete, competition among the research and development sections of SRL for space to work in the Caves was vigorous. Originally there were six operating positions, each with a pair of 'master-slave' manipulators. Later ten more positions were added. The manipulators had simple pincers inside the cells. The pincers were moved by systems of cables to duplicate the movements of the hands of the technicians, who remained outside the shielding and observed through thick glass windows. The technicians could feel, as well as see the manipulations." Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).

aluminum targets, as well as the development of coextruded target tubes created from aluminum-clad lithium–aluminum alloy billets. Hollow natural uranium slugs were clad with aluminum by hot press bonding but slug quality was improved when the hot-die-size process was developed in the early 1960s.[64]

As with reactors and fuel and target improvements, the Laboratory was likewise connected with improvements in the separations areas. From the beginning of the Purex process used to isolate plutonium, radiochemists at SRL worked to solve one of the first



Two views of High Level Caves showing heavily shielded cells with manipulators. Technicians, working on a wide spectrum of projects, could perform their work on materials with the same level of radiation that would be encountered in operations. (Above) The first view shows the High Level Cave Area circa 1960, with original equipment. Courtesy of SRS Archives, negative DPSPF 8929-1. (Left) The second view, taken about fifteen years later, shows updated equipment. Courtesy of SRS Archives, negative DPSPF 31184-11. Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).

problems associated with the process: solvent degradation. The first solution used to separate plutonium from the irradiated uranium was TBP, or tributyl phosphate, in a diluted form of a high grade of kerosene known as Ultrasene. It was soon discovered that Ultrasene could be replaced with "Adakane," with far better results. In continuing this line of work, laboratory researchers developed a contactor that would greatly reduce the amount of time the solvent was in contact with the feed solution. This led to the develop-

ment of the Centrifugal Contactor, which did the job quickly and kept solvent degradation to a minimum.[65]

The Laboratory was also active in the separations processes associated with the various thorium programs, some of which date back to the first days of the facility. As early as 1953–1955, thorium was irradiated to produce uranium-233, a fissionable isotope. One of the initial problems with irradiated thorium was that it also produced uranium-232, an unwanted byproduct that was not only highly radioactive, but also difficult to handle. In tackling this and other problems, the Laboratory helped develop the Thorex process that was eventually used to separate uranium-233 from irradiated thorium. The Laboratory also helped perfect the HM Process that was used to recover enriched uranium from uranium–aluminum fuel elements.[66]

ERA OF EXPERIMENTATION: SCIENTIFIC DISCOVERIES, HWCTR, AND TRANSPLUTONIUM PROGRAMS, 1959-1970

By the late 1950s, with the basic production processes well established and increasingly efficient, there was more time for less critical work. This inaugurated a period of experimentation that spanned the decade of the 1960s. Beginning with some scientific discoveries that occurred in the late 1950s, this work continued in the early 1960s with the development of the Heavy Water Components Test Reactor (HWCTR). It reached florescence in the late 1960s with the Transplutonium programs, pushed by Glenn Seaborg, then chairman of the Atomic Energy Commission. The Laboratory was crucial to all of these developments.

The discovery of the neutrino by Drs. Reines and Cowan at P Reactor in the middle to late 1950s only indirectly involved the Laboratory. Other discoveries were more direct. In 1957, Edward Albenesius and other researchers at SRL began to note that tritium was present in low-level liquid waste recovered from various well sites at Savannah River. At first believed to be the result of simple contamination, this tritium was later found to be the product of nuclear fission itself. By 1959, it was learned that a tritium nucleus was created from one out of every 10,000 to 20,000 fissions of uranium-235. This discovery was perhaps the greatest single scientific discovery of a theoretical nature made at the Savannah River Laboratory.[67]

The work conducted for the Heavy Water Components Test Reactor or HWCTR has been discussed. It should be noted, however, that the Savannah River Laboratory was involved in almost every phase of that work, beginning in 1956, when the AEC first expressed an interest in the program. At that time, when the heavy-water reactor was still known as the Power Components Reactor, the Laboratory was involved in conceptual and design work, with initial testing begun in the PDP.[68] From concept to construction in the early 1960s, to the final closing in 1964, the Laboratory was closely associated with the work at this experimental mockup of a heavy-water power reactor.

The Laboratory was integral to the various Transplutonium programs engaged at Savannah River in the middle to late 1960s. These too have been discussed in greater

The Nuclear Test Gage (NTG), a small, slightly subcritical facility, was developed to analyze production reactor components about ten times faster than the graphite moderated test pile in 305-M. It was placed in a shielded room in 777-10M while testing was ongoing. The experience gained from the prototype NTG was critical to the design of the permanent model. Source: Thomas F. Parkinson and Norman P. Baumann, The Nuclear Test Gauge, *Savannah River Site 50th Anniversary*, Proceedings of the Symposium, May 17, 2000 (WSRC-MS-2000-00061), 57-59.

NTG experimental prototype mocked up by SRL's staff (Below). Courtesy of the SRS Archives, negative DPSTF 178.

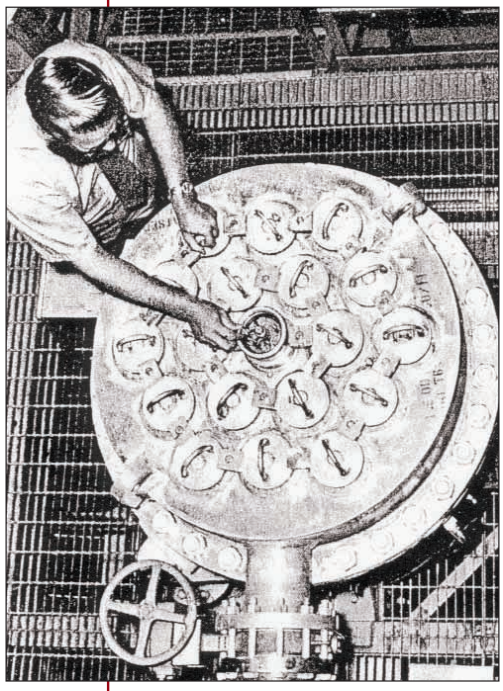


detail in earlier chapters, but it should be pointed out that SRL was particularly important in working out the kinks in the separations processes required for these new man-made elements, such as americium, curium, and californium. To effect the separations process, the Tramex process had to be replaced with the Rapid Ion Exchange, especially in the separation of californium. During this same period, there was a brief renewal of the thorium program for the production of uranium-233. The Laboratory was instrumental in creating the thorium oxide used in this process.[69]

IMPROVEMENTS TO THE MAIN MISSION, 1960s–1970s

Even though production of plutonium and tritium was reduced after 1964, the production of both continued throughout the period of the Transplutonium programs. By the 1970s, the production of both had been stabilized, not only in terms of production figures, but also in terms of process. After years of experimentation, the optimum fuel and target assemblies had been developed for use in the reactors, and the optimum separations process had been established. The Transplutonium program itself had helped establish the importance of mixed lattice assemblies in the production of radioisotopes. For all of these reasons, by the 1960s and 1970s, the Savannah River Laboratory had achieved national prominence as the primary center for the study of lattice arrangements for heavy-water reactors.[70]

In order to achieve an efficient stability in the production of plutonium and tritium, there had to be improvements at almost every step in the process, and the Laboratory had a hand in almost all of these. The development of hot-die-size bonding in the 1960s was a good example of the contribution made by the Laboratory in this general effort to improve the various production processes. An important innovation not put to use, because of the general wind-down of production, was the development of powder metallurgy as a means of producing fuel and target assemblies.[71] Improvements to the Nuclear Test Gage or NTG made this device smaller and more efficient.



Reactor mockup in Heat Transfer Laboratory, in which electricity rather than fission produced heat. Dave Knoebel, senior research supervisor, shows positions where full-scale dummy fuel elements are loaded aloft a 20–foot high–platform. Source: Heat Transfer Lab Means Improved Safety for Reactors, *Savannah River Plant News*, November 24, 1972.

While heat transfer studies were ongoing from the 1950s onward at the main laboratory and at CMX, a new laboratory dedicated to heat transfer research and ultimately to reactor safety was constructed in A Area. A prefabricated laboratory building (Building 786-A), roughly 40 by 80 feet in dimension, was constructed at a cost of nearly $1 million dollars. It housed a mockup of a reactor, heated by electricity to simulate the heat of a fuel target assembly. Researchers used the reactor mockup, outfitted with positions where full-scale dummy fuel elements could be inserted to perform tests that enabled the SRL Reactor Engineering Division, to calculate how fuel elements would perform under normal and abnormal conditions. The need for the advanced fuel testing equipment stemmed from the versatility of the Savannah River reactors; it allowed thorough testing of various fuel elements contemplated for use in the site's reactors that would exploit their versatility.[72]

Similar improvements were made to the separations processes. The development of inline monitors for separations processing was essential to speed up and simplify assay work, and to avoid dangerous conditions in canyon processing equipment. The Laboratory

made considerable progress in the development of such instrumentation as early as 1956. In later years, examples of these monitors included a gamma-radiation monitor for the 1C Bank waste stream, a fission counter for measuring the ratio of plutonium-239 to plutonium-240 in the B-Line, and a monitor counting beta and gamma contamination in wastewater streams.[73]

The production and storage of tritium, an isotope of hydrogen gas, was particularly tricky, and new methods were always explored to make this task easier and more efficient. Since most metals will react with hydrogen under certain conditions, the Savannah River Laboratory explored using metals to manipulate isotopes of hydrogen more efficiently. This led to the development of metal hydrides for the processing and storage of hydrogen. Metals that react with hydrogen to both absorb and release the gas under the right conditions, similar to a sponge that can absorb and release water, are called reversible metal hydrides, and this class of hydrides that is important for hydrogen storage and processing. Effective reversible metal hydrides can be made from pure palladium, titanium, or zirconium; or from alloys of two or more metals, such as iron and titanium, or lanthanum and nickel.[74] By the late 1970s, metal hydrides were used in tritium operations at Savannah River.[75] This use expanded in the 1980s,[76] and played an important part in the development of the Tritium Replacement Facility that began operation in 1994.[77]

Other achievements in the Separations areas were more peripheral to the main mission. With the development of power reactors in the 1960s, the AEC asked the Laboratory to begin study of the special needs of this rising technology. One example of this type of work was the development of the electrolytic dissolver. Because of extremely high temperatures, power-reactor fuel and target components were usually clad in corrosion resistant metals such as zirconium and stainless steel. These metals required special dissolving techniques before they could be processing in the canyons. For this purpose, the laboratory developed the electrolytic dissolver, which used electrical current to aid dissolution.

Initial small-scale research toward the development of an electrolytic dissolver was conducted in 1951 at the Knolls Atomic Power Laboratory. In 1959, the Atomic Energy Commission asked the Savannah River Laboratory and the Idaho Chemical Processing Plant to develop a practical large-scale unit.[78] By the early 1960s, initial designs had been completed; development work in experimental units was being undertaken at Savannah River's TNX facility by 1963.[79] During the next half-dozen years, the equipment and process was refined into the final dissolver design.

The electrolytic dissolver that was finally developed and installed in the H Area canyon, was a cylindrical tank, eight feet in diameter, enclosing a slightly smaller tank that contained cooling coils, a basket to hold the reactor components, and the solution in which the reactor assemblies were dissolved.[80] The basket was used to vertically support the materials to be dissolved. Just the basket, made of niobium, was ten feet long and weighed three tons.[81] A demonstration program proved that the recovery of uranium-235 was successful.[82] The electrolytic dissolver was used in a series of campaigns through 1979, processing most of the reactor components of stainless steel and zirconium that had been stored at Savannah River.[83]

Another area that saw steady improvement during this period was radiation safety, and much of this work hinged on accurate monitoring equipment. The Laboratory's Applied Physics Division created and evaluated instruments used to monitor ambient and localized radiation, and these instruments became increasingly sophisticated.

The early technologies used to measure radioactivity early on were crude and laborious. Analytical wet chemical separation of elements, light-emitting phosphors (ZnS) for measuring alpha activity, and Geiger Mueller counters using a counting scalar to measure beta–gamma activity, were all employed. Gamma spectrometry allowed SRP environmental monitors to make high sensitivity measurements of radioactivity by looking at the energy gamma ray or rays radioactive isotopes emit. This technology eliminated the need for wet-chemistry, quantitative, elemental analysis, and provided SRP with a sensitive technology that could be used to analyze thousands of samples in a cost-effective manner. Other advances followed. In the 1950s, for example, tritium could only be detected in the ratio of one part per one million. In later years, this was refined to one part per billion.[84] Laboratory scientist, Albert L. Boni, further describes technologies that developed over the 1950s and 1960s, such as field and laboratory concentration techniques that expanded the monitoring program. The construction of the first whole body counter in A Area in 1959 was a significant achievement in high sensitivity measurement of ultra-low amounts of radioactivity in the environment. SRP employees operated this facility, which was built using better materials technology to shield against background radiation, from 1959 to the late 1980s." [85]

The whole body counter was constructed as a room using 12-inch thick pre-World War II battleship armor plate with a 5-ton steel door and walls lined with lead and copper plate (to reduce low-energy x-rays produced by cosmic interaction with the steel). The use of the armor plate that was pre-World War II in origin was calculated to eliminate low-background radioactivity due to fallout emanating from the initial atomic bomb testing.

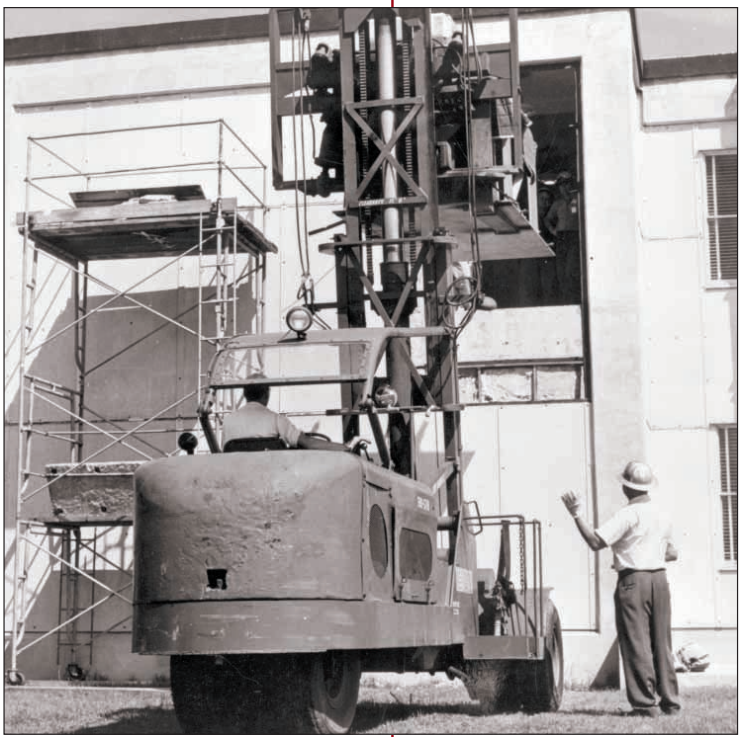
The need to perfect monitoring equipment was instrumental in the development of the Equipment Engineering Division, or EED. In the 1950s, this group began as a part of the Works Technical Division, when it was called the Engineering Assistance Section. Around 1970, the name was changed to the Equipment Engineering Department. Finally, in the 1980s, the organization was transferred to the Laboratory, where the name was changed again to the Equipment Engineering Division. From the beginning, this group checked the equipment needed by the many different technical fields at Savannah River, and was noted for its support work in reactor operations, particularly the interfaces that had to be created between the original reactor controls and the new reactor computers.[86] This accomplishment leads to the story of computer development at Savannah River, which became the domain of the Laboratory.

THE RISE OF COMPUTERS, 1960s–1980s

Computers played a role in the early development of Savannah River. As early as 1953, an IBM Card Programmable Calculator was used to perform some of the more exacting mathematical work required for Laboratory research.[87] From this relatively humble beginning, scientific computers became increasingly complex and integral to the operation of the plant.

A plant-wide, scientific, computing system was developed to perform sophisticated reactor-assembly and charge-design calculations, including the intricate computations required in the neutron-flux work associated with the Transplutonium Programs. This computer system, which began operation in 1968, was dubbed the "JOSHUA Operating

System," or simply JOSHUA. John E. Suich and Henry C. Honeck, researchers at the Savannah River Laboratory, did much of the conceptual work for this system. Although it was soon outclassed by the remarkable innovations that would spill out of the computer field in the years to come, at the time it was inaugurated, JOSHUA was a unique, state-of-the-art creation.[88]



Unloading computer into SRL, 1957. Courtesy of SRS Archives, negative 4424-6.

Online computers were deployed aggressively in site reactors to improve safety and productivity. The initial application, in 1964, provided data processing and alarms for control room operators, by scanning more than 3000 instrument signals. This was followed, in 1968, by automatic monitoring of assembly temperature limits, and in 1970, by closed-loop control of reactor power. Two pairs of redundant computers, two for control and two providing automatic shutdown for abnormal signals, replaced the online computer in 1974. The online computers were further upgraded in the early 1980s to provide automatic reactor shutdown, even if the safety rods should fail to function, and automatic diagnosis of multiple alarms.[89]

Although scientific computers were first used to assist in the design of plant reactors and other production facilities, they were soon applied to functions ranging far beyond. In 1984, plant-wide information systems were transferred to the care of the Laboratory, which had jurisdiction over the plant's central computer system. This led to the creation of a plant-wide computer network, with some 4000 user stations for the sending and receiving of e-mail. A new and more powerful central computer, the Cray XMP, was added to the Laboratory in 1988-1989.[90]

NEW AND CHANGING MISSIONS, 1970s–1980s

The use of computers in the 1960s and 1970s, and the enormous expansion in the scope of their use in the 1980s, is just one example of the rise of new missions in the last two decades of Du Pont's tenure at Savannah River. With the gradual decline of the Cold War and the main production mission, there was now time and energy to devote to new missions, many of which picked up where the old mission left off, especially in the arena of environmental clean up. Some of the new programs, however, also covered new ground.

PLANNING

Mission and technological changes, at the site level and within the DOE production complex, necessitated planning. The Technical Division was generally responsible for planning production needs and site operations in the 1950s. In the next decade, personnel

from SRL became the main contributors to the planning groups that were established to guide future site operations and later to provide support for the entire DOE complex.[91]

The 1960s saw the development of planning groups that were directly involved with planning site operations and future production options and costs. For example, the Advanced Studies Group, formed within the Reactor Engineering Division in 1963, was responsible for conceiving new reactor charges, that would produce a variety of radionuclides, and for developing irradiation tests for the Heavy Water Components Test Reactor.

Advanced Operational Planning was formed in 1964 to develop long-range plans for SRP's reactor operation, and to evaluate production costs given proposed production options. This group, formed as a staff organization that reported to the Director of the Technical Division in Wilmington, developed computer codes to model production and the costs of site operation. Advanced Operational Planning was later changed to the Operational Planning Division (OPD) and it was placed under the direction of the Savannah River Laboratory, where seven to ten senior staff members would contribute to it. Their assigned scope was to evaluate initiatives developed by SRL; conceive and evaluate production options; conduct cost vs. benefit studies; provide SRP information in support of NMP Planning studies; archive SRP's production and cost information; and develop long-range projections. In 1988, Richard W. Benjamin served as planning coordinator for OPD, and was joined by J. Brotherton, Paul F. Cronshaw, Donald E. Hostetler, and I. M. Macafee, Jr.

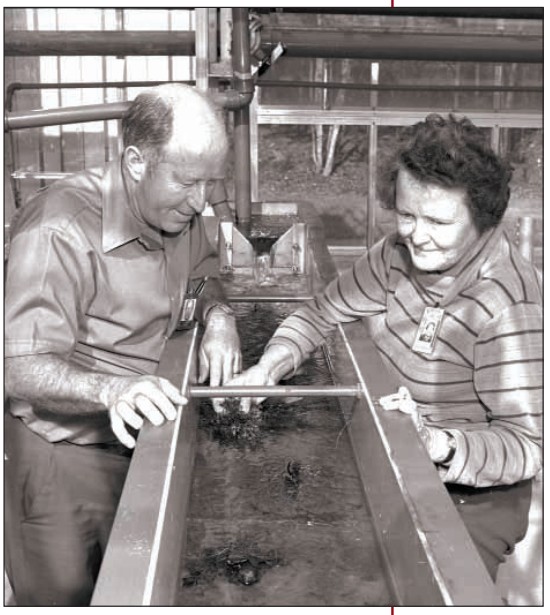
A third planning group, the Atomic Energy Combined Operational Planning (AECOP), also dates to the 1960s, but its scope was larger. This group was created at Oak Ridge to support planning for AEC-Headquarters (Washington) decisions on the operation of the production complex. Each site within the production complex was represented by one or two working members, who were transferred to Oak Ridge for one or two year terms. AECOP representatives from Savannah River were chosen from the Advanced Operational Planning Group. This planning organization was disbanded in about 1972, as AC HQ felt that the groups' studies were no longer responsive to their needs.

The Director of the Office of Nuclear Materials Production requested that Du Pont provide a senior management person to serve as a consultant to that office. Between 1980 and 1988, SRL staff members J. Roger Hilley, James M. Boswell, Richard W. Benjamin, Harold J. Groh, Charles P. Ross, and James M. Morrison served in that capacity during this decade. Also, Savannah River provided a consultant to the Albuquerque Operations Office, beginning in 1983, to advise their newly formed Office of Strategic Planning and Analysis. W. L. (Lee) Poe, J. G. (Mal) McKibbin, O. M. Ebra-Lima and L. P. Fernandez served in this position in the 1980s.

At the site, a Long-Range Planning Group was formed in 1981 to develop site operational information for both long-term and near-term management decisions, and to provide a focal point for Savannah River's long-range planning by site organizations. Key to the plan was facility requirements, a manpower plan, and funding requirements. The group, under the Manufacturing Division, consisted of four full time professionals and eight part time professionals. In 1984, this group was reassigned to the Planning Manager of the Technical Division in Wilmington, as was the SRL Planning Group, in order to centralize site planning efforts.

In 1982, the Nuclear Materials Production Planning Group was formed at SRL. This planning group was an outcome of a charter that was mutually developed by the Director

of the Office of Nuclear Materials Production and the Manager of the DOE Savannah River Operations Office, Robert L. Morgan. The mission of this group, known as the NMP Planning Group, was to provide planning support for the Office of Nuclear Materials production in Germantown, Maryland. Four senior SRL staff members and two professionals on loan from other sites within the complex traditionally composed the group. The scope of this planning effort was broad in scale, involving a national complex-wide dialogue involving DOE's Office of Nuclear Materials Production and the Office of Military Applications and the laboratories and sites within the DOE production complex. The NMMP was tasked with maintaining cognizance of planning activities throughout the DOE production complex; the planning and coordination of multi-site studies; the development and evaluation of production initiatives and alternatives; the evaluation of alternative complex configurations; the development and evaluation of production contingencies; the development of strategies for resource management; establish priorities and timelines for decision making; and finally to provide a consistent basis for uniform costs and production rates. In 1988, Tom Gould served as planning coordinator for NMPD Planning; J. L. Folk, Jr served as Chief of DOE-SR's Planning Branch. W. Lee Poe, Jeff Allender, David Howard, and Franklin King served on the NMP staff along with others from across the DOE complex.



SRL's Ray Harvey of the Radiological Sciences Division and Dr. Ruth Patrick of the Philadelphia Academy of Natural Sciences in Thermal Effects Laboratory built in 1971 on Upper Three Runs Creek. This facility was constructed as part of a long-term study of the effects of industrial heat on streams and rivers under the direction of SRL's Radiological Sciences Division and supported by the AEC's Division of Biology and Medicine. Creek water heated at various temperatures was pumped through six troughs made to recreate stream conditions in adjacent Three Runs. While thermal effects studies were ongoing since the early 1960s in Par Pond, the Thermal Effects Laboratory gave researchers an opportunity to look at organisms in running water and under controlled conditions. Courtesy of SRS Archives.

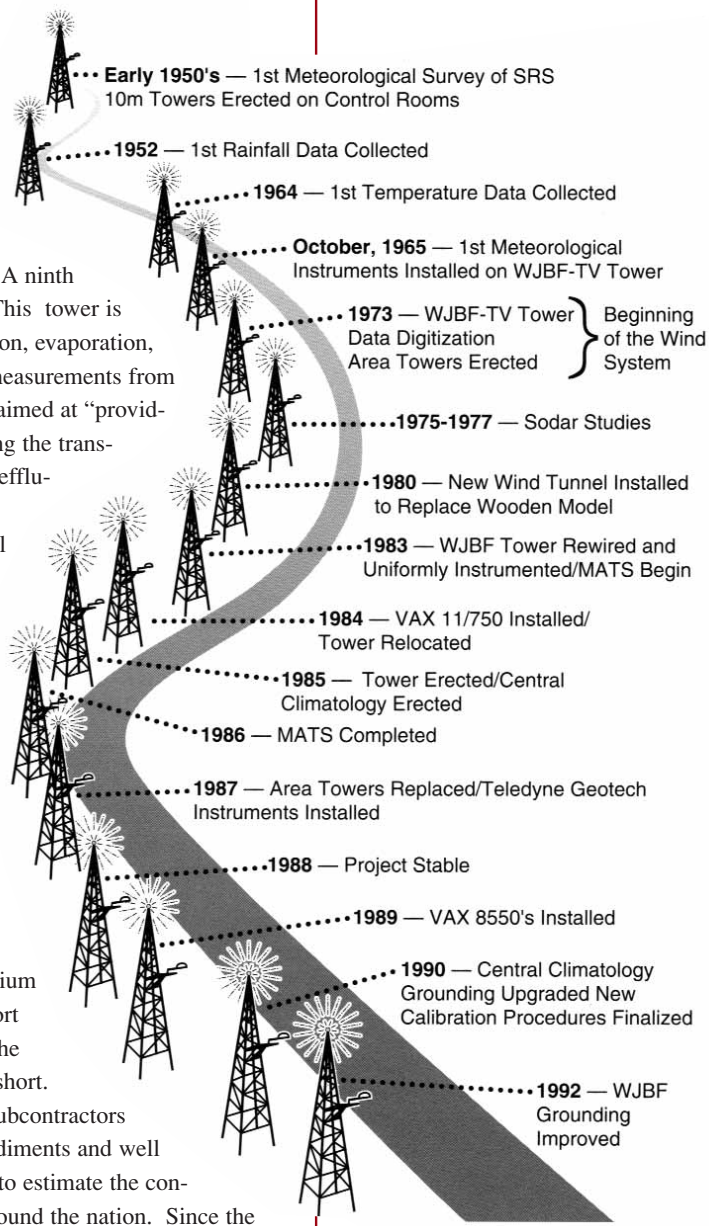
ENVIRONMENTAL RESEARCH

From the beginning of Savannah River, the Laboratory has had an interest in environmental monitoring for radiation. Initially, this was rather localized, such as monitoring personnel for unacceptable levels of radioactivity. It was this concern that led to the creation of the Health Physics Laboratory, which became an important part of the Laboratory function.

With the increase in environmental activities in the 1970s, the scope of this monitoring work grew exponentially. Soon the Laboratory was concerned with waste management, release studies of various radioactive elements, non-radioactive releases, the thermal effects of reactor effluent water on Par Pond, and the "environmental assessments" now required of construction programs.[92] This work would only increase as more environmental laws mandated increasing monitoring of the area around the plant. Advances in monitoring technology at SRS have been significant:

> Numerous advances at SRS in the development of field and real-time radionuclide sampling, real-time radiation monitoring, and thermal remote sensing related to the measurement of small amounts of radioactivity in the environment, have achieved national and international recognition. Field sampling for atmospheric tritium chemical forms, streams and river-water transport concentration of trace radionuclides, and the electrostatic high volume portable sampling of atmospheric aerosols developed at SRS, are widely used in international safeguards and national security programs.[93]

The meteorological monitoring program developed by the Environmental Technology Section of the laboratory is a case in point. For the first two decades of operation, SRS meteorological research was sporadic and completed with now-obsolete instrumentation. Weather information was supplied to the site by the Augusta office of the Weather Bureau (now the National Weather Service). New environmental laws, passed in the early 1970s, mandated more stringent air pollution monitoring. In response, SRS developed its first comprehensive monitoring system, under the direction of Todd V. Crawford, that involved the construction of a network of observation towers onsite and additional meteorological instrumentation on the WJBF-TV tower in the Beech Island, South Carolina vicinity. A ninth tower (Central Climatology) was constructed onsite in 1985. This tower is used for additional measurements of solar radiation, precipitation, evaporation, soil temperature, and boundary layer structure, with periodic measurements from a Sound Radar (Sodar). The monitoring program is primarily aimed at "providing current, accurate meteorological data as input for calculating the transport and diffusion of any unplanned release of an atmospheric effluent." [94] It plays a significant role in the site's Weather INformation and Display (WIND) System. The meteorological data stored in climatological databases is used for diverse applications: chronic dosimetric and air quality calculations, engineering analyses, and site environmental characterizations prepared for inclusion in Safety Analysis Reports (SAR), Environmental Impact Statements (EIS), and risk assessments.[95]



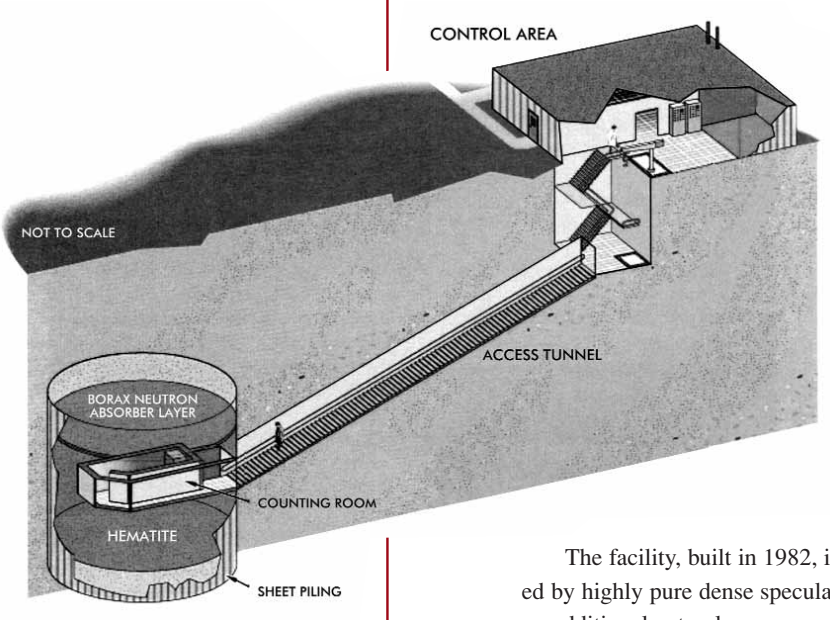
Timeline on Meteorological Instrumentation at Savannah River. Source: Matthew A. Parker and Robert P. Addis, *Meteorological Monitoring Program at the Savannah River Site*, WSRC-TR-93-0106 41 (Aiken, South Carolina: Savannah River Laboratory, 1993).

NATIONAL URANIUM RESOURCES EVALUATION PROJECT (NURE)

In 1974, the Savannah River Laboratory was asked to take part in a set of programs to locate and evaluate sources of uranium in the United States. The information was undertaken to support domestic nuclear power production. The program was called the National Uranium Resources Evaluation project or NURE for short. The role of Savannah River was to analyze samples taken by subcontractors doing field collections, generally from stream water, stream sediments and well water at 10 square-mile-intervals.[96] These samples were used to estimate the concentration of potential uranium deposits at various locations around the nation. Since the analysis was done by neutron activation, a laboratory facility, the National Neutron Activation Facility, was set up in the C Reactor area in 1975. The fully automated facility, upgraded in 1976 to a processing capacity of 15,000 samples per month, analyzed over 263,000 samples for the NURE program that was headed by Bob Folger.

Despite a promising beginning, the NURE program ended in the early 1980s, as interest in power reactors declined in the wake of the Three Mile Island incident. Even with

this limitation, the Laboratory's contribution to the program went beyond initial expectations: 33 reports of the analyses and surveys were published, providing a valuable database of information, on not only deposits of uranium, but of other minerals as well. SRL completed evaluations of the assigned 31 states, as well as aiding in additional evaluations for western states when the program was closed. The NURE facility in C Area continued to be used until 1985 for determining uranium content in urine, a type of analysis for which the facility proved to be particularly adept. This work was discontinued when the reactor was shut down in 1985.[97]



Underground Counting Facility—high –sensitivity counting and measurement. Source: Albert L. Boni, High Sensitivity Measurements of Ultra-Low Amounts of Radioactivity in the Environment, *Savannah River Site 50th Anniversary, Proceedings of the Symposium, May 17, 2000* (WSRC-MS-2000-00061), 275.

ADVANCES IN HIGH SENSITIVITY MEASUREMENTS OF ULTRA-LOW AMOUNTS OF RADIOACTIVITY

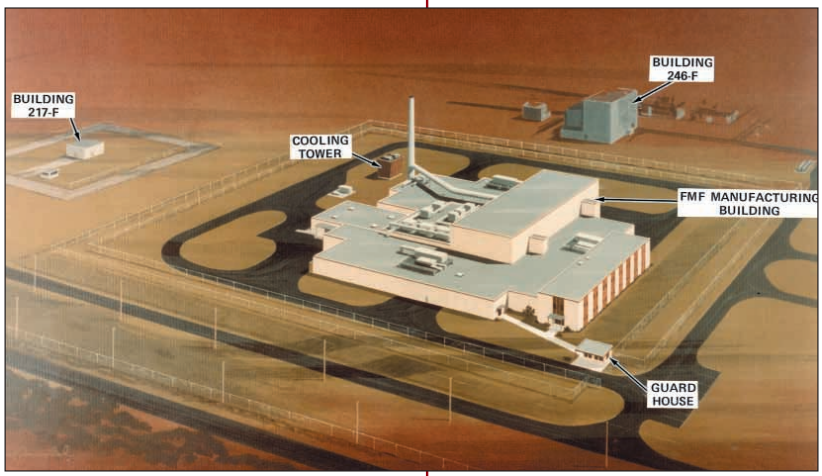
Savannah River made considerable advances in this area during the 1980s in terms of measuring radioactivity in the environment, as well as in analytic measurement of radioactive and non-radioactive compounds, elements, and isotopes that were produced at Savannah River. As a result of these accomplishments, a unique facility, specifically designed as an underground ultra-low background underground radioactivity-measurement facility, was constructed at SRP.

> The facility, built in 1982, is... buried underground, and surrounded by highly pure dense specular hematite ore. The facility contains no additional natural or man-made materials that contribute radioactivity to the background. The facility is entered from a tunnel from an above ground clean room facility, where all of the information from the detectors within the underground shield is read out. This one-of-a kind facility is used to support special site programs and work for other federal agencies. For example, NASA uses this facility to measure trace radionuclides in materials returned from space... The detection sensitivity of this facility is equivalent to less than one part in 1 trillion, or the ability to find one penny in the U.S. national debt, about $5 trillion, circa 2000.[98]

The TRAC vehicle, a mobile unit designed and equipped to measure trace radioactive materials in the atmosphere, was also a product of the early 1980s. This mobile research and development laboratory is used for high-sensitivity remote radiation measurements, and is available for interagency use and for emergency response. Other laboratory achievements include the development of a highly sensitive mass spectrometric laboratory able to efficiently measure actinides in environmental and bioassay samples, and the development of the californium activation facility, one of the oldest in the nation that is still in operation.[99]

FUEL MATERIALS FACILITY (NAVAL FUELS)

During the brief increase in weapons production in the early 1980s, Admiral Hyman G. Rickover and the Department of Defense became concerned that there was only one facility in the country that could produce the fuel used in the U.S. Navy's nuclear fleet. At Rickover's request, Du Pont agreed to build a new plant at Savannah River to produce fuel for the nuclear navy. This plant became known as the Fuel Materials Facility.[100]



Conceptual Drawing of Fuel Manufacturing Facility. Courtesy of SRS History Project.

In 1982, the Savannah River Laboratory built and began operating a semiworks plant related to the project. The plant was set up to help transfer naval fuels production technology to the site, then to be used as a pilot process facility. During the early research efforts, laboratory staff uncovered some problems and suggested improvements to key equipment being used at that time. By the end of 1982, test quantities of fuel material had been produced, and personnel involved felt they had a good understanding of the processes involved.[101]

During the ensuing years, what was thought to be an improved production process was developed. The facility incorporated new processing technology, the particulars of which remain classified. The facility was completed in 1986, but never went into full operation. The facility was closed by the Department of Defense in 1989, due to the reduced need for naval fuels.

DEFENSE WASTE PROCESSING FACILITY (DWPF)

One of the greatest achievements of the Laboratory is the Defense Waste Processing Facility, or DWPF. From its conception in the late 1970s, to its construction and testing during the 1980s and early 1990s, the research and development, entailed in the processes involved in this vital but difficult work, were hammered out largely at the Savannah River Laboratory. One of the core processes for the DWPF, the vitrification of the high-level waste, was worked out in the Laboratory's High Level Caves, early in the 1980s.[102] The research and testing at TNX, discussed earlier, laid the foundation for its successful operation. While a full history of the DWPF is provided later, it is fitting to end this discussion of the Laboratory's achievements on this topic. Having begun its existence during the Cold War in the service of producing fission and fusion materials for nuclear weapons, the Savannah River Technical Center, through its achievements in the DWPF, is a significant national player in the cleanup of the waste produced during that era.

16 The Middle Years (1964–1979)



(Foreground) William Overbeck, SRL Director, (left) shakes hands with Dr. Glenn T. Seaborg, AEC Chairman, Nobel prizewinner, and co-discoverer of nine transuranium elements including plutonium, at Augusta's Bush Field. Seaborg was en route to the site for SRP's twentieth anniversary celebration where he gave an address, stating that the value of one of the plant's peacetime products—californium-252—could not be measured in diamonds. (Background) Nathaniel Stetson, SROO Manager (left) and Julius Rubin, DOE-HQ (right). Courtesy of SRS Archives, negative 14556-4.

The era between 1964 and 1979 could be styled the "middle years" of Savannah River. The initial period of growth, power ascension, and "full-steam" production was over. It was during this period that Savannah River reached its maturity. While nuclear weapons material production continued throughout this period, albeit on a reduced scale, allowances were now made for new missions. The first of these were the special irradiations that created radioisotopic heat sources, but this work was soon followed by a series of ambitious campaigns to create new transplutonium elements that could be produced on a large scale only by the heavy-water reactors at Savannah River. It was also during this period that the techniques required to fulfill Savannah River's primary mission, the production of nuclear weapons materials, reached their full potential. In the use of the reactors, in the development of the fuel and target assemblies, and in the chemical processes needed to separate the materials, Savannah River reached its apogee. Safety, always of key importance to Du Pont, became an even greater concern during this period, as new ways were sought to make the production process safer and less subject to the vagaries of human error.

None of these developments, however, took place in a vacuum. Changes in the national and international landscape set the stage for the reduction of nuclear weapons materials production, and it was this development that allowed Savannah River to begin the shift away from its first primary mission.

INTERNATIONAL EVENTS AND IMPACT ON HANFORD AND SAVANNAH RIVER

The Limited Test Ban Treaty signed in 1963 by the United States, the Soviet Union, and Great Britain, marked the end of an era. In addition to banning atmospheric testing of nuclear weapons, it also marked the informal beginnings of the era of "détente" between the Cold War superpowers.[1] Even the leadership style changed. The new American President, Lyndon Johnson, did not have Kennedy's appetite for brinkmanship. And in

1964, Leonid Brezhnev and Aleksey Kosygin, who were likewise more cautious, replaced Khruschev. When Johnson announced a slowdown in the production of nuclear weapons materials in his January 1964 State of the Union message, both the United States and the Soviet Union already had a formidable arsenal of nuclear weapons.

Despite the Vietnam War, which preoccupied Johnson and Nixon in the late 1960s, the era of détente continued. Based on the idea of peaceful coexistence, détente was formalized and popularized by Henry Kissinger, Secretary of State under both Nixon and Ford. The Limited Test Ban Treaty was followed by discussions for the first Strategic Arms Limitation Treaty (SALT), which were temporarily sidetracked by the Soviet invasion of Czechoslovakia in 1968, picked up again by Nixon and Kissinger the following year, and finally ratified by the U.S. Senate in 1972. SALT II, which was negotiated soon afterwards, called for nuclear parity between the United States and the Soviet Union. Although it was signed by Brezhnev and President Carter in 1979, the Senate held up SALT II's ratification after the Soviet invasion of Afghanistan.[2] By this time, détente had run its course. President Carter was veering away from its premise before the election of his successor, Ronald Reagan, who left no doubt that the United States was once again prepared to take a more aggressive role in nuclear politics.



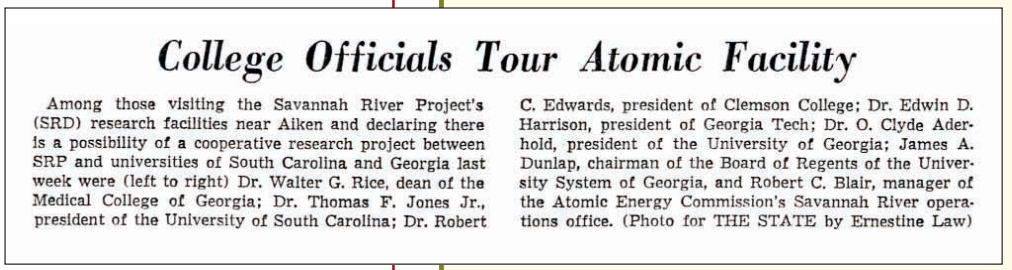
AEC management portrait, circa 1970. Courtesy of SRS Archives, negative 11457-1.

The era of détente, from 1964 through 1979, had an immediate and lasting effect on the United States production reactors, both at Hanford and at Savannah River. The U.S. production of plutonium was curtailed, while the production of weapons-grade uranium ceased altogether. At Hanford, the oldest and largest of the nuclear materials production centers, this downswing in production had effects that were both immediate and long lasting. Beginning in 1964 and continuing until 1971, all of the older production reactors were shut down. In the 1970s, only Hanford's N-Reactor was still in operation, and even then, only because it was a dual reactor, producing both nuclear materials and electricity.[3]

The impact on Savannah River was also immediate, but not as drastic. R Reactor, the oldest of the five SRP reactors, was shut down in 1964. Even though R was studied as a possible power reactor, this facility was never restarted.[4] Four years later, in 1968, L Reactor followed suit, as the AEC demand for nuclear weapons materials continued to decline.[5] The remaining three reactors, P, K, and C, remained in operation during this

"A Challenge to the CSRA"

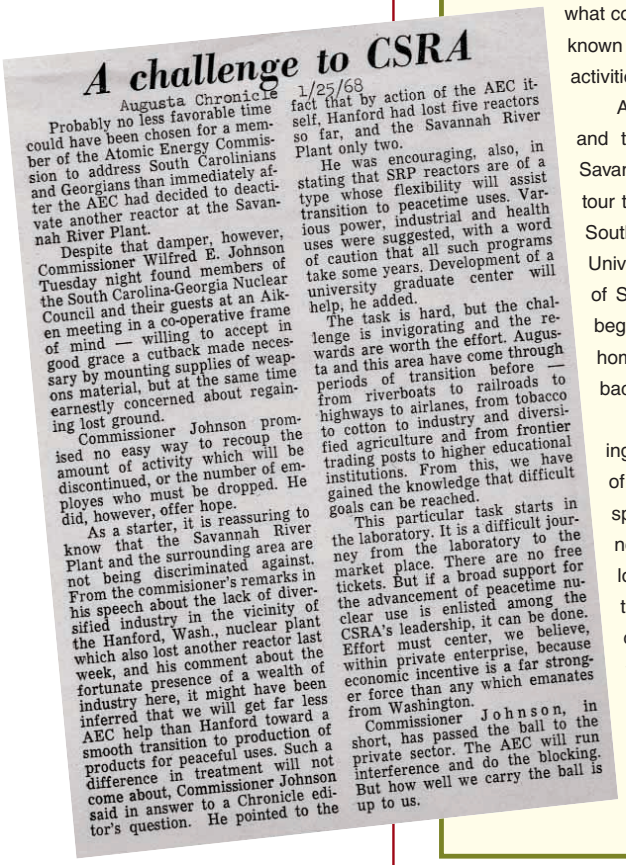
South Carolina and Georgia's politicians responded to the news of the shutdown of R Reactor, then L reactor with dismay. They promptly combined forces, and then mounted a united response to Washington. Newspaper articles in *The Augusta Chronicle*, and the *News & Courier,* state that Governors Donald Russell of South Carolina and Carl Sanders of Georgia went to Washington in early November 1963 "to impress upon their states congressional members the economic value of the Savannah River Nuclear Plant at Aiken."



College Officials Tour Atomic Facility

Among those visiting the Savannah River Project's (SRD) research facilities near Aiken and declaring there is a possibility of a cooperative research project between SRP and universities of South Carolina and Georgia last week were (left to right) Dr. Walter G. Rice, dean of the Medical College of Georgia; Dr. Thomas F. Jones Jr., president of the University of South Carolina; Dr. Robert C. Edwards, president of Clemson College; Dr. Edwin D. Harrison, president of Georgia Tech; Dr. O. Clyde Aderhold, president of the University of Georgia; James A. Dunlap, chairman of the Board of Regents of the University System of Georgia, and Robert C. Blair, manager of the Atomic Energy Commission's Savannah River operations office. (Photo for THE STATE by Ernestine Law)

Governor Russell of South Carolina was accompanied by South Carolina State Development Board Director Walter Harper and Aiken member Stathy Verrenes as well as State Senator Edgar Brown and State House Speaker Sol Blatt. Augusta's Mayor, Millard A. Beckum; Mayor-elect, George Sancken, Jr.; Sherman Drawdy, Augusta resident and president of the Georgia Railroad Bank and Trust Company; and Georgia's Democratic Chairman, J. B. Fuqua, composed the Georgia contingent, headed by Governor Carl Sanders. In what could be described as a full court press, the group went to Washington to make known that the state governments had considerable interest in the diversification of activities at the plant to ensure its longevity.



A challenge to CSRA

Augusta Chronicle 1/25/68

Probably no less favorable time could have been chosen for a member of the Atomic Energy Commission to address South Carolinians and Georgians than immediately after the AEC had decided to deactivate another reactor at the Savannah River Plant.

Despite that damper, however, Commissioner Wilfred E. Johnson Tuesday night found members of the South Carolina-Georgia Nuclear Council and their guests at an Aiken meeting in a co-operative frame of mind — willing to accept in good grace a cutback made necessary by mounting supplies of weapons material, but at the same time earnestly concerned about regaining lost ground.

Commissioner Johnson promised no easy way to recoup the amount of activity which will be discontinued, or the number of employes who must be dropped. He did, however, offer hope.

As a starter, it is reassuring to know that the Savannah River Plant and the surrounding area are not being discriminated against. From the commisioner's remarks in his speech about the lack of diversified industry in the vicinity of the Hanford, Wash., nuclear plant which also lost another reactor last week, and his comment about the fortunate presence of a wealth of industry here, it might have been inferred that we will get far less AEC help than Hanford toward a smooth transition to production of products for peaceful uses. Such a difference in treatment will not come about, Commissioner Johnson said in answer to a Chronicle editor's question. He pointed to the fact that by action of the AEC itself, Hanford had lost five reactors so far, and the Savannah River Plant only two.

He was encouraging, also, in stating that SRP reactors are of a type whose flexibility will assist transition to peacetime uses. Various power, industrial and health uses were suggested, with a word of caution that all such programs take some years. Development of a university graduate center will help, he added.

The task is hard, but the challenge is invigorating and the rewards are worth the effort. Augusta and this area have come through periods of transition before — from riverboats to railroads to highways to airlanes, from tobacco to cotton to industry and diversified agriculture and from frontier trading posts to higher educational institutions. From this, we have gained the knowledge that difficult goals can be reached.

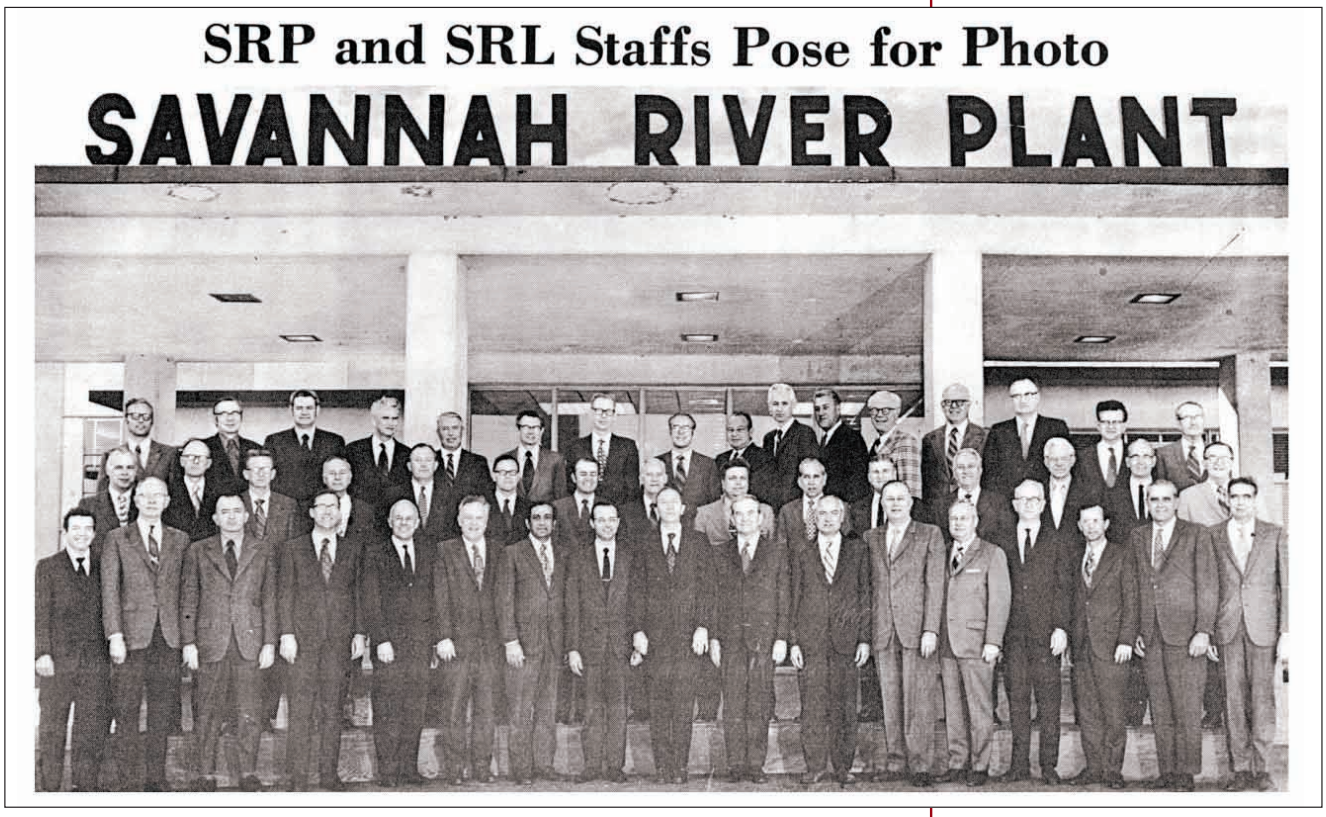
This particular task starts in the laboratory. It is a difficult journey from the laboratory to the market place. There are no free tickets. But if a broad support for the advancement of peacetime nuclear use is enlisted among the CSRA's leadership, it can be done. Effort must center, we believe, within private enterprise, because economic incentive is a far stronger force than any which emanates from Washington.

Commissioner Johnson, in short, has passed the ball to the private sector. The AEC will run interference and do the blocking. But how well we carry the ball is up to us.

A cooperative venture between the Universities of South Carolina and Georgia and the Savannah River Laboratory had been discussed as early as 1963. Savannah River Operations Office Manager, Robert Blair, had given a laboratory tour to the deans and presidents of the Medical College of Georgia, University of South Carolina, Clemson University (then Clemson College), Georgia Tech, and the University of Georgia in 1963 to foster such ties. The young but growing University of South Carolina–Aiken established in 1961 in the wake of SRS, had already begun to respond to the educational needs of its highly scientific and diverse home community. But more was needed should Savannah River's mission be cut back in the national interest.

In 1968, an address by AEC Commissioner Wilfred E. Johnson at a meeting of the South Carolina-Georgia Nuclear Council in Aiken, after the shutdown of L Reactor, occasioned an editorial in *The Augusta Chronicle*. The editorial spelled out what the SRP meant to the CSRA, urging the development of economic incentives within the private sector to keep the plant vital. The need for local university graduate education and political support for research programs that had peacetime applications of the nuclear technology, were cited as the challenge that lies ahead. For many, the path to Savannah River's future was the Laboratory.

Sources: "College Officials Tour Atomic Facility," *The State and the Columbia Record,* July 21, 1963, "A Challenge to CSRA," *The Augusta Chronicle*, January 25, 1968.



(Front Row) From left to right: W. M. Sloan, superintendent, Industrial Engineering; Arthur Croll, superintendent, E and I; William J. Mottel, superintendent, Separations; James E. Conaway, general superintendent, Production; William P. Bebbington, general superintendent, Works Technical; Gerhard Dessauer, director, Physics Section, SRL; Samuel Mirshak, director, Nuclear Engineering and Materials Section, SRL; Leon H. Meyer, assistant director, SRL; Clark H. Ice, director, SRL; Kenneth W. French, plant manager; James K. Lower, assistant plant manager; L. G. Ahrens, general superintendent, Works Engineering: William E. Babcock, general superintendent, Business Services and Security; J. W. Morris, director, Professional and University Relations, SRL; H. J. Groh, director, Separations Chemistry and Engineering, SRL; Jack L. Gosnell, superintendent, Maintenance; Robert H. Dietz, superintendent, Raw Materials; **(Second Row)** V. I. Montenyohl, supervisor, Budget and Planning, SRL; Edward L. Albenesius, research manager, Radiological Sciences, SRL; Alfred S. Jennings, research manager, Separations Engineering, SRL; Dewey E. Waters, manager, Laboratory Operations and Services, SRL; William E. Winter, superintendent, Clerical; Norman J. Howard, superintendent, Accounting; Richard T. Huntoon, research manager, Nuclear Materials, SRL; N. J. Bell, superintendent, Traffic and Transportation; George A. Poda, superintendent, Medical; Don G. Ebenhack, superintendent, Service; Harold J. Bowman, superintendent, Project; Eugene P. Eckardt, superintendent, Power; C. W. Cole, superintendent, Personnel; Paul K. Burg, retired as Security superintendent; Thomas C. Evans, superintendent, Engineering Assistance Section; **(Back Row)** John A. Porter, research manager, Separations Chemistry, SRL; Jack L. Crandall, director, Advanced Operational Planning, AED; J. Roger Hilley, research manager, Experimental Physics, SRL; Paul A. Dahlen, superintendent, Reactor and GS; Robert M. Radford, superintendent, Laboratories; James M. Boswell, research manager, Theoretical Physics, SRL; Ben C. Rusche, director, Environmental Analysis and Planning, AED; Paul D. Tennant, manager, Computer Operations SRL; J. W. Wade, director, Computer Sciences, SRL; L. W. Fox, superintendent, Reactor Technology; William O. Christy, superintendent, Engineering and Control; Stewart W. O'Rear, supervisor, Technical Information Service, SRL; John N. Wilson, superintendent, Planning and Analysis; Everett B. Sheldon, superintendent, Separations Technology; C. Maurice Patterson, superintendent, Health Physics. **Not Shown:** Ivan R. Smith, superintendent, Security; Henry C. Honeck, research manager, Computer Applications, SRL; and Robert L. Folger, research manager, Analytical Chemistry, SRL.

Key personnel in plant and laboratory organizations in April 1972. Source: "SRP and SRL Staffs Pose for Photo," *Savannah River Plant News*, July 1972.

period, but they were often used to fulfill missions quite different from those envisioned by the original planners.

THE SEARCH FOR NEW MISSIONS

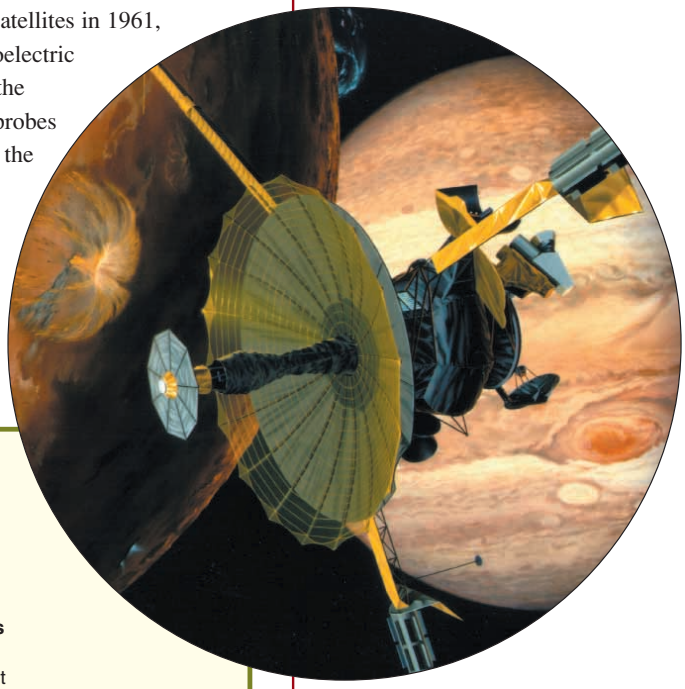
Even in the 1950s, during the heyday of nuclear weapons materials production, the Savannah River reactors were producing radioisotopes for non–weapons uses. This trend continued and accelerated in the 1960s with the reduction of Savannah River's military mission. What began as work on thorium for breeder–reactor research and isotopes for heat sources, soon reached its height with the transplutonium programs that were put into play by Glenn Seaborg, who served as chairman of the Atomic Energy Commission from 1961 to 1971. Before the reactors were shut down in 1988, over 100 different radioisotopes had been made at Savannah River.[6] Most of these were made in minute amounts for various research purposes, and others were made incidentally in the course of other programs, but the greatest production of non–military isotopes at Savannah River was undoubtedly the period between 1964 and 1970. This was not only the peak of isotope production for heat sources, but was also the peak of production for transplutonium elements never before seen by man.

As early as 1961, Du Pont had expressed an interest in the production of radioisotopes for possible company profit, reversing a long-standing policy of disinterest in the future of nuclear materials production. As Crawford Greenewalt explained in a letter to the AEC, Savannah River and the Du Pont Company were interested in expanding the scope of their contract to include the production of other, non–military, materials that the AEC might require. The company was also interested in any research and development programs that might result.[7] As both Du Pont and the AEC knew, the heavy-water reactors at Savannah River were the most versatile production reactors in the country, and were ideal for the production of all sorts of radioisotopes. In 1965, in the wake of the slowdown of nuclear weapons material production, the Savannah River Laboratory issued a "Five-Year Plan" that outlined Savannah River's search for new missions. Among other things, the plan called for the production of cobalt-60 and polonium-210, as well as the production of curium-244 in conjunction with a high-flux operation.[8] All of these played a role in the production of non-weapons radioisotope production that became prevalent at Savannah River during the late 1960s.

HEAT SOURCES FOR ELECTRICITY

As discussed earlier, some of the first non-weapons isotope products made at Savannah River were heat sources for Arctic stations, as well as thermoelectric sources for use in NASA's space program. These programs continued and expanded during the late 1960s. Cobalt-60, one of the first isotopic heat sources, was also found to have applications in cancer treatment, food sterilization, as well as a power source for thermoelectric generators.[9] Plutonium-238, however, had already proved to be far better as a heat source for thermoelectric generators. During the heyday of the NASA space program—the race to the moon—and during the subsequent unmanned missions to the far reaches of the solar

system, plutonium-238 proved to be the most effective source for electrical power. An alpha emitter, it produced virtually no gamma radiation, and thus required minimal shielding. With a half-life of around 88 years, it also lasted longer than most other isotopic heat sources.[10] First used in space on board the Navy's navigational satellites in 1961, plutonium-238 became the standard fuel for "radioisotope thermoelectric generators" or RTG's during the 1960s and 1970s, especially on the Apollo missions. Plutonium-238 was especially useful in space probes that explored the further reaches of the solar system beginning in the 1970s with the Voyager and Galileo probes. Production of plutonium-238 began at Savannah River in the late 1950s and continued until 1986. Plutonium-238 was created by neutron irradiation of neptunium-237 in an increasingly sophisticated series of reactor assemblies during this period. "Most of the exploration of the moon and the earth's fellow planets has depended on power supplied from plutonium-238 made at SRP."[11]



Artist's conception of Galileo with Jupiter in the background and the moon to the foreground. Courtesy of NASA/JPL/Caltech.

Space Missions That Have Used Plutonium-238 Power Sources

Spacecraft	Mission Type	Launch Date	Status
Transit 4A	Navigational	June 1961	In orbit
Transit 4B	Navigational	November 1961	In orbit
Transit 5-BN-1	Navigational	September 1963	In orbit
Transit 5-BN-2	Navigational	December 1963	In orbit
Transit 5-BN-3	Navigational	April 1964	Mission aborted
Nimbus B-1	Meteorological	May 1968	Mission aborted
Nimbus III	Meteorological	April 1969	In orbit
Apollo 11	Lunar	July 1969	On lunar surface
Apollo 12	Lunar	November 1969	On lunar surface
Apollo 13	Lunar	April 1970	Mission aborted
Apollo 14	Lunar	January 1971	On lunar surface
Apollo 15	Lunar	July 1971	On lunar surface
Pioneer 10	Planetary	March 1972	Operated beyond solar system
Apollo 16	Lunar	April 1972	On lunar surface
Triad-01-1X	Navigational	September 1972	In orbit
Apollo 17	Lunar	December 1972	On lunar surface
Pioneer 11	Planetary	April 1973	Operated beyond solar system
Viking 1	Mars Lander	August 1975	On Martian surface
Viking 2	Mars Lander	September 1975	On Martian surface
LES-8 and -9	Communication	March 1976	In orbit
Voyager 2	Planetary	August 1977	Operated beyond solar system
Voyager 1	Planetary	September 1977	Operated beyond solar system
Galileo	Planetary	October 1989	Orbiting Jupiter
Ulysses	Planetary	September 1990	In polar orbit around sun
Mars Pathfinder	Mars Lander	December 1996	Operated on Mars
Cassini	Planetary	October 1997	On route to Saturn

Source: Richard R. Furlong and Earl J. Wahlquist, "U.S. Space Missions Using Radioisotope Power Systems," *Nuclear News* 42. No. 4 (April 1999):28.



Plutonium-238 has provided a source of energy for many uses, from experimental pacemakers to deep space exploration. Courtesy of SRS Archives, negative DPSPF-35055-1.

Other isotopes were also studied as possible heat sources. Among these was curium-244, which would later play a much greater role in the early transplutonium programs. Even though it supplied more heat than plutonium-238, curium-244 was limited by its half-life of 18 years. Another isotope examined during this period was polonium-210. Even though it was a powerful heat source, its half-life of around four months made it ineffective for long-term use.[12]

THE TRANSPLUTONIUM PROGRAMS

As important as heat sources were, what really distinguished Savannah River during this period was its crucial role in the Atomic Energy Commission's various transplutonium programs. Although the first of these programs began in the late 1950s, they reached their peak in the late 1960s with the production of californium-252. And it is not a coincidence that this achievement occurred when Glenn Seaborg was chairman of the AEC. The co-discoverer of plutonium itself, Seaborg had an abiding interest in man-made elements heavier than plutonium—elements that could only be created in an atomic blast, or in a nuclear reactor. It was the role of Savannah River to provide those elements, after its military mission began to subside in the years after 1964.

In the years before he became chairman of the AEC, Seaborg had concentrated his studies on the elements that were heavier than plutonium, otherwise known as transplutonium elements. For this work, and his original work on plutonium, the General Advisory Committee recommended him for the 1959 Enrico Fermi Award. At the time of the award, Seaborg had already had a distinguished scientific career, and was serving as chancellor of the University of California at Berkeley. To cap off that career, on March 1, 1961, he was made chairman of the Atomic Energy Commission, a post he would hold for 10 years, until August 16, 1971.[13] Seaborg was one of the few scientists to hold this post and he made good use of the opportunity. While chairman of the AEC, he helped coordinate the Commission's transplutonium program, both at Savannah River and at other nuclear facilities around the country.

Even though the earliest transplutonium work at Savannah River began in the late 1950s and early 1960s, the programs really got under way in the years that followed the shutdown of R Reactor in 1964. This work began with the Curium I program, which was planned in late 1963, after the AEC requested three kilograms of curium-244 from Savannah River. At the time, curium-244 was sought as a possible heat source for the thermoelectric generation of electricity, but it was also desired as a target material for the anticipated production of californium, the production of which was the ultimate goal of the transplutonium programs.[14] With irradiation work conducted in C Reactor, the Curium I production campaign began in May 1964, and was concluded by December of that same year.[15]

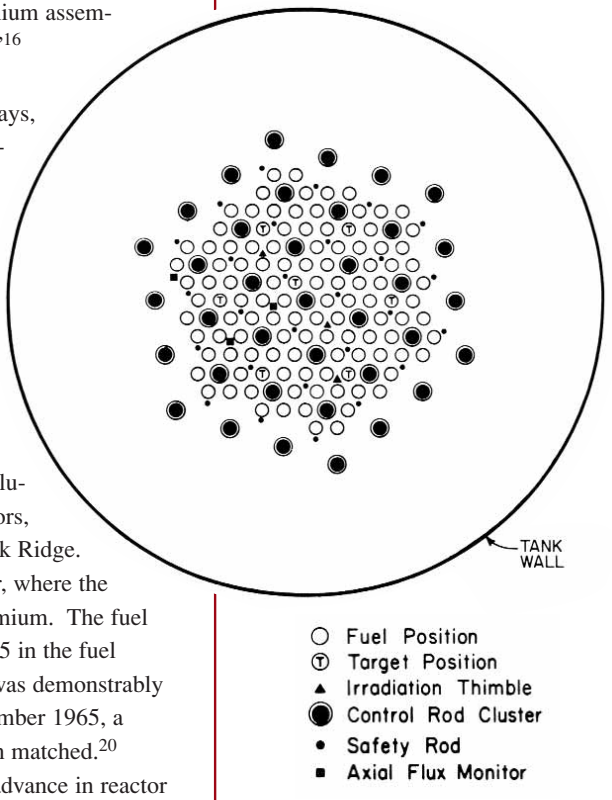
Like earlier transplutonium work, Curium I was initiated with the irradiation of plutonium-239. Unlike the earlier work, however, this was a "main-line" effort rather than an incidental one. In Curium I, plutonium-239 was alloyed with aluminum and then fashioned into aluminum-clad billets, which were then extruded into thin-walled fuel tubes. "A full reactor load was fueled by a uniform mixture of plutonium–aluminum assemblies and enriched uranium–aluminum assemblies. Each assembly contained a poison rod of

aluminum–lithium alloy. As the plutonium was burned up, the decrease in reactivity was compensated by replacing the burned up uranium fuel with the fresh uranium assemblies, and by replacing the poison rods with rods containing less lithium."[16]

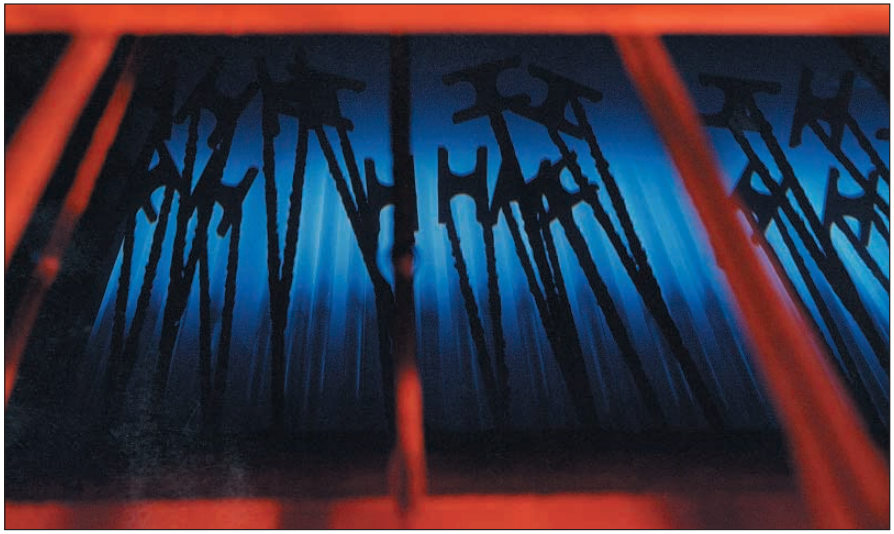
The entire progression from plutonium-239 to curium-244 was both lengthy and complicated. After successive neutron captures and beta decays, the plutonium-239 was transformed by stages from plutonium-240 to plutonium-241, followed by plutonium-242, plutonium-243, americium-243, americium-244, and finally curium-244.[17] The whole progression had to be divided into two programs due to differences required in the manufacturing techniques. Curium I took the progression from plutonium-239 to plutonium-242. The second program, Curium II, would require a much higher neutron flux to push the material to curium-244, higher than had ever been attempted before. For this reason, a separate High Flux Program was interjected between Curium I and II.[18]

The High Flux Program or Demonstration was started in February 1965, and was concluded one year later, on February 9, 1966, at the conclusion of the 28th fuel cycle.[19] This work was conducted in C and K reactors, with work also conducted at the High Flux Isotope Reactor (HFIR) at Oak Ridge. The main portion of the Demonstration High Flux was done in C Reactor, where the target was usually plutonium-242 and the control rods were made of cadmium. The fuel positions were greatly reduced, while the active length of the uranium-235 in the fuel assemblies was reduced by half. Within this core area, the neutron flux was demonstrably increased in neutrons per square centimeter per second. In fact, in December 1965, a high neutron flux record was established in C Reactor that has never been matched.[20]

The High Neutron Flux Program was perhaps the most outstanding advance in reactor technology made at Savannah River. Many of the heavier transplutonium elements could be created only through multiple neutron captures, and this required high neutron flux.[21] Even though the High Flux Program was developed in support of the curium programs, it had applications that went well beyond curium. Much of the plutonium-242 used in the High Flux Program was bumped up to curium-244, but about one milligram of californium



Example of High Flux Lattice. Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).



One of the non-military projects at Savannah River was a High Flux Demonstration Program, during which several transplutonium elements were produced in the reactors. Here, Cerenkov radiation emanates from these reactor assemblies irradiated during the transplutonium program. Courtesy of SRS Archives, negative 1-8839.

was also created.[22] This paved the way for the creation of greater amounts of higher isotopes, such as californium-252, and even rarer isotopes like einsteinium-255 and fermium-257 and -258. In order to facilitate the production of these esoteric isotopes, a device known as the "rabbit" was designed at Savannah River Laboratory, with the help of Albert Ghiorso and Ken Hulet of the University of California Radiation Laboratory. This devise could remove samples from the reactor and deliver them to an experimenter within a matter of seconds, before they could begin to decay. The "rabbit" was specifically designed to help produce fermium-258 from fermium-257.[23]



Ike Hobbs, director, SR Technical and Production Division and Dr. Edward J. Hennelly, research associate in Theoretical Physics Division of SRL with High Flux Plaque in 773-A, 1966. Courtesy of SRS Archives, negative DPSPF 11,396-1.

Another achievement associated with the High Flux Program was the creation of High-Specific-Activity-Cobalt-60. At high flux operation, cobalt-59 is preferred for use in reactor control and safety rods, since lithium tends to melt at a lower temperature. As a result of this use, the highest specific activity cobalt-60 ever made was produced at Savannah River: 700 curies per gram.[24]

The High Flux Program was followed by Curium II, which was conducted in K Reactor.[25] Initiated in December 1965, Curium II was concluded in May 1967. The goal of the Curium II program was to finish the production of curium-244 by transmuting the plutonium burnout residue from Curium I, using a high flux lattice.[26] Curium II began with the separation and purification of materials from the first program. The plutonium from Curium I was refabricated into new plutonium–aluminum fuel tubes, while the americium and curium produced in Curium I was set aside for later combination with the greater quantity of material that would come from the second program. The irradiation program for Curium II entailed a mixed lattice of five



A slug of cobalt-60 (glowing cylinder) fabricated in the Isotope Process Development Laboratory in SRL. Courtesy of SRS Archives, negative DPSTF-1-11881-2.

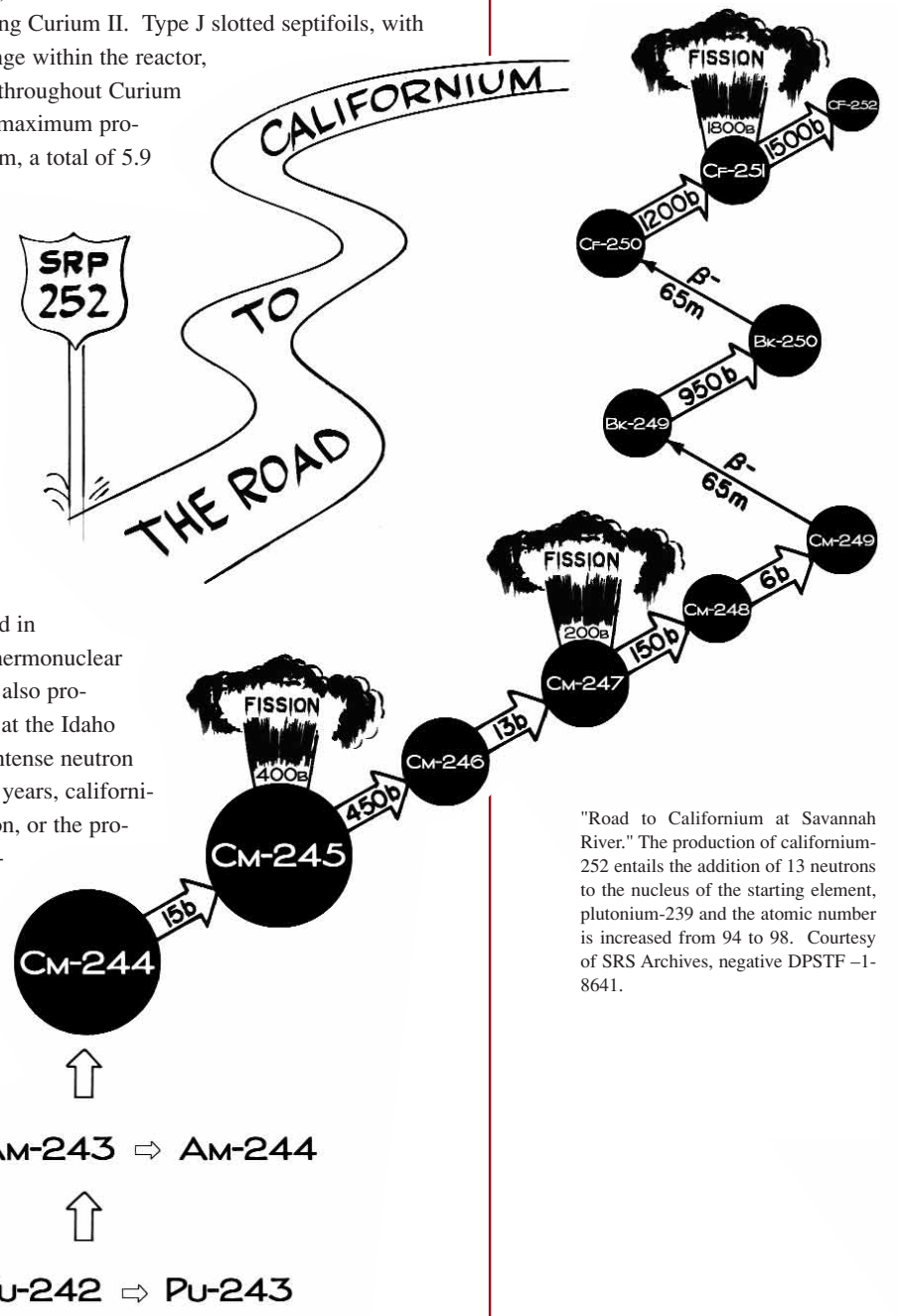
enriched uranium–aluminum fuel assemblies and one plutonium–aluminum assembly. In this configuration, the load was then bombarded by a neutron flux in excess of 10^{15} neutrons per square centimeter per second. This exposure continued until the plutonium-242 and americium-243 approached a steady-state condition.[27] Curium-244 then resulted from the decay of americium.

A number of reactor innovations were implemented in the course of both High Flux and Curium II. The Mark XII fuel assembly, with three fuel tubes of enriched uranium-aluminum alloy, was designed and used during Curium II. Type J slotted septifoils, with slots on the side to allow greater heat exchange within the reactor, were introduced during High Flux and used throughout Curium II. All of these advances made possible the maximum production of curium. By the end of the program, a total of 5.9 kilograms of curium-244 were produced—almost double what had initially been requested by the AEC.[28]

The Curium I and II programs were valuable precursors to the later production of californium. The curium programs not only provided source material for the creation of californium, but they also provided valuable information on the operation of reactors at high flux. In addition, Curium II itself produced around three milligrams of californium by the end of the program.[29]

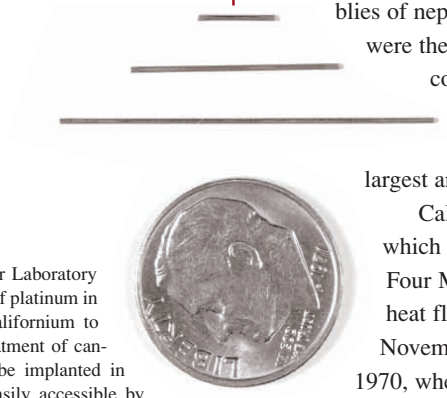
Californium, one of the heaviest of the transplutonium elements, was first discovered in 1952, in the blast debris left by the Mike I thermonuclear explosion. That same year, californium was also produced in the course of plutonium irradiation at the Idaho Engineering Development Laboratory. An intense neutron source with a relatively short half-life of 2.6 years, californium is uniquely capable of spontaneous fission, or the production of neutrons. The program to specifically create californium, identified as Californium I, began in August 1969 and continued until November 1970, with irradiation work conducted in K Reactor. The purpose of the program was to generate the element in sufficient quantities to make the isotope available to industry and medical facilities.[30]

The residues provided by Curium II were used as targets for the production of californium.[31] Californium I presented special difficulties in reactor control, since it



"Road to Californium at Savannah River." The production of californium-252 entails the addition of 13 neutrons to the nucleus of the starting element, plutonium-239 and the atomic number is increased from 94 to 98. Courtesy of SRS Archives, negative DPSTF –1-8641.

combined high neutron flux, low rod worth, and four percent residual xenon in the targets.[32] A new high flux lattice had to be developed for the campaign. This consisted of 96 large-diameter assemblies of uranium-235 and plutonium-242, and 104 target assemblies of neptunium-237 for the production of plutonium-238. Mark 18 and 18-A were the drivers used for the production of californium, and each contained three concentric fuel tubes of enriched uranium–aluminum alloy. As in High Flux and Curium II, cobalt was used in the control rods. When the program ended in November 1970, it had produced 2.1 grams, the largest amount of californium ever produced.[33]



The Savannah River Laboratory fabricated needles of platinum in which to encase californium to be used for the treatment of cancer. These could be implanted in deep tumors not easily accessible by other forms of treatment. Here, three different sizes of needles are shown next to a dime for scale. Courtesy of SRS Archives, negative DPSTF-1-12346-2.

Californium I was fraught with a number of technical problems, many of which could not be adequately anticipated under normal laboratory conditions. Four Mark 18 assemblies burned out in January 1970 as a result of the intense heat flux; this was the most serious incident that occurred in K Reactor from November 1969 to May 1970.[34] An incident that occurred on November 9, 1970, when an antimony–beryllium source rod melted while suspended above K Reactor, was even more hazardous. The cleanup required by this incident took over three months, and effectively ended the Californium I program.[35]

Long before the source rod failure closed down Californium I, studies were being conducted on the potential usefulness of the new element. As early as 1965, researchers at the Savannah River Laboratory proposed that californium could be employed in cancer treatment since it appeared to be more selective than radium at destroying cancer cells while leaving healthy cells relatively undisturbed. Based on this information, some of the first californium was fashioned into “needles” that could be inserted into cancer patients. Eventually, over 3000 of these needles were manufactured. Other studies determined that californium could detect subsurface gold, and could be used to search for oil, as well as underground water.[36]

The most ambitious of the plans to develop californium was the Californium Loan Program. In the course of this program, the AEC attempted to identify potential markets for californium, based on the isotope’s potential in medical applications, oil and mineral exploration, and neutron radiography. To fuel interest in the new element, californium samples were loaned to various organizations with an interest in those applications. In the early 1970s, Savannah River Laboratory’s Medical Source Facility prepared hundreds of californium sources for hospitals and medical research facilities. Larger sources were prepared in the Chemical Processing Facility in the Isotope Process Development Laboratory. In conjunction with the loan program, there was a scientific publicity campaign to popularize and help market the new element; numerous papers and reports were disseminated from the Savannah River Laboratory extolling the virtues of californium.[37]

Despite the work of the Loan Program and the attending publicity blitz, no viable market was ever found or developed for californium. With a few exceptions, this applied to the other transplutonium products as well. This simple market fact spelled the true end of the transplutonium programs. The Savannah River reactors and separations facilities were huge and had high operating costs. In order to be cost-effective, the reactor facilities had to operate at high power and engage in full production, and none of this could be sustained without a high demand for the product.[38] This, unfortunately, never materialized. In the end, the product was simply too expensive, and its use was too limited.

STABILIZATION OF THE MAIN MISSION: PLUTONIUM AND TRITIUM PRODUCTION, 1970

After the production rush of the 1950s and early 1960s, and after the heady years of the transplutonium programs, the main military mission of Savannah River—the production of plutonium and tritium— entered an era of stabilization. This was achieved through the use of lower power, the occurrence of fewer problems as operation techniques were perfected, and by the development of new mark assemblies that maximized the production of plutonium and tritium.[39]

All of this was good, because by the 1970s, Savannah River had completely eclipsed Hanford in the production of nuclear materials for military use. After 1971, Hanford had only one operating reactor (N Reactor), while Savannah River had three (P, K, and C). After years of fluctuating production levels in the late 1960s, culminating in 1970 with a record 81 reactor cycles—66 of which were californium—Savannah River in the 1970s achieved a production equilibrium of around 15 cycles per year. Savannah River's reactors provided the bulk of the nation's demand for new nuclear materials for military use.[40]

IMPROVEMENTS TO REACTOR OPERATION

Between 1964 and 1979, there were two major improvements to the operation of the Savannah River reactors. The first was in the nature of the housing that took the reactor assemblies into the reactor tank, and the second was the rise of reactor computers.

The first improvement to the housing for the reactor assemblies was called the semi-permanent sleeve. The sleeve was a series of hollow tubes used to guide fuel assemblies into the reactor. First tested in November 1964 in P Reactor, the semi-permanent sleeve went into full operation in 1965 with the Mark V-ELSD— similar to the Mark V-E except that it was specifically designed for use with the semi-permanent housing.[41]

The semi-permanent sleeve was in turn replaced by the Universal Sleeve Housing, or USH. Introduced in 1967–1968, the USH was not only more versatile and less expensive than its predecessor, but it also took full advantage of the openings in the reactor tank, allowing an increase in fuel diameter. This led to the retirement of all previous assemblies, specifically the Mark V-R (plutonium producer) and the Marks VI-B and VI-E (tritium-producers), as new ones were developed to take advantage of the increased size.[42]

The second improvement was even more far-reaching, as computerization was introduced in the monitoring and finally the operation of the Savannah River reactors. The impetus behind the use of computers in the reactor control room resulted from the problems created by the power increase of the late 1950s and early 1960s. As power increased, there were a greater number of instrument signals that had to be analyzed and monitored for proper operation, leading to an increased chance for human error. The first computers, used solely to monitor these instruments, were eventually replaced by others capable of control.[43]

The first computers installed in the reactor control room were the GE-412s, online process computers. Installed in K Reactor in 1964, these computers were placed in the other operating reactors by 1967. The GE-412s were installed by General Electric, which also trained selected Savannah River employees in their use.[44] State of the art at the time,

The Diverse Products of Savannah River

Savannah River participated in the Peaceful Uses of Atomic Energy programs of the Atomic Energy Commission in several ways, one of which was by making greater use of the versatility of its reactors for numerous non-weapons products. Products shown in red below were produced at the Savannah River Site.

The commission had from its establishment the dual purpose of supporting nuclear weapons production and promoting the peaceful uses of atomic energy—from the production of radioisotopes to the generation of electricity. The radioisotopes produced under this aspect of the Atomic Energy Commission's duties covered a wide spectrum of elements and included uses ranging from space exploration to research into the fundamental constituents of matter to new and promising medical treatments.

The figure below shows some of the numerous isotopes that have been produced by reactors under the Atomic Energy Commission and its successor agencies. As can be seen, the reactors at Savannah River were used primarily to produce heavy elements. To give an idea of the weight of these, polonium-210 is heavier than most natural lead, which exists in the isotope lead-208. The transplutonium isotopes usually include all radioisotopes heavier than plutonium-239, and these account for a significant number of the radioisotopes produced at Savannah River. The range of isotopes actually produced in the Savannah River reactors was much greater than those shown in the chart since reactor operations include numerous decay and neutron capture scenarios. Many of these additional isotopes and their decay products are held in waste storage locations at Savannah River. Courtesy of SRS Archives, negative 11395.



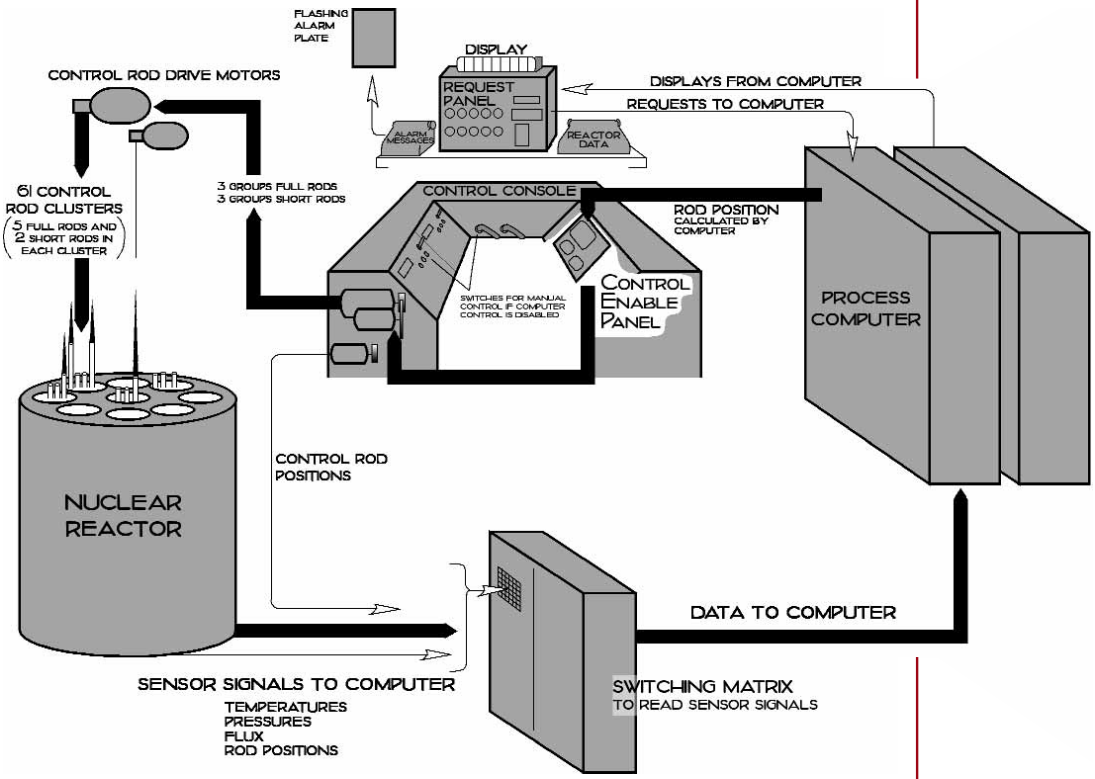
Sources: R. E. Tomlinson, B. F. Judson, and L. L. Zahn, Large-Scale Fission Product Recovery, *Proceedings of the Third International Conference on the Peaceful Uses of Atomic Energy,* held in Geneva, 31 August through 9 September 1964 10 (1965):544 and 547; Department of Energy, *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences* (Washington, DC: U.S. Department of Energy, 1997),150; E. E. Fowler, Recent Advances in Applications of Isotopes and Radiation in the United States of America, in *Peaceful Uses of Atomic Energy*, vol. 14 (New York: United Nations, 1972), 31--41; Atomic Energy Commission, *Major Activities in the Atomic Energy Programs, July--December 1954* (Washington, DC: Government Printing Office, January 1955),93; and *Science and Engineering at the Savannah River Plant and Laboratory* (Aiken, South Carolina: ca. 1970).

the GE-412 could process over 3000 instrument signals in each reactor. In 1964, it was capable of scanning and processing more signals than any other computer in the country, including those employed at NASA.[45] It was also the first known application of a computer to a nuclear reactor.[46]

The use of the first computers allowed reactor operators to retire the temperature monitor safety circuit, in addition to other recorder panels.[47] Even before the last of the GE-412s were installed, however, plans were being made to do more than that. As early as 1966, attention was given to designing a computer program that would automatically shut down a reactor in case of accident or other emergency.[48]

The first such computer was tested in October 1970 in K Reactor. Called Closed-Loop Computer Control, its main function was the automatic control of the reactor operation. The system read reactor data from the instruments, and adjusted the control rods accordingly by way of motors. In this manner, it was able to control overall reactor power levels, as well as specific areas of the reactor core, eventually controlling over 90 percent of the life of a typical reactor cycle.[49] Closed-Loop Computer Control called for two different types of computers in an arrangement that came to be referred to colloquially as "four in the floor." It was the first such computer control system implemented in the United States, and possibly the world.[50]

In 1973, after extensive testing, it was decided to replace the old GE-412s with the new computers, four to each reactor.[51] Two were responsible for reactor control, with one serving as backup. The other two were safety computers and replaced the original mechanical



Automatic Control of a Nuclear Reactor Using a Computer. Source: Kris L. Gimmy, Reactor Online Computer Applications in *50 Years of Excellence in Science and Engineering at the Savannah River Site, Proceedings of the Symposium May 17, 2000,* Report No. WSRC-MS-00061.

safety circuits.[52] The new computer system, Interdata Model 70, replaced the old GE-412s beginning in 1975–1976, when the first models were tested and installed in K Reactor. Installation in the other reactors was completed by 1978.[53] The new safety computers were soon taking on the task of Automatic Backup Shut down, which relied on injecting a solution of gadolinium nitrate, among other things, to shut down the nuclear reaction.

The use of safety computers is just one small element in the whole issue of reactor safety, which became increasingly important throughout the 1960s and 1970s. Since reactor safety is not directly tied to reactor efficiency, further discussion of this issue will be deferred to the end of this chapter. So far as efficiency is concerned, there were a great many other achievements, and these are discussed immediately below.

NEW ASSEMBLIES AND MIXED LATTICES

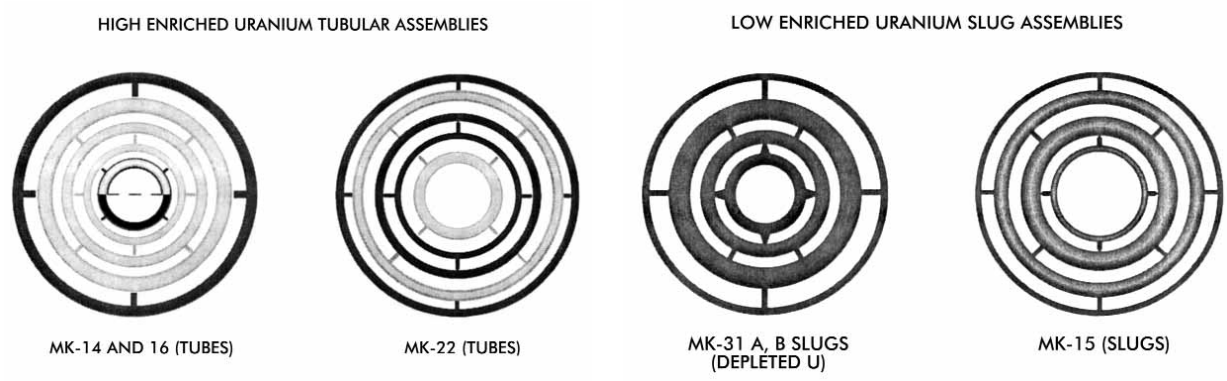
One of the significant achievements during this period—the one that more than any other was responsible for the efficient production of plutonium and tritium—was the development of the optimum fuel and target assemblies for use in the Savannah River reactors. After years of experimentation in the late 1950s and 1960s, mark assemblies were standardized in the early 1970s, as were the lattice arrangements needed to bring them to peak performance.

The development of the new efficient marks, and the mixed lattice arrangement that made them work, owed much to the transplutonium programs of the late 1960s. The Mark V-R fuel assembly for the production of plutonium, used in 1967–68, was the last to be used with the old semi-permanent sleeves. The development of the Universal Sleeve Housing (USH) required a different design, as did the success of the mixed lattice demonstration that occurred about the same time.[54] A component of the transplutonium programs, the mixed lattice arrangement, became a standard of reactor operation in the 1970s and 1980s.

Initial Savannah River reactor operations relied on what was called a uniform lattice, or a reactor core arrangement in which all assemblies were identical, with fuel and target elements within each assembly. A mixed lattice featured a core arrangement that combined uranium-235 fuel assemblies and other assemblies specifically designated as targets. The first mixed lattice operation at Savannah River was proposed in a report to the AEC in 1966, and was conceived in conjunction with the installation of Universal Sleeve Housing.[55] Mixed lattices were used in the transplutonium programs, especially Curium II, and the idea was quickly extended to the production of plutonium and tritium as well. In May 1967, a Mixed Lattice Demonstration, using a different target materials, was conducted in K Reactor following the end of Curium II.[56] The first assemblies or marks designed for this mixed lattice arrangement were the Marks 50-A and 50-B, which served as targets, and the Mark XII-A, which served as the driver or fuel source. It was not coincidental that Mark XII-A was similar to the Mark XII charge designed for the production of curium.[57] These first marks were soon followed by others: Marks 14 and 16 as drivers, and Mark 30 and 31 as a depleted-uranium target.[58]

By 1968, Mark 14 and Mark 30 had been developed as the driver and the target assemblies, respectively, for the first regular mixed lattice production of plutonium. The Mark 14 assembly contained three highly enriched uranium-235 fuel tubes, while the

Mark 30 series of target assemblies contained depleted uranium.[59] The Mark 30-series charges became the standard for the new plutonium producers.[60] The Mark 30 series were mixed lattice assemblies that always required enriched uranium drivers, usually Mark 14 or 16. The Mark 16 assemblies contained twice as much uranium-235 as the Mark 14's, and this allowed for several target stages for each Mark 16 cycle, with each successive Mark 30 assembly containing less depleted uranium. This lattice arrangement had the advantage of better "neutron economy," which made possible more products per reactor exposure, as a result of the increased level of uranium-235. It also meant a reduction in



Examples of high enriched uranium tubular assemblies and low enriched uranium slug assemblies, developed at Savannah River. Source: SRS History Project.

fuel assembly costs, since the Mark 16 assemblies could stay in the reactor longer than was possible with the Mark 14s. By the 1970s, the MK16-31 configuration had become the plutonium-producing workhorse at Savannah River, and remained popular until the reactors were shut down in 1988. Even though Mark 15, tested in 1983 in a uniform lattice, proved to be the single most productive of all the plutonium-producers used on site, its use was limited due to the high cost of feed material. Its high composition of 1.1 percent uranium-235 could not be manufactured without expensive adjustments to the existing uranium-enrichment facilities.[61]

A similar standardization occurred in the production of tritium, even though in this instance a uniform lattice, not a mixed lattice, became the norm. Early in the 1970s, the Mark 22 was introduced as an improved charge for tritium production, and was designed to take full advantage of the Universal Sleeve Housing. Mark 22 had two concentric fuel tubes of enriched uranium-aluminum alloy, placed between inner and outer target tubes of lithium-aluminum alloy. Its semi-permanent outer housing contained no lithium so that it could be used in the reactor for years before it had to be replaced. The first full load of Mark 22 charges was placed in operation in 1972, and Mark 22 quickly became the standard in K Reactor. It quickly became the tritium-producing workhorse of Savannah River.[62]

The mixed lattice arrangement, and the new marks that followed, proved to be highly successful, and were custom-made for an era in which the reactors were producing a variety of nuclear products, particularly plutonium-238. The versatile mixed lattice arrangement also had other ramifications. It gave the Savannah River reactors a distinct advantage over the Hanford reactors at a time of reduced plutonium production. As a result, the success of the mixed lattice at Savannah River is believed to have been a major factor in the AEC decision to shut down all the reactors at Hanford—with the exception of N

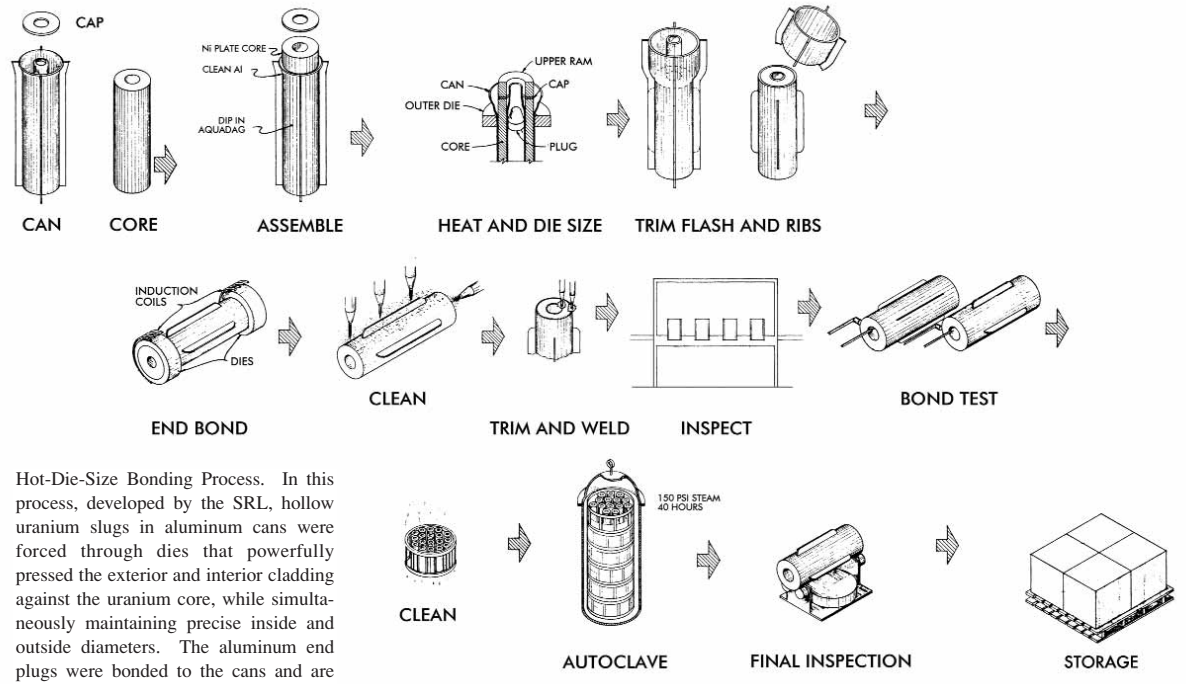
Process-Flow - Hot-Die-Size Bonding

Materials and models used in fuel fabrication: uranium, aluminum, crucible, mold and core, U-AL ingot, pre-extrusion billet, pre-extruded log, aluminum weld rings, aluminum sheaths, coextrusion billet, machined components, partially extruded billet, coextrusion die, and mandrel. Negative 28509-28.



Success in the development of thermonuclear weapons required that the SRP reactors produce greater quantities of tritium. To do so, fuel elements needed to be manufactured from uranium that contained a high percentage of uranium-235. "To dissipate the heat generated it was necessary to design thin tubes with large surface area relative to the amount of uranium within them. The first of these "extended surface" fuel elements were developed by and procured from Nuclear Materials, Incorporated. The tubular fuel elements were composites of three layers made by coextrusion of a composite billet. The middle layer was an alloy of enriched uranium with aluminum that was clad, inside and out with aluminum." The production of the enriched-uranium tubular fuels was moved to Savannah River where a new facility was built in M Area for its manufacture.

Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 102–104.



Hot-Die-Size Bonding Process. In this process, developed by the SRL, hollow uranium slugs in aluminum cans were forced through dies that powerfully pressed the exterior and interior cladding against the uranium core, while simultaneously maintaining precise inside and outside diameters. The aluminum end plugs were bonded to the cans and are seal-welded by the process.

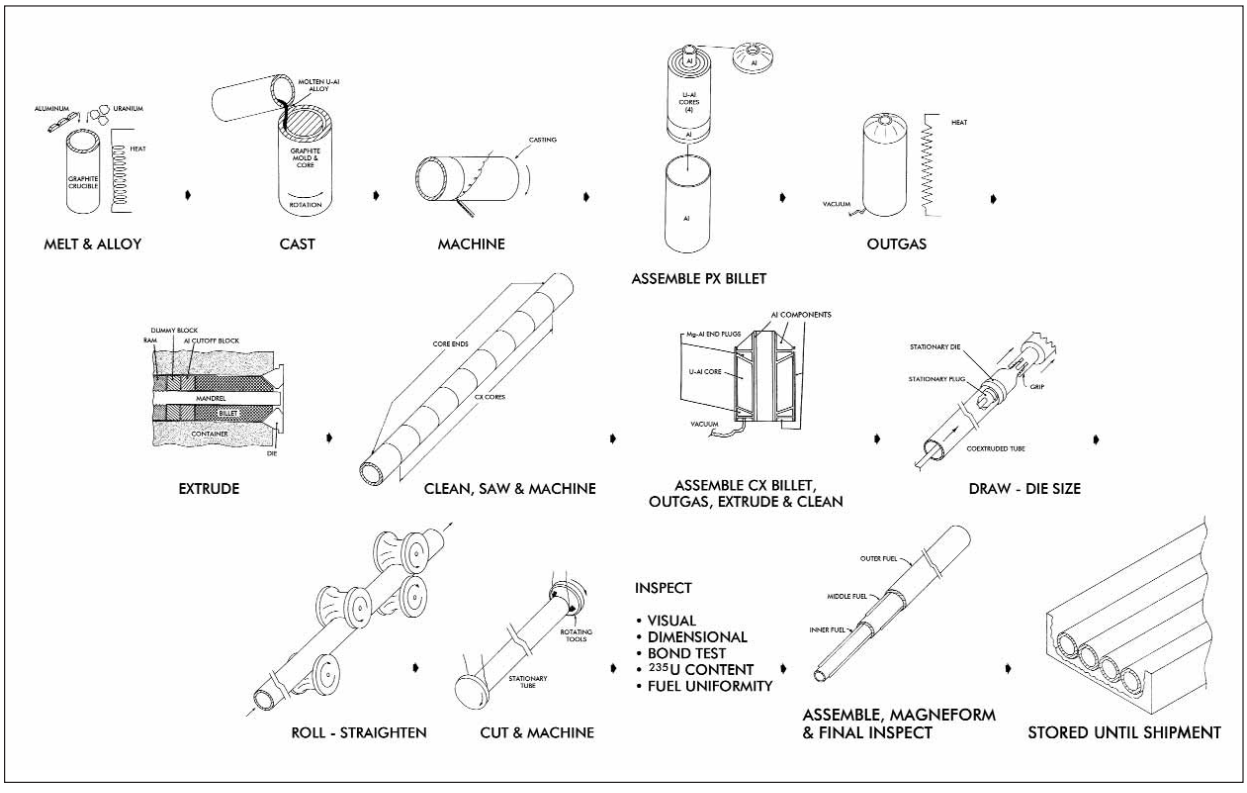
Process-Flow - Fuel Fabrication

These thin tubular fuel elements (and later similar target elements) made possible further exploitation of the intrinsic versatility of the SRP reactors. The fabrication process began with a nest of three short, thick-walled hollow cylinders—the innermost of pure aluminum, the middle, or core, of enriched uranium-aluminum alloy, and the outermost of pure aluminum. Thick aluminum discs at each end completed the composite billet. This billet was then forced through a heated die that reduced its diameter and thickness, and greatly increased its length while at the same time forming fins on the inside or outside to center the tube with mating components in the reactor assembly. The aluminum discs at each end of the billet closed off the ends of the enriched-uranium aluminum-alloy core so that it was completely covered with aluminum. In thin tubular target elements, lithium–aluminum alloy comprised the core.

Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 102–104.

G. E. Minor welding extrusion billet component in SRL Lab. Courtesy of SRS Archives, negative DPSTF-1-13826-36.

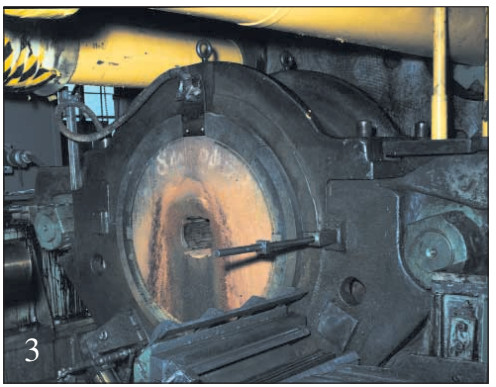


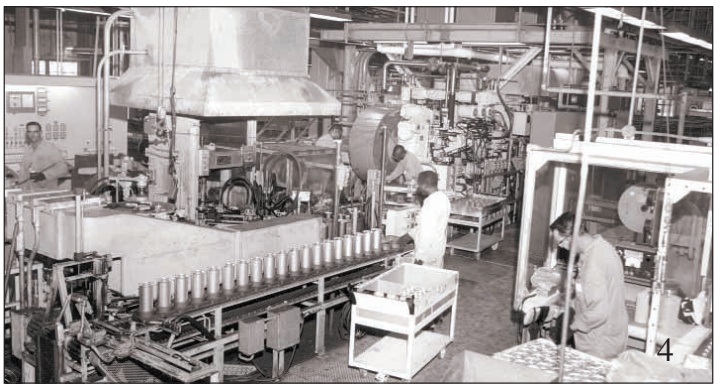


Fuel Fabrication Step by Step

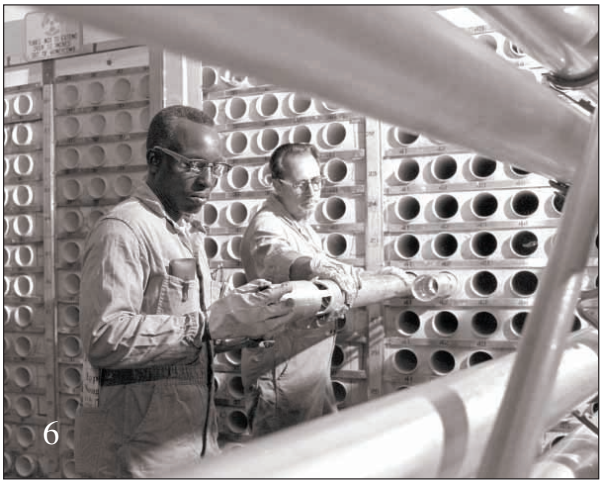

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Reactor, which also produced electricity for the Pacific Northwest. Because N Reactor produced plutonium with a higher percentage of plutonium-240 than that required by the AEC for weapons-grade plutonium, the Savannah River reactors had to produce plutonium with a lower percentage of plutonium-240, so it could be blended with the Hanford material to create the required percentage.[63]

At Savannah River itself, perhaps the best indicator of the success of the new assemblies and lattices was the retirement of the Process Development Pile (PDP) in 1979. Having outlived its usefulness, the PDP saw its last experiments in March, and was shut down in September of that same year.[64]

300-AREA MANUFACTURING INNOVATIONS

The greatest single innovation in the manufacturing techniques used in the 300-Area, or Raw Materials Area, was the adoption of hot-die-size bonding as the method of canning large-diameter tubular elements. The Savannah River Laboratory began studies on hot-die-size bonding in 1961, and the technique was tested throughout that decade. In 1969, the process replaced hot-press bonding as the standard for reactor tube production.[65] Not only did hot-die-size bonding represent a lower cost in the canning of tubes from the previous methods, but the bond strength was greater. In addition, the new method provided more surface for heat transfer than that offered by the previous techniques.[66]

In the 1970s, there was no single innovation that could compare with hot-die-size bonding, but there were numerous improvements to equipment and techniques throughout the decade. Perhaps the greatest of these was the replacement of the first Nuclear Test Gage (NTG) with the second set of smaller NTGs in the late 1970s. Unlike the original NTG, which operated close to criticality, the new NTGs, or "Mini-NTGs," had better instrumentation and were safer, since they operated well below criticality. Unlike the old NTG, which used radium-beryllium as source material, the new NTGs used californium-252, which meant a reduction in hazardous gamma rays.[67] The new NTGs also had the advantage of being much smaller than the original. About four feet square, they had a test port allowing access to the active area, which was about 16 inches long. Rods, targets, and fuels were passed through to test their reaction to neutron flux.[68]

Other improvements included the installation of the first computers in the tube manufacturing building. In 1977, the MODCOMP II/26 replaced the first computer process monitor, the MODCOMP III/15, installed in the early 1970s.[69] In the late 1970s, almost all production fuel assemblies consisted of fuel tubes, no matter what the production techniques. Fuel assemblies had a 12.5-foot-long core that usually consisted of three concentric tubes, with interior and exterior diameters that ranged from 1.75 to 3.75 inches. The fuel was mixed with aluminum to facilitate the separations process, and it was also clad in aluminum to prevent contamination of the heavy-water moderator.[70]

The manufacturing of tubes was improved. The late 1960s saw the first use of ribbed extrusion billets for the production of ribbed tubes.[71] It was also around this time that aluminum tubes were extruded from cylindrical billets, using the die-and-mandrel process, rather than the older porthole-die process.[72] By the late 1970s, titanium molds and cores replaced graphite molds in the production of lithium-aluminum alloy tubes. This eliminated the persistent problem of graphite inclusions in the metal.[73]

(Opposite Page) 1. Casting, negative 90-2372-23. 2. Assembly of coextrusion billets prior to capping negative DPSPF 143951-57. 3. Extrusion press and billet loader, negative 39755-6. 4. Hot-die-size bonding of hollow uranium slugs, negative 13555-21. 5. Tube straightening, negative DPSPF 1-7552. 6. Inspection of fuel elements and storage in M Area honeycomb. The honeycomb storage rack system was specially made for fuel storage. The racks shown are composed of concrete slabs, pre-cast from boreated concrete as a safety feature, and pierced with cylindrical holes from end to end, that were tightly stacked to store fuel until they were needed in the reactor areas, negative DPSPF 19537-7. All photographs courtesy of SRS Archives.

Powder metallurgy, a much more radical technology, was thoroughly tested during this period. As uranium was reused, Uranium-236 and Uranium-238 built up. Powder metallurgy would have enabled continued use of recycled uranium and indeed production of Plutonium-238. This technology would have created fuel tubes with a higher weight–percentage of uranium through the use of uranium oxide–aluminum tube cores, rather than the usual uranium–aluminum alloy. The powder metallurgy tubes would have been made by isostatic compaction, and would have been assembled in billets and extruded using conventional coextrusion techniques.[74] This technology was tested and tinkered with throughout the 1970s, but it was never implemented.[75] Even though it could have been an improvement over the older method of tube manufacture, with the declining demand for nuclear materials, it was simply not worth changing over the whole system to accommodate the new technique.



The final shipment of heavy water to Ontario Hydro, for use in the first of four reactors projected to be built by the Ontario Hydro-Electric Commission near Ontario, is ready for departure in 1970. D Area employees take advantage of this photo opportunity (from left) Cecil B. Scruggs, Herb Parrott, Warren Long, Vernon Ford, Ken Boren, D. J. Barsh, Jr., Harold Bullard, Charlie Davis, Glenn Stokes, Don Bowman, L. E. Tuten, Martin E. Coon, Frank Luminello, Jack Cawthon, and H. H. Sullivan. Courtesy of SRS Archives, negative 14185-1.

HEAVY WATER

With only 412-D in operation and the partial conversion of the DW plant, heavy-water production and rework continued through the 1970s with a workforce that slowly expanded to 351 in 1975. The rework unit received diluted heavy water from the reactors, and reconcentrated it to original specifications. During this period, the peak production year for heavy water was 1969 when 908,400 pounds were produced. The plant histories show a steady decline in production rate through the early 1970s, but also document healthy sales or leases of the D Area product to domestic and foreign users by the AEC.

Billed as the Free World's major source of heavy water, D Area produced the only SRP product that brought in cash earnings from the production facilities. The 1968 sale of 521,000 pounds of heavy water was valued at $15 million dollars. Two years later, sales or leases of 1,856,800 pounds of heavy water fetched $50,656,000 in revenues for the Commission. The next year, sales decreased somewhat with 1,159,000 pounds of heavy water bringing in $33,494,000.[76] Foreign shipments became commonplace to AEC personnel such as Jack Donnahue and D Area workers who worked with both national and international consumers, testing the purity of the product prior to its shipment, cooperating with shipping, and arranging the monetary details involved.

While D Area served the world market, its "home market," the Savannah River reactors, was dwindling. A reserve stock was already in storage that would meet future needs and the AEC's interest in continuing heavy-water sales and leases had peaked. The two GS units shut down in 1957–58, 411-D and 413-D, were targeted for dismantlement and the continuance of the area's primary mission was in question.

SEPARATIONS AREAS

As the places where nuclear materials were processed and purified after they left the reactors, F and H areas, known as the Separations Areas, were crucial to the operation and

ultimate success of Savannah River. By the plant's middle years, the majority of the operations that chemically processed the radioactive materials sent over from the reactors, had been in use for almost a decade. By the late 1960s, most of the kinks in the system had been hammered out, and the essential processes used in the recovery of plutonium and tritium had been refined. The few incidents, even accidents, that did occur, such as the sand filter collapse of 1969 and the F Area A-line explosion of 1975, only served to tighten operations in F and H areas.[77]

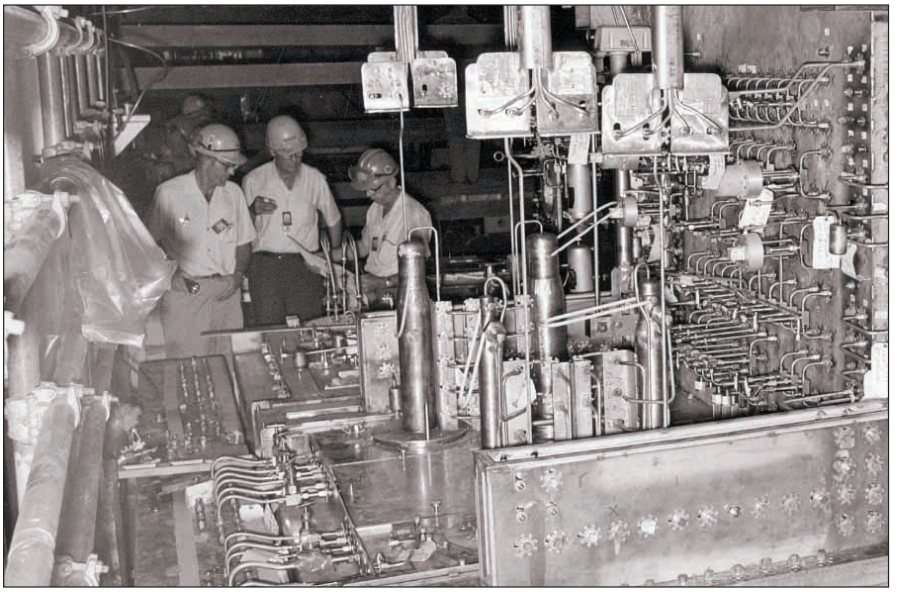
The processing of nuclear waste materials, which was undertaken in the Separations Areas, was likewise improved during this period. In the early 1970s, seepage basins, which had been standard in the early years of Savannah River, were retired in favor of lined retention basins. This reduced the seepage of radioactive materials into the ground, and cut down on the contamination of the regional aquifer.[78] It was also during this period that the nuclear wastes stored at Separations, previously held in alkaline solutions, were switched over to an acidic matrix, which was an improvement over the previous arrangement.[79]

The biggest changes to the Separations Areas, during this period, were the further development of techniques needed to process nuclear materials for the heat source and transplutonium campaigns, often lumped together as "special programs." It is important to remember that everything made in the Savannah River reactors, including the "special products," had to be processed in the Separations Areas. Many of the changes made to the Separations processes that made it possible to handle the heat source and transplutonium programs, have already been discussed. A few additional changes will be discussed here as well.

Separations work on plutonium-238, the primary heat source material, began in 1960.[80] As this work increased, more accommodations were made to the process. In 1967, Building 235-F was retooled to make more neptunium-oxide target slugs needed for the production of plutonium-238.[81] This work was augmented by the construction of the Plutonium Fuel Form Facility (PuFF) in the same building in the 1970s.[82] Begun in the early years of the decade, the facility was largely completed by 1975, and was authorized to begin production in December 1978.[83]

The processing of transplutonium elements also began in 1961. Although this work continued throughout most of this era, the bulk of the processing took place between 1965 and 1970.[84] New separations processes, like Tramex, were developed to handle the production of elements like curium and californium.[85] To further accommodate this mission, the Multipurpose Processing Facility (MPPF) was built to consolidate all americium, curium, and californium processing in the Separations Areas. The MPPF, however, was constructed too late to participate in the big transplutonium programs of the late 1960s. Started in 1970 and completed two years later, the facility was put on standby in 1973 until the market for transplutonium materials improved. This anticipated upswing simply failed to materialize, and the MPFF was not put into use until 1978.[86]

During this period, the Separations Areas were active in work associated with the burgeoning nuclear power industry. Separations work on uranium-233 associated with the thorium campaigns of the late 1960s and early 1970s, were part of the AEC's ongoing breeder reactor programs. Separations also did research for the power industry that was totally independent of the work that went on in the reactor areas. One example was work on the electrolytic dissolver, which was crucial to the development of power reactor fuels.

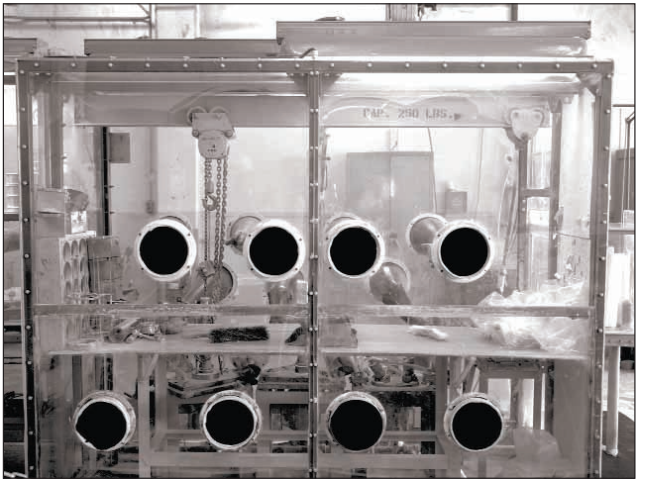


(Right) Mockup of MPPF equipment racks in F Area Mockup Building, 1971. Courtesy of SRS Archives, negative DPSPF 15054.

Since power reactor fuel assemblies had to endure much higher temperatures than those normally encountered in a production reactor, their fuel assemblies usually had components made of stainless steel and zirconium, rather than aluminum. Unfortunately, neither stainless steel, nor zirconium, could be dissolved in chemical solutions that used nitric acid, essential to the Purex process, or that used stainless steel tanks, like those found at Savannah River. It was found, however, that these materials could be dissolved "anodically," as the anode of an electrolytic cell. As a result, as early as 1959, the AEC asked Savannah River to develop this process on an industrial scale for the benefit of the burgeoning nuclear power industry.[87] After years of research, the first electrolytic dissolver campaign was conducted at Savannah River in 1969. This was followed almost immediately by at least four more campaigns conducted in the early 1970s.[88]



Left is a thorium slug ready for shipment to P Area reactor for irradiation to produce uranium-233. Solid metal slugs like this one, produced in 1962, could be produced with standard metalworking equipment. Later thorium assembly components were produced from thorium oxide powders, which had to be handled in gloveboxes (Right), due to the hazards associated with inhaling the metallic powders. Courtesy of SRS Archives, negatives DPSPF-8556-1 and 11078-5.



SAFETY DEVELOPMENTS

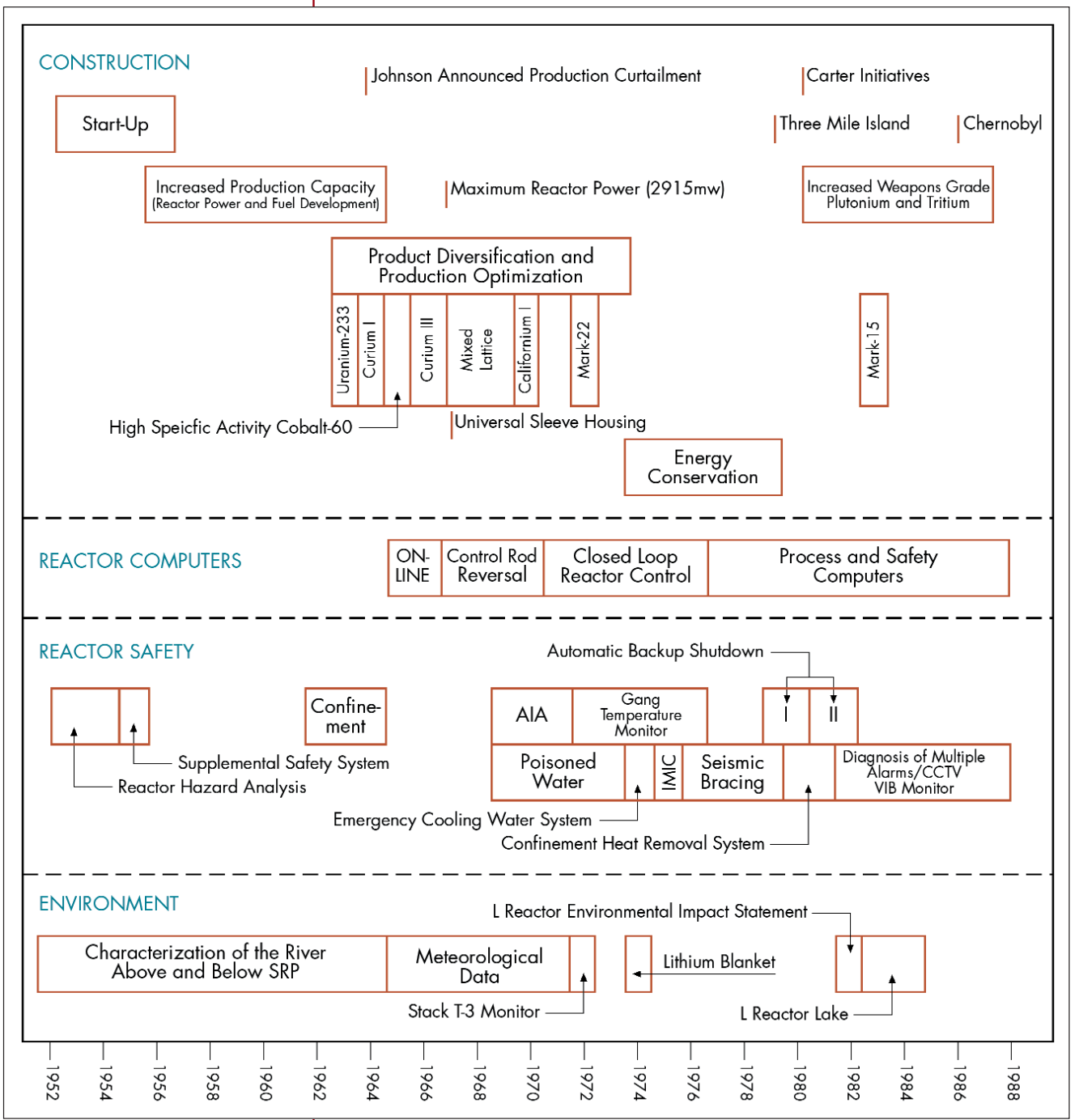
One of the hallmarks of the Du Pont operation at Savannah River was a concern for safety. This was apparent during the construction of the plant, and it remained an important part of the operation of the plant throughout the 1950s and beyond. It became even more of a concern in the 1960s. In 1965, for example, "reactor safety" became for the first time an independent topic heading in the official Savannah River Laboratory histories.[89] This was not only due to the slowdown of production, which allowed it to become a more pressing concern, but also because there was a growing interest in nuclear safety in general, not only at the plant, but in society at large.

Within the nuclear industry, there were a number of reasons for this heightened interest in safety. The first was the occurrence of the worst nuclear accident ever to have taken place in the United States: on January 3, 1961, three lives were lost as a result of the SL-1 military reactor accident at the National Reactor Testing Station.[90] The second was a push by the AEC to clean up older nuclear sites no longer needed for production. In the 1960s, the oldest reactors, dated to the World War II era, were shut down, and this forced the Commission to come to grips with the legacy of a radioactive facility.[91] This, in turn, led to the first attempts to operate reactors in such a way as to minimize the need for massive cleanup in the future. In this fashion, the disposal of waste materials became a greater concern than had been the case previously. At Savannah River, this led to the retirement of seepage basins in 1970.[92]

The increase in safety issues can even be seen in the shift in engineering styles within the nuclear industry. With the rise of power reactors in the 1960s, there was greater emphasis on the new "electrical" style of nuclear engineering, favored by General Electric, Westinghouse, and Admiral Rickover. The new style of engineering favored extensive planning, unlike the older engineering style of "cut and try" adaptability, favored by chemical companies like Du Pont.[93] The older "chemical" style tolerated a certain level of low radioactivity as the price of running a nuclear plant. The new "electrical" style was more concerned with minimizing that threat. Du Pont believed in "defense in depth," with an emphasis on good procedures, good facilities, and reliable people. And this had certainly paid off. By 1962, the National Safety Council was giving awards to the AEC and its contractors for low injury rates: 2.03 per million within AEC facilities, compared with 5.99 per million as the average for all U.S. industry.[94] By the later 1960s, however, that was not enough. Throughout the decade, and into the 1970s, the AEC continued to ratchet up the safety requirements at all of its facilities.[95]

One of the reasons reactor safety continued to get pushed at Savannah River was the continuation of reactor incidents in the 1960s, especially in C Reactor. In May 1965, the tank top of C reactor leaked when a semi-permanent sleeve was raised during full power operation, spilling 2100 gallons of heavy water on the floor around the reactor tank. As a result of this incident, the reactor assembly forest was redesigned, with the inclusion of physical barriers that limited the amount of upward movement during reactor operation.[96] That same year, chloride stress corrosion cracks appeared in the C Reactor tank.[97] Despite changes to the heavy-water chemistry to reduce the potential for such cracking, the problem worsened over the next few years, especially at the knuckle joint, which had to be repaired by patching. In 1968, the reactor had to be shut down for patch repairs, many of which were performed by a robotic service arm created to do this work.[98] The other reac-

tors had their own problems. In February 1972, K Reactor was shut down by its safety instruments, due to poor power distribution within the reactor as a result of personnel error. This led to an increased emphasis on the use and scope of the safety computers.[99] Other problems in K Reactor soon followed, like the target leakage problem apparent during tritium production.[100]



As a result of these and other incidents, there was a continual push from the AEC to review nuclear safety and to install new devices to ensure the safe operation of the Savannah River reactors. The first serious review of Savannah River reactor safety was conducted in August 1964 by the AEC's Advisory Committee on Reactor Safeguards (ACRS). This led to some overhaul of safety features by 1966. One of the first of these was the Emergency Cooling System, installed to cool down a reactor in the case of nuclear accident. According to the standards established for the Emergency Cooling System in 1966, the system would supply 9000 gallons per minute within 40 seconds of an accident. A spray system would be available anywhere that irradiated fuel was handled, ensuring that it would be too cool to melt. The system also provided sufficient flow to remove radioactive decay heat for three months after a reactor shutdown.[101]

In December 1969, a Poisoned Light Water System was installed in C Reactor. The system was designed to overcome the positive reactivity transient from light water in the fuel coolant annuli of the Mark 16 enriched–depleted driver assemblies. The success of this system in C led to its installation in P and K reactors by the early 1970s.[102] This was followed by the installation of the Poisoned Emergency Cooling Water System (ECW) in 1973. The ECW was also designed to accommodate the Mark 16-31 charges, specifically the possible radioactivity from the emergency addition of light water to the Mark 16-31 charges.[103] In 1973, the Emergency Cooling System was modified by the addition of automatic emergency cooling, which included the addition of larger pumps for the removal of contaminated water and increased storage capacity for contaminated water.[104]

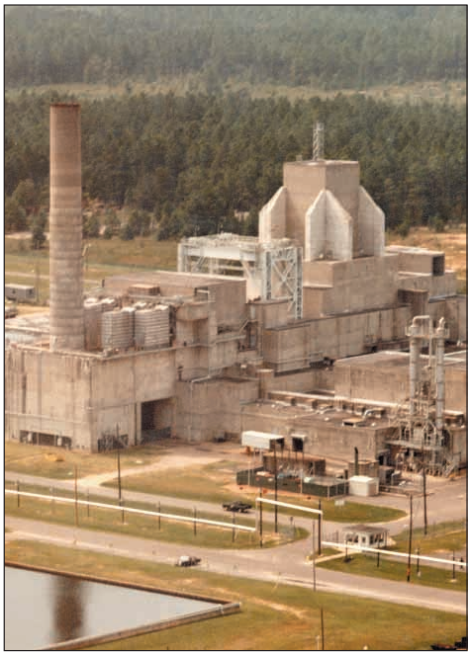
The first Automatic Backup Shutdown Gang Temperature Monitor (ABS-GTM) was installed in P Reactor in 1974. The ABS-GTM was a backup reactor shutdown system that was completely independent of the safety rod scram system. The ABS could automatically inject gadolinium nitrate into the reactor tank, which essentially automated the function of the SSS. This system was soon installed in the other reactor areas.[105]

The Emergency Light Water Cooling system had to be modified in the late 1970s due to an infestation of fresh-water clams *(Corbicula manilenensis)*. The clam infestation was first noted in 1975 in the cooling water heads of the main process water heat exchangers. Although this infestation adversely affected cooling water reaching the reactor, the problem was more serious for the Emergency Light Water Cooling System. As a result, the water source for the cooling system had to be changed from river water to water supplied from a 500,000-gallon storage tank.[106]

Another addition to the Savannah River reactors was the seismic safeguards that were studied and finally installed in the mid-1960s and 1970s. Although it is not known for major earthquakes like those associated with the Pacific Rim, South Carolina has had its share of earthquakes. The most famous occurred in Charleston on August 31, 1886, but at least 40 others have been recorded within a 200-mile radius of the site since the middle of the 1800s.[107] By the mid-1960s, due in part to the earthquake safeguards required for power reactors, the AEC began to suggest seismic safeguards for the operating reactors at both Hanford and Savannah River. At Savannah River, this led to the first earthquake study, organized in 1966.[108]

This study, headed by Dr. George Housner of the California Institute of Technology, also included Du Pont officials and representatives from other engineering firms. The study, and others, all conducted and written in 1967, established an outline for future programs to protect against the threat of seismic activity. Basically, it was determined that

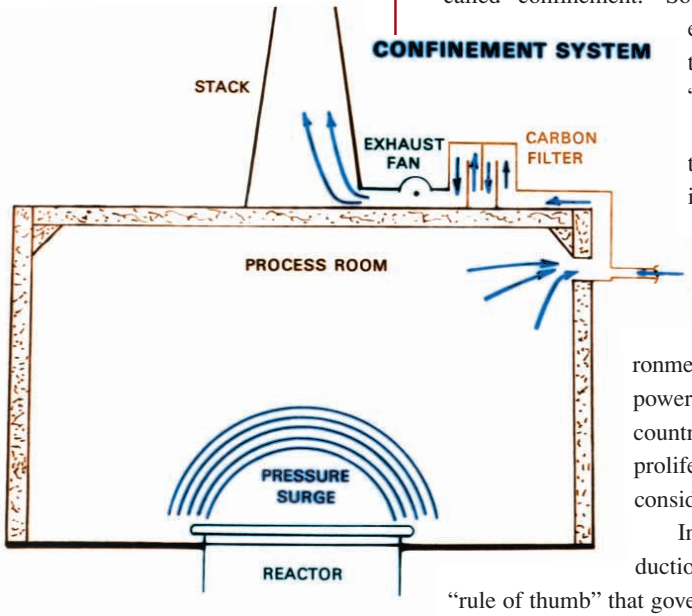
(Opposite Page) Improvements to Reactor Operations Over Time. Source: J. M. Boswell to A. H. Peters, "SRP Graphic History," March 30, 1990, 22-29, personal collection of J. M. Boswell.



Aerial view of 105-P Reactor with seismic bracing or buttresses on high hat, 1979. Courtesy of SRS Archives, negative 3772-79.

most buried installations would suffer minimal damage, with the exception of the waste tanks in the Separations Areas. Well-anchored equipment at or near ground level should likewise suffer minimal damage, as would reservoirs and containment basins. Alternatively, reactor instruments would probably not survive intact, and the same could be said for the taller portions of the reactor buildings and other structures.[109] A structural analysis of the more "at-risk" buildings at Savannah River was done two years later by John A. Blume and Associates of San Francisco. That study concluded that exposed actuator towers and exhaust stacks needed to be strengthened. These improvements were carried out throughout the 1970s.[110]

The greatest of the safety issues, dealing with the Savannah River reactors, would have to be the controversy over "confinement" and "containment." Beginning in the 1960s, and certainly in the 1970s, there was increased concern not just for reactor safety, but also the containment or confinement of radioactive materials that might be released from the reactors into the atmosphere or surrounding area.[111] Simply accepted as a possible risk in the 1950s, such releases were mitigated by ad hoc measures in the 1960s in an approach to the problem that came to be called "confinement." Soon, even this was considered inadequate as newer reactors were encased in domes or made with other all-encompassing structures. This holistic approach to the problem came to be called "containment."



This progression of concern developed hand-in-hand with the rise of power reactors, virtually unknown in the 1950s, but increasingly popular in the decade that followed. By around 1970, power reactors had clearly superseded production reactors in the use of electrical power and in the sheer number of reactors around the nation.[112] The more relaxed attitude toward environmental releases in the 1950s made sense when the largest and most powerful reactors were localized to two isolated areas in the entire country: Hanford and Savannah River. As power reactors began to proliferate adjacent to urban concentrations, this attitude was no longer considered acceptable.

In 1950, when there were no power reactors and only a few production reactors, the AEC Reactor Safeguard Committee established a "rule of thumb" that governed reactor placement. No attempt was made to confine, much less contain, radioactive contamination released into the environment. It was simply

assumed that such releases would occur periodically, and it was assumed that ample land and spacing around the reactors would provide protection against the adverse effects of such releases. Distance provided the buffer between the airborne release of radioactive contamination and neighboring population areas. Not only would it provide time for an adequate warning of the release, but it also allowed for the dispersal of the most dangerous materials. It was understood that lethal doses of radioactivity would be rare at the distance of, say, 10 to 15 miles from the reactor.[113] The rest was just considered an accepted risk.

As power reactors became more popular in the 1960s, and as they were increasingly sited adjacent to the population centers they served, simple distance was no longer a realistic option. As power reactor designs became safer in response, with confinement giving way to absolute containment of radioactive releases, the older production reactors at Hanford and Savannah River had the almost impossible task of trying to catch up. Short of the absolute containment, a measure that was almost universally considered too expensive for the older reactors, everything possible was done to mitigate or lessen the potential bad effects of any radioactive releases into the environment. This was the premise behind "confinement."[114]

First implemented in the 1960s at the behest of the AEC, the confinement measures employed at Savannah River were increasingly sophisticated. One of the first of these was the creation of negative pressure inside the reactor buildings to keep radioactive releases from escaping into the atmosphere.[115] Confinement Filter Compartments were installed in all the reactor areas to filter contaminated air, and this performed well when the antimony–beryllium source rod failed in November 1970— the incident that shut down the Californium program.[116] As outlined in reports dated to that time, the Savannah River

SROO Staff, 1978. Seated from left: Dale Sandberg, Duane Sewell, Assistant Secretary for Defense Programs, DOE-HQ, Nat Stetson, manager, and Ernie Chaput. Standing from left: Chuck Simpson, John Cumbee, Bill Reese, Ed Goldberg, Bob Caldwell, Ben Harmangour, Tom Marsh, Newt Seebeck, Melvin Sires, David Peek, and Bob McFeeley. Courtesy of SRS Archives, negative 27967-2.



confinement system adhered to the theory of "defense in depth," with a number of devices designed to catch radioactive materials at various stages before they could be released into the atmosphere.[117] As part of this program, the 100-Areas Central Environmental Committee was formed in January 1973 to monitor and control all radioactive material released into the atmosphere from the reactor areas.[118]

Supporting Views



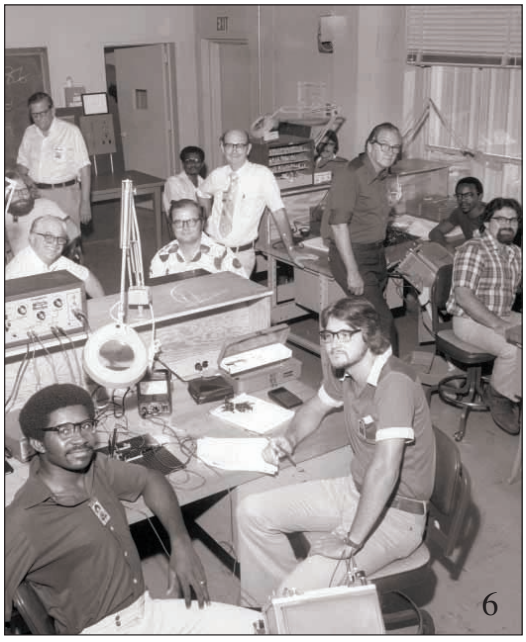


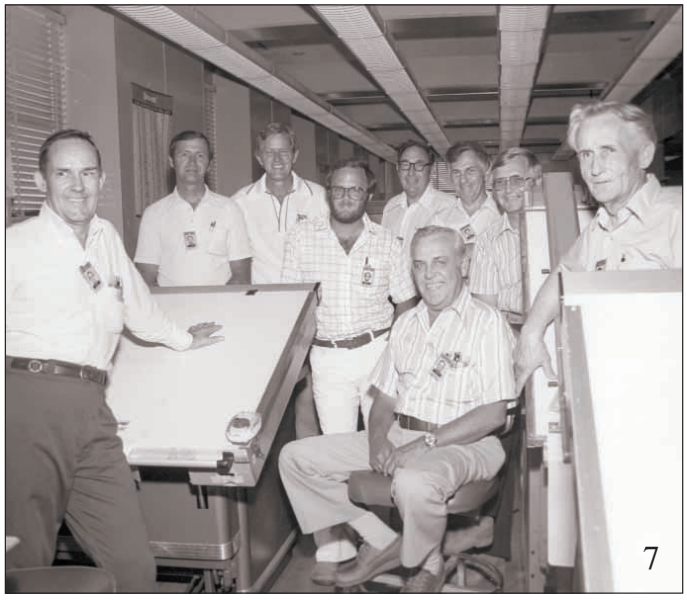
1. Clerical pool from 703-A, 1978. Individuals unidentified. Courtesy of SRS Archives, negative 27204-2. 2. Equipment Engineering Division's Applied Physics Group. Left to right: Greg Dyches, Joe Hopkins, George Thomas, Herbert O'Connor, 1978. Courtesy of SRS Archives, negative 27227-39. 3. Firehouse Crew, 700 Area, 1978. Left to right: Ray Siegler, Marion Muns, Mike Frazier, Jerdan Seigler, Earnest Drumming, Jennings Burnett, and Ralph Pilot. Courtesy of SRS Archives, negative 27227-7. 4. Plant Manager's Secretary's Office, 1978. Left to right: Becky Brice, Mary Willis, Maude Laren, Louise Hendricks, and Pearl McMahan. Courtesy of SRS Archives, negative 27227-10. 5. E & I Welding Shop in 717-A, 1978. Left to right: Jack Johnson, David Copeland, Paul Corbitt, Clarence Napier. Courtesy of SRS Archives, negative 27227-35.











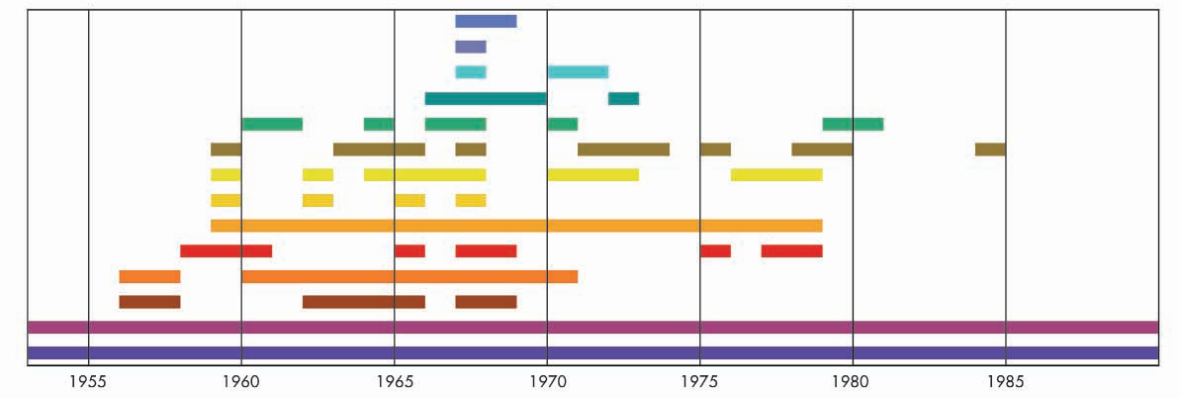
6. E & I Training School in 724-A, 1978. K. D. Byram, Anthony Roberts, Benny Fanning, Chip Poston, Dusty Rhodes, J. R. Martin, Luther Hanson, Glenn Parker, Bo Hagler, Earnest Glover, W. P. Leaphart, and Ted Stringfield. Courtesy of SRS Archives, negative 27374-7. 7. Project Drafting Room in B Wing, 703-A, 1978. Left to right: J. J. White, Jim Babb, Tom Davis, Mark Paulos, Bill Sadelle, Pete Williams, Jim Mitchell, Leo Marrs, and Greer Burke. Courtesy of SRS Archives, negative 27227-26. 8. Judy Jernigan poses for SRP News article at Panther Crossing, 1967. Courtesy of SRS Archives, negative 12021-11. 9. C-Area Committee receives coveted award for housekeeping, circa 1970. Courtesy of SRS Archives, negative 13742-2.





Isotope Production at SRS over Time

A wide variety of radioisotopes have been produced in Savannah River reactors and the laboratory and separations facilities for government, commercial, and research programs. The versatility of the reactors was being explored during the early operations period to 1965. That versatility was further exploited between 1965 and 1970, particularly with the production of elements heavier than plutonium. The most consistently produced non-weapons product was plutonium-238, the heat source that supplied many of the power generators for satellites and space exploration vehicles. Savannah River produced more plutonium-238 than any other facility in the United States.



Sources: J. M. Boswell to A. H. Peters, *"SRP Graphic History,"* March 30, 1990, 22-29, personal collection of J. M. Boswell; W. P. Overbeck, C. H. Ice, G. Dessauer, *Production of Transplutonium Elements at Savannah River* Report Number DP-1000 (Aiken, South Carolina: Savannah River Laboratory, 1965), 7-8, NTIS; *Savannah River Plant History, Separations Area, July 1954 Through December 1972*, Document Number DPSP-55-454-2 deleted version (Aiken, South Carolina: Savannah River Plant, February 1974), 186 and 188-189; Department of Energy, *Plutonium: The First 50 Years, United States Plutonium Production, Acquisition and Utilization from 1944 through 1994* (Washington, DC: U.S. Department of Energy, February, 1996), 59; and Carlisle Pickett, personal communication, November 10, 1998.

In the long run, none of the discussed measures would make a difference. As increasing numbers of people were made aware of the dangers posed by technological advances, first in the 1960s and with increasing impact in the 1970s and 1980s, the dangers of radioactivity from production and power reactors were popularized and even over-dramatized. As society at large embraced a new view of the nuclear reactor, it became apparent that reactor confinement would not satisfy the unease the American public had developed toward reactors and nuclear energy. The environmental movement, which began in the 1960s and came of age in the 1970s with the first oil crisis, spelled change for the AEC, which was renamed and reorganized in 1974. Soon the whole issue of nuclear energy was called into question. The next chapter will explore how this came about, and how these changes affected Savannah River.



PART 4

Environmental Impact

CONTENTS

Chapter Seventeen
Early Stewardship

Chapter Eighteen
Rise of Environmentalism and Its Impact on Savannah River

Stewardship of the site environment began with its acquisition. Teams of scientists tasked with creating environmental baseline studies quietly entered the project area in the 1950s. Their job was to capture a before picture by which to measure the impact of the Plant's processes on the environment. Scientists from the Universities of Georgia and South Carolina collected baseline data on plant and animal communities. A team from the Academy of Natural Sciences in Philadelphia under the leadership of Dr. Ruth Patrick performed a biological study of the Savannah River. And Du Pont's Site Survey team of Health Physics personnel completed a landmark study of local natural radioactivity under William Reinig between June 1951 and January 1953. In addition to the ecological studies, the U.S. Forest Service, under contract with the AEC, launched a forest management program in the 1950s and developed set-aside areas. Thus environmental concern and nuclear advancement were closely tied together at Savannah River from its inception and programs put in place to measure the impact of the plant processes and to safeguard the workforce and the public.

While these studies allowed for internal monitoring, social forces were at work that called for more public input into environmental monitoring and the operation of the nation's nuclear production and power reactors. Public perception of the nuclear industry shifted as incidents such as Three Mile Island occurred. Part Four describes the early environmental baseline studies at SRP and the internal programs they generated to safeguard the site and the neighboring communities. It further details the rise of public environmentalism, changes in perceptions concerning the safety of nuclear energy, and the direct impact of the environmental movement on the plant.

(Opposite) Aerial view of the Savannah River in SRS, Looking North. Photographer Byron Williams, SRS Photographic Services.

17 Early Stewardship

Stewardship of the site began at its inception. From the site selection to the most sophisticated monitoring program at the site, there has been regard for the environment. This stewardship began with baseline studies and deepened into full-fledged research programs that explored and continue to explore the impact of the nuclear industry on the site and the region. The plant's initial health-physics staff joined with consultants and area universities to create a remarkable record of the over 300 square miles that became the Savannah River Site.



SREL researchers Dr. Rebecca R. Sharitz and Dr. J. Whitfield Gibbons investigate the effects of thermal effluent from site reactors into the Savannah River Swamp, 1974. Courtesy of SRS Archives, negative 18576-12.

ENVIRONMENTAL BUFFER

The cornerstone of the site's early environmental history is the site itself—its size, location, and the layout. Environmental safeguards were mandated within the site-selection criteria that required that a large area of land be selected that was relatively isolated and within specified "safe" distances from major population centers. The size and isolation of the 300-square-mile site was based on protecting the public in the unlikely event of a nuclear accident. The effects of the accident would be contained within the site boundaries or sufficiently mitigated to minimize impact on the population.

The distances between the reactor and separations facilities and the distance between any one facility and the plant perimeter were carefully selected to maximize safety. The process areas, five reactors and two separations plants were spaced about two to three miles apart along a roughly seven mile diameter circle at the center of the site. These areas were located eight miles or more up the tributary from the river. This arrangement provided the greatest possible protection of the public, from a nuclear accident. Between the manufacturing core and the site perimeter lies a safety envelope, six miles in width.

These distances safeguarded the surrounding area from two possible dangers: the possible release of radioactivity to the atmosphere and to the area streams and, second, the adverse impact of cooling water pumped from the river, heated and passed through the

reactors, then returned to the river via streams.[1] While distance may not have guaranteed safety, it provided the best known defense in 1950. With that proviso in mind, Du Pont and the AEC sited and laid out the new plant.

ESTABLISHING AN ENVIRONMENTAL BASELINE

Du Pont's establishment of an environmental baseline for the site of the nuclear facility was in keeping with its broader industrial policy in which baseline studies were conducted prior to the establishment of its plants. However, the nature and range of the proposed work at Savannah River—from chemical and industrial manufacturing to nuclear-materials manufacturing—demanded a broader data-collection strategy. In the summer of 1951, an array of scientists skilled in interpreting the natural environment arrived to assess—from a physical and cultural perspective—the federal reservation that was under transformation.

While pollution was handled on a plant-by-plant basis, abatement programs were in place in Du Pont plants in the 1920s. A 1938 Executive Committee resolution placed "industry's responsibility to control trade waste" on par with safety or fire protection.[2]

Dr. Eugene Odum, University of Georgia professor and pioneer in his discipline, was interested in the biota of old fields and ecological succession. This photograph was taken in Field 3-412; one of the first set-aside areas for ecological research at the site, circa 1955. Dr. Odum's *Fundamentals of Ecology,* published in 1953, established him as the "father of modern ecosystem ecology." Courtesy of Savannah River Ecology Laboratory.

Vast Field Laboratory

Early in 1951, we received word at the University of Georgia that the Atomic Energy Commission was interested in supporting ecological inventories and possibly other studies on the Savannah River Plant Reservation…. The Division of Biology and Medicine (DBM) at AEC was anxious to have "pre-installation environmental inventories started before the onset of major construction at Savannah River."



We prepared, on short notice, a very ambitious proposal. We proposed to put six teams into the field…. The budget was $150,000 for the first year. We submitted our proposal on April 12, 1951 to Dr. Paul B. Pearson, chief of the Biology Branch of DBM. As was evident from Dr. Pearson's letter of April 26 rejecting our proposal, DBM had no intention at that time of supporting work of such a large scale as we had proposed, but rather was considering granting small amounts of money to a number of agencies and universities.

The thinking at the time was in terms of an inventory of the natural environment as a basis for assessing the subsequent impact of the atomic energy installations as they were phased in…. I remember saying that we ought to do more than just "inventory," but it was clear the DBM had in mind only limited studies…. Essentially, then, the DBM wanted the two universities [University of Georgia and the University of South Carolina] to work on terrestrial flora and fauna and the general ecology of the area.

I stated in that [new] proposal that ecological succession was one of the most important principles in ecology and I pointed out that except for the work of Dr. Henry Oostling at Duke, no large-scale studies of natural succession had been made in the Southeast… We proposed to take a look at heterotrophs (organisms that feed on organic matter) in old field succession and to take general advantage of a vast field laboratory for the study of the dynamics of succession.

I also pointed out that ecological study of terrestrial habitats and watersheds has practical, as well as basic, value because many questions are bound to arise in the future in regard to this large tract of land which will receive a treatment so radically different from the surrounding territory.

– Dr. Eugene Odum

Source: As quoted in Jane M. Sanders, *Forty Years and Beyond, Savannah River Ecology Laboratory, 1951–1992*. Fall 1992, 2–3.

Diatoms and the Big Picture

…I was intrigued with the idea that diatoms could solve the large-scale problems of this earth. Having been taught by my father that I must leave the world a better place than the one I came into, my question was how I could use my love of diatoms to solve some of the important social problems. It was amazing how everything fell in place.

I gave a talk in the fall of 1945 at the American Association for the Advancement of Science. In this talk, I gave illustrations of how diatoms could elucidate general problems such as the undulation of the Coastal Plain and Dismal Swamp and the origin of Great Salt Lake. Mr. W. B. Hart, a minor official at the old Atlantic Refining Company came up to me after the talk and said, "You have discovered something that will help us in this problem of water pollution. I am coming up to see you."



And so he did. He came to the Academy of Natural Sciences and discussed with me just how I would approach a problem concerning water and diatoms. He explained his concerns about pollution and its effect on aquatic life and asked if I thought I could determine what was going on in a river by studying shifts in diatoms. We did not discuss it further at the time, but what I did not realize was that Mr. Hart was head of the State Chamber of Commerce at Pennsylvania. About a year later, he told our President, Charles M. B. Cadwalder, that he had raised a large sum of money (the equivalent of about a million dollars today) that he wanted to give to the State of Pennsylvania to give to the Academy of Natural Sciences to support my research. Specifically, he wanted me to try to determine from a study of shifts of the types of species I found in the river whether pollution was present, what sort of pollution it was, and how it was affecting the aquatic life.

Mr. Cadwalder was thrilled with the proposal because the Academy was poor and had never had that kind of money for research. However, when Mr. Hart informed him that he wanted Dr. Ruth Patrick to lead the research team he was horrified. Mr. Cadwalder said that he could not allow this, because Dr. Patrick was a young woman and all young women waste money. Fortunately, Mr. Hart told him there would be no money for the Academy of Natural Sciences, because he had gotten this money so that Dr. Patrick could direct the project. Mr. Cadwalder's attitude quickly changed, and he told Mr. Hart that if he felt that way about it, Dr. Patrick could organize the team and do the work.

However, Mr. Cadwalder approached a Dr. Charles Stein, who was one of the codiscoverers of nylon in the Du Pont Company, with his concerns that I, because I was a young woman, would waste money. He asked Dr. Stein to look over my shoulder, so to speak, to make sure that I was not wasting the Academy's money. Once my project was started in the summer of 1947, Dr. Stein usually visited once a month, sometimes once a week, to ask questions about what I was doing. He was an excellent scientist. He did not know the science of limnology, but he would pose very interesting and important questions. I have always appreciated the help of other scientists, and I knew I needed help in trying to solve this big problem, so I asked various friends of mine to be my advisory committee. They included G. Evelyn Hutchinson of Yale; Arthur Hassler of the University of Wisconsin; Malloch, a water chemist of the University of Wisconsin; and Lockner, then of the University of Michigan and later of the Smithsonian Institution. I would call them whenever Dr. Stein posed a question I was not sure how to answer. Thus, the work of my first team of scientists was carried out.

(My) findings (on the aquatic life of the Conestoga watershed) were of great interest to Dr. Stein, who went to the President of the DuPont Company, Dr. Greenewalt, and told him that I had discovered something that would be of great use to the Du Pont Company in the burgeoning problem of water pollution. The Du Pont Company was rapidly expanding at that time. Dr. Greenewalt… has already issued a memo (in 1949 or 1950) to the heads of his departments indicating that they should not start a new plant without knowing the condition of the body of water that would receive their wastes and the effects their wastes would have on it. In other words, they should examine the stream in which they were going to discharge their wastes, and they should carry out toxicity tests on the various important species within the stream, such as algae, invertebrates, and fish. It is interesting to note, that before there were any general pollution control laws in the country, an industrialist was that concerned about the effects of his company's wastes on our rivers. Since we were the only group that had teams of scientists to study rivers, Du Pont gave us all their work.

Source: Ruth Patrick, "The Development of the Science of Aquatic Ecosystems," *Annual Review Energy and Environment 1997,* 22:1–11.

From this resolution came a single position within the firm devoted to trade waste. In 1946, a committee was formed where representatives of Du Pont's industrial departments, and Engineering, Legal, and Public Relations, came together to form policy and trade information. The idea was to problem solve, not only the abatement methods available but also how to present the abatement program and the need for it to the public. By 1952, Du Pont had assembled and distributed a manual for its plant managers to assess the public relations implications of their waste-disposal problems.

By the time of the Site's acquisition, a company policy had evolved in which new plant locations were studied to obtain pre-operational data on their environmental health. This environmental record of the pre-operational site would enable Du Pont to measure the impact of their industry on the environment. Strong emphasis was placed on self-policing and awareness of all data that contribute to that record, particularly with rivers and streams; e.g., municipal sewage dumped in rivers. Pioneering studies on the health of river systems undertaken by Dr. Ruth Patrick, a Department of Limnology staff member at Philadelphia's Academy of Natural Sciences, had attracted the attention of Du Pont. In 1949, Patrick and her department had worked successfully with Du Pont on another project, and it was at their behest that she and her staff became part of the Savannah River Project when Du Pont received the AEC contract in 1950.

While the inclusion of the Academy of Natural Sciences in the project team was attributable to Du Pont, the AEC's Division of Biology and Medicine (DBM) brought local universities onto the scene to perform terrestrial ecological studies. The DBM approached the University of Georgia (UGA) and the University of South Carolina (USC) to conduct environmental inventories before the onset of SRP construction, and possibly other studies. University of Georgia professor Eugene Odum wrote an ambitious proposal to address the exciting yet large scope of work involved, but that proposal was rejected. The rationale for the rejection was cost and the AEC's preference for providing work to both regional universities. The AEC later announced that they were prepared to grant each university about $10,000 a year for field work on baseline ecological studies that would record the terrestrial flora and fauna and the general ecology of the area.[3] Both universities signed on. Among the Academy of Natural Sciences, the University of Georgia, and the University of South Carolina, ecological studies began in the summer of 1951.

The study of natural radioactivity on or near the project area prior to operations was another matter. For this, Du Pont looked to their ranks and selected C. M. Patterson, who had led Du Pont's radiation protection program at Hanford. Patterson was in charge of recruiting scientists and engineers to staff the Savannah River survey. "Throughout the nation, probably fewer than 30 scientists and engineers were involved in these activities. Several graduate programs in health physics sponsored by the Atomic Energy Commission had begun a year earlier. The team, designated as the Site Survey Group, that assembled at SRP during the summer of 1951 was a mix of people from other AEC sites, universities, and Du Pont Plants."[4]

(Opposite Page) Dr. Ruth Patrick at Savannah River, circa 1965. Dr. Patrick was one of three female ecologists in the nation in 1950 when she was asked by Du Pont to conduct a study of the water quality of the Savannah River and its plants and animals. Courtesy of SRS Archives, negative DPSPF 10646-3.

ACADEMY OF NATURAL SCIENCES STUDIES

The operation of SRP's five reactors would increase the water temperature of the Savannah River. Both Du Pont and the AEC felt it would be valuable to have a record of

the river's biological diversity before impact to compare the natural environment and the changes it would undergo. This biological baseline work was conducted by the Academy of Natural Sciences of Philadelphia (ANSP) under the direction of Dr. Ruth Patrick, who has since maintained a long and fruitful association with Savannah River.

Patrick's work with Du Pont began in 1949. Her first mentor at the company was Dr. Charles Stein, followed soon after by Crawford Greenewalt himself. She did her first work for the company in Delaware.[5] In the years that followed, she was closely involved in most of the environmental work conducted by Du Pont, but her landmark project was at Savannah River.[6] There, in the early 1950s, Patrick studied the biological conditions of the river and its surrounding wetlands. Her reports, in the form of quarterly studies as well as several follow-ups, would prove to be the most thorough floral and faunal study that had heretofore been conducted on an Eastern coastal-plain river.[7]

When the survey started, the project area was still dotted with farms and fields, as well as animals abandoned by a displaced population. In particular, this included dogs that often hampered the survey crew. Patrick recalled that they often had to launch their boats into the river just to escape the dog packs.[8] The boats used to navigate the river and its waterways had small five-horsepower engines. It was later recalled that the equipment used on the survey could fit into a station wagon.[9]

Patrick's study was not only a landmark for its size, but also for its methods. Previous biological studies had concentrated on one or two "indicator species," which were then used to judge the health of the local biological community. Patrick's study chose to examined all of the major plant and animal groups on the river, and noted the balance between them. The work required a team effort, as well as a check system for noting different species. The method was later used in similar studies on the Amazon. Not only was the study a classic example of quantitative analysis, rather than the qualitative work that had been done previously, but the researchers also checked seasonal variability of species, one of the first times this had been done on a project of this size. It was a study of biodiversity, and one of the first interdisciplinary environmental programs ever conducted over such a large area.[10]

Musk Eaters

I was at 400-D Pump Station in the very early stages one evening in 1951 and a lady came down river and docked at that location. She was in a very small boat with a very low-powered push engine attached. She had a large group of sample bottles, some containing insects and some she said she hoped contained microscopic specimens. I have always been under the impression that this person was Dr. Ruth Patrick.

If you only had one limnologist working the river in May of 1951 it was indeed Dr. Patrick.

In answer to her inquiry if I had to stay in that location all night by myself and wasn't I concerned about my safety from any wild animals that may be in the area, I told her that mosquitoes were terrible in the area at night but that they could be fought off. This incident is the first instance that I recall that made me realize that we had to enunciate more clearly if we could not rid ourselves of our strong Southern accent. "Musk Eaters," she exclaimed in horror. And it took me about a half-minute to help her realize what I was saying. "Oh, mosQUITOES," she exclaimed in relief.

-R. W. Jolley

Source: SRS History Project.

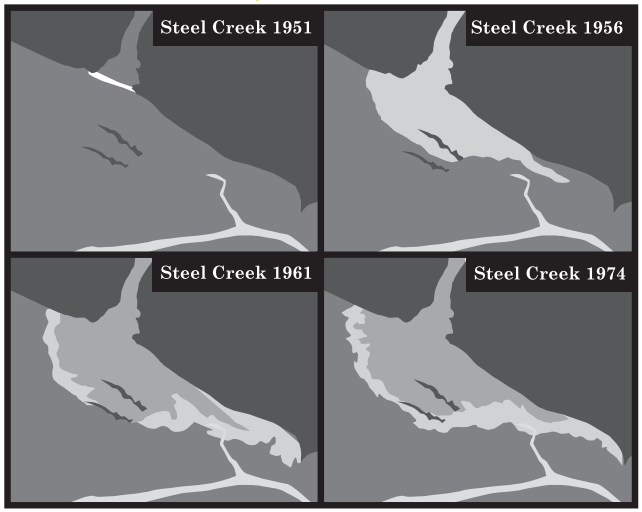


Research team from Philadelphia Academy of Natural Sciences at work on and in the river with weir, 1954. Courtesy of SRS Archives, negatives DPSFP 1741-8.

Once the facility was built and operational, ANSP scientists conducted comprehensive river surveys at three- to five-year intervals, looking for signs of biodegradation, using the initial survey data as the baseline study. Here, the emphasis was on possible chemical pollution, not on radioactive releases, which was left to other groups to study and monitor. In addition to these surveys, the scientists in the field continuously collected diatoms, microscopic one-cell algae that are indicators of river conditions and change, and sent them semimonthly to the ANSP for analysis. The ANSP completed the 25-year monitoring program in 1976. The results of the 16 surveys for all species (95 for diatoms) have been placed in a database for future researchers. The data compiled by the Academy and computerized by ETD included over 200,000 environmental entries in 1979.[11] Over time, these studies have charted biological change within the river that stems from a variety of sources; e.g., the dam project at Clarks Hill, the increasing industrialization of the CSRA, sewage treatment, and the effects of dredging in the river. As a result of these surveys, it was determined that virtually no biological alterations had occurred to the river environment as a result of the operation of the Savannah River facility.[12]

In checking for biological damage, the ANSP researchers collected data from defined environmental checkpoints that the first ANSP team had selected. The five checkpoints were located in an array: one upstream from the site, three within the site boundaries, and a fifth downstream from the last possible plant discharge. These river checkpoints did not allow measurement of the impact of reactor operations on the inland streams and wetlands at the point of discharge, nor the transient damage caused by the heat of the water.[13] All ANSP work was confined to the river by their contract.

For a thirty-year period, coolant water from the reactors was discharged into the bottomland hardwood forests of Steel Creek, Pen Branch, and Four Mile Branch corridors and deltas. The flow and temperature killed the vegetation, the seed stock, and rootstock in these forested wetlands.[14] Essentially, the river tributaries served as a buffer between the production facilities and the rest of the environment. Throughout the 1950s and 1960s, possible environmental degradation within the buffer zone was simply accepted as the price of running an industrial facility. Only in the 1970s and 1980s, with the rise of increasing environmental regulation, would this practice be called into question in all industrial settings.



Steel Creek received discharges from the site's reactors that often exceeded 45 degrees centigrade from 1954 to 1968. As a result, the original swamp forest has been destroyed and the area of tree loss extended to the southeast due to flooding. Source: "Steel Creek," authored by Laura Janacek, SREL, August 10, 1998 from *An Album of Research at the Savannah River Site: Past, Present, and Future* prepared by the Savannah River Ecology Laboratory.

UNIVERSITY OF GEORGIA, INVENTORY AND BEYOND

Terrestrial studies occurred concomitantly with the Academy of Natural Sciences study. Two regional universities, UGA and USC, divided the ecological inventory work. UGA was responsible for inventorying warm-blooded vertebrates and invertebrates. USC was to complete a biological survey and a checklist of cold-blooded vertebrates. The Georgia university would also study old field succession, taking "general advantage of a vast field laboratory for the study of the dynamics of succession."[15] Radiation ecology studies were also an early research focus.

The University of Georgia's Institute of Ecology professor Dr. Eugene Odum began working at Savannah River with three graduate students: William Cross, Edward J. Keunzler, and Leslie Davenport. Each was from a different university and had been recruited by Dr. Odum:

> Because of the intense construction activities underway in the center of the SRP, we first concentrated our work in the peripheral areas. Our first headquarters was located in a sort of two-story barn which we rented from a private citizen…. Equipped with a stove, refrigerator, tables and some bunks, we soon had comfortable quarters. We could set up microscopes, Burlese funnels, other laboratory equipment, and store traps and other field gear…. Several old fields near this first headquarters site were selected for intensive study. During the fall of 1951–52, the crew spent a lot of time exploring the area via Jeep or truck, mapping the vegetation or crop residues in the open lands and recording forest types and other noteworthy features…. We were especially interested in locating unusual areas worthy of subsequent study and preservation. Among these were the Carolina bays, sandhill vegetation, spring runs and the virgin hardwood stand on Lower Three Runs Creek.[16]

The early 1950s UGA work concentrated on inventory and also took advantage of the opportunity the site offered for ecological research. The University of South Carolina had completed its initial inventory work and then departed, leaving UGA to move forward with future research on the reservation. The original mission to simply inventory plant and animal life deepened into a small, but full-fledged research program.

Dr. Robert A. Norris was hired as the first full-time resident ecologist, and the ecology lab moved to the Bush House, a historic dwelling adapted for reuse. The lab, known as the Laboratory of Radiation Ecology, had a budget of $60,000 and a staff of 15. Under Dr. Norris and Dr. Odum, radiation ecology studies became a central research focus. Dr. Odum joined in this research endeavor through study at UCLA, Hanford, and Oxford University to broaden his knowledge of radiation ecology and atomic energy.[17] The ecologists studied the effects of radiation in natural environmental settings by exposing plants and animals to controlled radiation doses under laboratory and field conditions. Radiation sources were procured and animals and plants were irradiated. This work and the research performed at other DOE laboratories and facilities constitutes what is known about the effects of radionuclides on plants and animals today. Research using radionuclides as tracers of basic ecological processes was also conducted.[18]

The baseline ecological data collected from different habitats in the early 1950s and land-use studies led to the selection of representative examples of ecological habitats present at SRP for specific research. By doing so the researchers provided valuable information to the AEC, setting the stage for the present day Set-Aside Program. Seven areas were chosen as representatives of extant plant ecosystems in 1967 and set aside for ecological research; three more followed the next year. Old fields, sandhills, upland hardwoods, pine forests, bottomland forests, swamp forests, Carolina bays, and freshwater

An Eye on Nature





1. First Laboratory – The Bush House. Courtesy of Savannah River Ecology Laboratory. 2. Savannah River Ecology Laboratory Staff in front of second laboratory, a military barracks, 1968. Courtesy of SRS Archives, negative DPSPF 12927-1. 3. University of Rhode Island researchers using weir in Par Pond, 1972. Courtesy of SRS Archives, negative DPSPF 14681-9. 4. Dr. I. Lehr Brisbin, an AEC postdoctoral fellow and Dr. C Phillip Goodyear, an NIH postdoctoral fellow, place an identification tag on a young alligator prior to its release in a thermally-affected PAR Pond at Savannah River. SREL researchers studied seasonal movements and ecology of the alligator population in the field and laboratory. The apparatus in the background was used to test the ability of animals to navigate using sun-compass orientation. Field studies emphasize the orientation and movements of the alligators particularly in reference to the thermal gradients imposed on the reservoir by reactor discharges. Courtesy of SRS Archives, negative DPSPF 13537-34. 5. Early SREL research used an outdoor cesium-137 source that emitted radiation to study effects of exposure. Courtesy of Savannah River Ecology Laboratory.







streams and impoundments are the eight vegetation communities considered characteristic of SRS. This program protects these important areas that cover about 0.5 percent of the Site from public access, forest management, and general site activities.[19]

In 1961, the Savannah River Ecology Laboratory (SREL) was established as a permanent facility and its name changed to better reflect the broad spectrum of ecological studies carried out on site.[20] Between 1962 and 1967, Dr. Frank B. Golley directed the laboratory program that was housed in abandoned military barracks. In 1962, the staff grew from two Ph.D. scientists, technicians, a secretary, and a graduate student to a laboratory with 15–20 scientists and an expanded support staff. The laboratory's research program was mostly directed toward basic ecological studies, with about two-fifths of the research program aimed at radiation effects and the use of radiotracers. In Golley's words, "it was a time when ecology was in a period of rapid growth. It was the beginning of real concern for the environment. People were turning to ecology with questions…."[21] The main research and teaching paradigm during this period was the ecosystem concept, championed by Eugene Odum in his textbook, *Fundamentals of Ecology*. SREL and its researchers were at the heart of the developing paradigm, defining what an ecosystem was and how it worked, thus producing cutting-edge research.



Division of Biology and Medicine (DBM) meeting at Savannah River Plant was the occasion for this group photograph of SRP, SREL, and headquarters staff, November 14, 1969. Front row left to right, W. F. Bale, ACBM, A. J. Haagen-Smit (ACBM), D. P. Cohen, Chairman (ACBM), Rosemary Elmo, (DBM), and R. D. Mosely (ACBM). Back row, H. M. Patt (ACBM), C. M. Patterson (SRL), J. J. Wise (SROO), J. D. Ellett, Manager (DuPont), J. R. Totter (DBM), E. P. Odum (UGA), R. J. Beyers, (SREL), and P. B. Stout (ACBM). Courtesy of Savannah River Ecology Laboratory.

Dr. Robert J. Beyers became laboratory head in 1967 after Dr. Golley accepted a position with the University of Georgia's Institute of Ecology in Athens, Georgia. Under Dr. Beyers, about 50 percent of the laboratory's efforts were devoted to basic research and the remaining half to radioecology studies. SREL researchers studied the effects of temperature changes, radiation, and mechanical disturbance on stable ecosystems in experimentally controlled microcosms. They also looked at the effects of pollutants in stream channels and broadened ongoing studies on American alligators, turtles, wild hogs, deer, and owls by tagging or labeling animals to monitor movement. Much of this research was carried out in set-aside areas.

Thermal ecology became a major research program for SREL researchers in the early 1970s. This research focus set out to study the effects of thermal water from the site's reactors on animal and plants within the site's streams, ponds, and swamps. The results of their work helped underpin the developing field of thermal ecology, and SREL sponsored the first symposium on that topic in 1973. In addition, SREL researchers would expand their work in studying the effect of contaminants on the environment and of mineral cycling.

The next decades—the 1970s through the 1990s—would be considered the boom years for the program that started out with an initial budget of $10,000. Under Dr. Michael Smith's guidance, the laboratory became increasingly engaged in environmental issues at the site and across the nation, as public interest in energy-related technologies and their impact on the natural environment heightened.



The AEC acquired land that was originally farmland, cutover forest or abandoned fields. The first task facing the foresters with the U.S. Forest Service, was to plant trees to prevent erosion, provide screening, control dust and noxious weeds, and to provide a marketable crop of timber. By June of 1960, 75 million pine seedlings had been planted. Pine planting at Road A and Skinface Lodge Road, began in December 1952. Unidentified workers were instructed on hole digging, while others were taught how to plant from the three-seated tractor equipped with buckets to facilitate planting. Courtesy of SRS Archives, negatives DPSPF 889-1,4.

U.S. FOREST SERVICE

The U.S. Forest Service formed an early association, in August 1951, with the Savannah River Site for land-management services for plant areas not used for operations. The Forest Service's work at other federal reservations was a model for what was needed at the SRS, and the AEC quickly entered into an agreement with them. Their first deliverable, under the moniker of the Savannah River Project, was an initial study and recommendations on how the Commission could best use, protect, and manage the forests, which were estimated in 1951 to cover 67 percent of the Site area.[22] After reviewing these recommendations, the AEC authorized a forest management program to help control erosion and weed growth, provide protective screening, and provide a monetary return to the government through the sale of pulpwood and timber. The Forest Service was also asked to train the AEC and Du Pont in forest fire-fighting methods and to help establish a preventive fire program.

The first contract requested that the Forest Service set out about 10 million pine seedlings on 30,000 acres. The seeds for planting were collected locally, within 100 miles of the project, then shipped to the U.S. Forest Service's Stuart Nursery at Pollock, Louisiana, for planting. At nine months they were ready for transplanting to the site. The first seedlings were planted along the plant perimeter for screening. The Webster Transplanter Company of Cornelia, Georgia, was contracted for the first phase of planting. The large-scale mechanized program had 16 machines in operation.[23]



A forest-management program for an additional 60,000 acres was soon launched under the direction of John Hatcher, project forester, and a handful of other foresters. Under that program an additional 26.5 million pines were planted by 1955, and 10 million more each year were slated for planting through 1960. The timber-management program







1. Savannah River Project Forester John Hatcher amid long leaf pines planted in 1953 surveying "pine plantation." Courtesy of SRS Archives, negative 5238-4. 2. USFS employee explains the mechanics of tree-cutting and loading as part of a public outreach program, 1978. Timber and heavy water were the site's only income-producing products. Courtesy of SRS Archives, negative 16676-7. 3. Revenues collected from the sale of pulpwood harvested on the site are turned over to the U.S. Treasury. Courtesy of SRS Archives, negative 10544-9.

yielded a harvest of $300,000 of marketable pulp and timber annually in the 1960s and early 1970s. By 1973, the value of the Site's timber resources had grown from its assessed value when SRS was acquired of $19,000,000 to $30,000,000, reflecting the success of the program.[24] In addition to its financial success, another outcome of the Forest Service program was the green space it created within western South Carolina. The industrial character of the site (12 percent of land within site boundary) is belied by current aerial photography that shows the legacy of the 1950s programs, a large expanse of green surrounded by a developed countryside.

1973 was a landmark year for the Forest Service and SRS. An ecosystem management plan was developed and implemented that sought to integrate the site's natural resource objectives and allowed the start of a number of soil-restoration and erosion-con-

trol projects. The 1970s also saw the expansion of U.S. Forest Service involvement into more sitewide activities as well as a change of name to the Savannah River Forest Station.[25]



(Left) Health Physics personnel checking equipment, circa 1955. Courtesy of SRS Archives, negative DPSPF – 8-1.

RADIOACTIVITY STUDY AND THE BEGINNINGS OF ENVIRONMENTAL MONITORING

A landmark study of local natural radioactivity commenced in June of 1951, and was concluded by January of 1953. Led by William Reinig, Du Pont's Site Survey Group's work was virtually without precedent. There were no federal or state laws or regulations to mandate such an undertaking, and there was no public demand for it. As Reinig would later put it, if you used the word "ecology" in those days, you had to define the term.

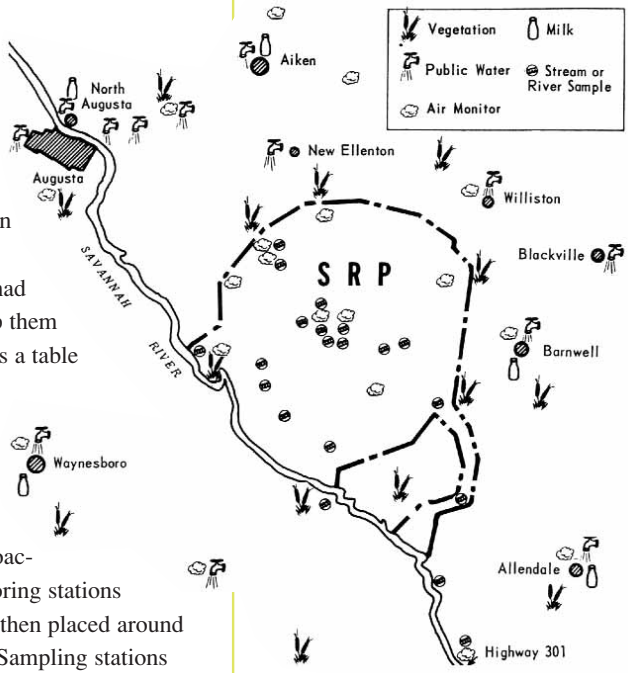
The study entailed the collection of samples from an area of over 6000 square miles in South Carolina and Georgia. Data collection began on July 26, 1951, when Ralph Gosline drew the first river-water sample. By summer, the small force of Du Pont's health physicists grew to 12.

> We were really pioneering. No other nuclear plant had ever made an extensive survey to determine natural radiation benchmarks on which future environmental monitoring would be based. Now, all nuclear sites make these surveys. Facilities were primitive in the summer of 1951. We had our counting room in a Construction shed in the TNX area, which was just being built. Since the shed wasn't air-conditioned and the humidity was so high, we had to pack the counters every day with a drying agent to keep them operating. A large tree stump outside the shed was used as a table to prepare the environmental samples for counting.[26]

Wells that supplied water to former residents became test wells for the Site Survey group. Courtesy of SRS Archives, negative DPSPF 4-1.



By early 1953, the natural radiation in a 1500-square-mile area was determined and the personnel, monitoring stations, and equipment needed for future monitoring were in place.[27] The Survey group had targeted the process facilities as primary sources of environmental radioactivity. Thus monitors were attached to stacks and pipelines, and monitoring stations were located in proximity to the main facilities. A ring of stations was then placed around the process areas, and an outer band of stations at the site boundaries. Sampling stations were located as far as 25 miles from the plant. The latter were described as small buildings equipped with instruments to collect air and rainwater samples. The streams at the plant were sampled at various locations, and there were 16 checkpoints in the river. Both water and sediment samples were taken from these riverine sample stations. The number of monitoring stations was greatest at and near the process facilities, and decreased with dis-



Environmental monitoring stations Source: William P. Bebbington, *Nuclear Operations and the Environment Savannah River Plant, Atomic Energy Division* E. I. du Pont de Nemours & Company, January, 1973.

We Didn't Catch Many Flies

In June 1951, I was sent to SRP to head a Du Pont team whose mission was to measure the natural radiation at the site, and to plan the environmental monitoring program. Construction was only beginning when the team (the first Operations group at SRP) started its work using sheds as laboratories.

We had a tight schedule because atmospheric weapons testing was about to begin in Nevada, and we needed to complete base-line measurements before the radioactive fallout reached the site. To detect the arrival of the fallout we planned to place sheets of stick flypaper around the site to collect the radioactive particles.

Instead of the flypaper that we ordered, we received a large box of flyswatters. Since the weapons tests were about to begin, we rushed to Augusta, Georgia, and going from store to store, we bought out the city's supply of flypaper. We had the sheets in place just in time to detect the arrival of the first man-made radioactivity at the Savannah River Plant.

The person who ordered the flyswatters instead of our requested flypaper later told us that he made the change because he thought the swatters would be better for killing pesky flies. He was right. We didn't catch many flies.

-Bill Reinig

(Above Inset) Flypaper Station. Courtesy of SRS Archives, negative DPSPF 18-1.

tance from them. The survey team also analyzed crops from local farms and open wells from pre-federal farmsteads. Some of these wells would be left open for future monitoring, others were filled in.

John F. (Buddy) Kirkland, F Area Health Physics, was interviewed in 1955 as one of the oldest hires still at the site.

I've had some interesting experiences since I came to work August 12, 1951. I had been farming around Bamberg, and I applied for clerical work. From construction they referred me to John Creadick. I talked with him and Bill Reinig. I was hired and I've been working with Bill ever since. He's my area supervisor now.

They told me I'd be working in Health Physics. The first six months I spent setting up sampling points and routes for the HP regional surveys. I stayed in that work for about 3 1/2 years. It was fun making boat trips to take river samples. I once saw an alligator 12 feet long, also a 12-point buck.

Source: *Savannah River Plant News*, Volume V, No. 1, February 15, 1957.



The expectation that American nuclear testing in Nevada in the late fall would bring environmental radioactivity into the area was the impetus for a push to get baseline data in place and fallout monitors installed through the summer and fall of 1951. The three air-monitoring stations set up—two on site and one in Aiken—caught debris from unexpected Soviet testing halfway around the world in October.[28] A month later, more fallout came from the expected American sources. In addition to the air-monitoring stations, flypaper was placed at locations to detect fallout. The survey team used this inexpensive paper to collect fallout particles that stuck to the paper. "When the paper was placed on photographic film, dark spots on the film caused by the radiation from the particles were counted to get a relative measure of the fallout."[29]

This study of natural radioactivity provided more than just a baseline study of natural radioactivity at the site before operation; it also laid the groundwork for Savannah River's Health Physics Department housed in Building 735-A under the Works Technical Department. As noted earlier, C. M. "Pat" Patterson was the first chief of Health Physics, and served in that capacity until his retirement in 1978.[30] The team that came in the early 1950s mixed well with the other environmental organizations that were combing the plant area for data. Health Physics was the first operations group for Du Pont on the plant, and their monitoring operation had been up and running for 30 months when the final process building went into operation. Lessons learned through the rough but exciting survey period, sustained by involvement in a "one-of-a kind activity and the thrill of being part of the atomic age," helped shape the new department and allowed them to test what instruments would work in the humid environment.

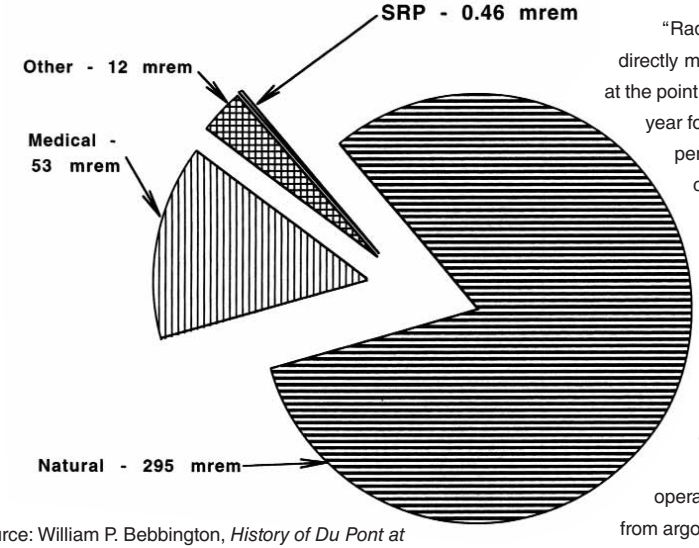
Regional monitoring continued to evolve, and results were obtained by collecting samples at points within three bands around the site, one at the plant perimeter, a second at a 25-mile radius, and a third at stations 100 miles out from the site. Particulate radioactive



Environmental monitoring station, State Park, Jackson, South Carolina, 1970. Courtesy of SRS Archives, Negative DPSPF-141145.

fallout was continuously monitored at 38 stations just inside the site perimeter and at the 25-mile radius. Data from stations as distant as Savannah and Macon, Georgia, and Columbia and Greenville, South Carolina, has been gathered. "Over the years, the levels of radioactivity have ranged between low and high by a factor of 1,000, but there have never been consistent differences in level between the near and far station."[31]

For the AEC, Du Pont, and the many field groups that participated in these baseline studies, their work was groundbreaking. As part of the atomic age, each contributed to the



Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990).

"Radioactive doses to the offsite population are far too low to be directly measurable; they must be calculated from measurements made at the point of emission. A maximum dose is calculated and reported each year for a hypothetical person who stayed 24 hours per day, 365 days per year at the point on the plant boundary where the calculated concentration of radioactivity was the highest. Analogously, the average dose was calculated for a person who lived at the point on the boundary that had the average concentration. The hypothetical maximum dose from atmospheric releases in 1988 was about 0.16 percent of the dose from natural radioactivity in the vicinity of SRP and the average, about 0.06 percent of natural. The total individual dose from natural radioactivity, medical procedures, and consumer products averages 360 mrem per person per year.

Of the dose attributable to atmospheric releases from SRP operations, about 67 percent is from tritium and about 18 percent from argon-41, formed by neutron activation of naturally occurring argon-40 in the air spaces around the reactors."

Closely Monitoring the Environment





1. Frieda Bagwell, Health Physics, takes a vegetation sample for laboratory test, 1956. Negative DPSPF 3912-17. 2. Scientists checking Health Physics equipment, circa 1955. Negative DPSPF 8-1. 3. Scientist sampling riverwater, circa 1955. Negative DPSPF 5-1. 4. Bob Cromer and Pliny Shropshire of the Regional Survey Group of Health Physics Department completed river monitoring on alternate Fridays, November 4, 1955. Negative DPSPF 2950-1. All photographs courtesy of SRS Archives.





rebirth of the site as a nuclear facility, and through continued and evolving studies, each continues to steward and monitor its growth and change. Bill Reinig's comment on the significance of the 1951–52 radioactive study is equally applicable to all the environmental baseline studies:

> Why should this study made 50 years ago be considered significant today? My answer is simply this—the pre-operational environmental survey inaugurated the long tradition of environmental stewardship that has served the Site and its neighbors so well. By focusing on environmental radioactivity, it helped to imbue in the institutional consciousness of the Site and the importance of controlling releases to the environment.[32]

18 Rise of Environmentalism and Its Impact on Savannah River

The rise of environmentalism at Savannah River is tied to the development of environmentalism in the nation at large. From its beginning, environmentalism evolved to become one of the defining characteristics of the nuclear industry. When environmentalism became a popular movement in the 1960s and 1970s, the impact on Savannah River became much more direct. The first national environmental regulations were put on the books in the late 1960s, and these increased in number and complexity in the years that followed. In the early days, environmentalism developed in tandem with other concerns inherently friendly to the nuclear industry, such as conservation of the natural resources and energy resources. The growing concern for renewable energy sources in the early 1970s, put new life into the search for a successful breeder-reactor program. It also paved the way for the reorganization of the Atomic Energy Commission itself, transformed first into the Energy Research and Development Agency, and finally into the Department of Energy. By the late 1970s, however, environmental perception of the nuclear industry had changed, as environmental advocates turned increasingly anti-nuclear. This development was best illustrated by the reaction to the Three Mile Island accident of 1979. The story of these developments is the subject of this chapter, and sets the stage for the tremendous changes that would occur at Savannah River in the 1980s and 1990s.

THE RISE OF ENVIRONMENTALISM IN THE 1960s

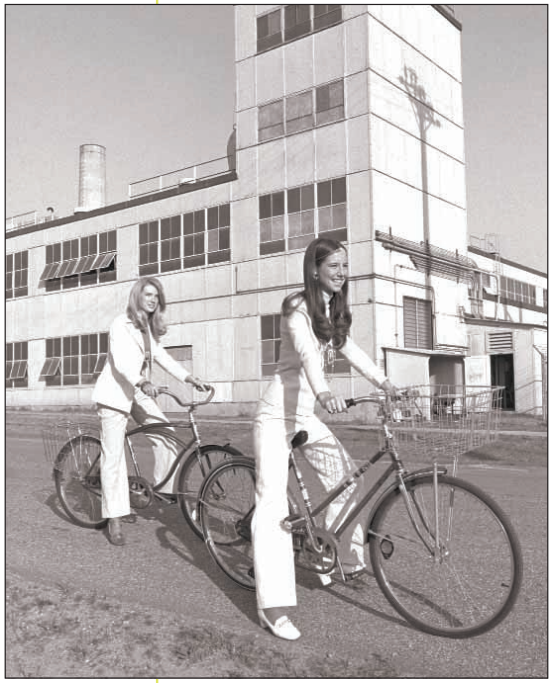
The 1960s were a pivotal period in the development of environmentalism as a popular movement. At the beginning of the decade, it was virtually unknown, and by the end of that period, the nation had its first comprehensive environmental law. A great deal had to happen to make such a transition possible.

The first bolt out of the blue was Rachel Carson's *Silent Spring*, which was published in 1962 to tremendous acclaim.[1] The result of extensive oceanographic and biological study with the U.S. Fish and Wildlife Service, Carson's book underscored the various dangers of environmental pollution, and in particular noted the danger of DDT, an insecticide harmful to birds and other wildlife. The book also pointed out the negative effects on the environment created by a highly industrialized society.

The Civil Rights Movement and the Vietnam War changed many areas of American life in the 1960s, and the environmental movement gained strength as a result of those

changes. The war in Vietnam was particularly pivotal. First, under President Lyndon Johnson, and then under Richard Nixon, Vietnam was a protracted struggle that dragged on for at least seven years—from the first major build-up in 1965 to 1972, when the last U.S. troops were withdrawn from the country. Ill-conceived and over-planned, the Vietnam conflict was the first military defeat in the country's history. It engendered a bitterness that led increasing numbers of people to question many of the assumptions previously accepted by the government, the military, and much of American society. In one of the consequences of this shift, environmentalism swelled from a fringe movement to one that became virtually mainstream.

Johnson's presidency, which championed a remarkable number of Civil Rights bills, was basically destroyed by Vietnam, and Nixon's presidency foundered in the same morass. Nixon tried to deflect criticism of his conduct of the war by capitalizing on "peripheral" issues like environmentalism. As a result, his administration was favorably inclined toward the environmental bills that now began to crop up in the Democratic Party-controlled Congress. None of this saved Nixon from the disaster of Watergate, but it is still ironic that Nixon, famous as a Cold Warrior in the 1950s, and a hawk in Vietnam, was also the nation's first president to support "environmental regulation." By executive order, Nixon mandated environmental studies on all federal lands, but even more pivotal was the National Environmental Policy Act (NEPA).[2] NEPA was passed by Congress in 1969, and signed into law by Nixon in January of 1970. By the terms of this law, the federal government was committed to study the environmental impact of construction and other major activities on federal lands throughout the country. These studies were to take the form of Environmental Impact Statements or EISs. The new law also established the U.S. Environmental Protection Agency, or EPA, which was mandated to help enforce the law and establish general environmental standards.[3]



Inter-building bicycle traffic in A Area, 1978. During the Energy Crisis, approximately 50 bicycles were purchased for area use to cut down on gas consumption. A less visible energy-saving measure was the site's gasohol program introduced in 1979 in which automotive and non-automotive gasoline-powered equipment used three different blends of ethanol and unleaded gasoline. The conventional gasohol blend of 10 percent ethanol and 90 percent-unleaded gasoline (10/90) was used in addition to 15/85 and 20/80 blends in the site's 900 automotive and 250 non-automotive units. Between July 1979 and October 1980, the transportation fleet clocked an estimated ten million miles, consuming almost one million gallons of gasohol. Source: Dan Grogan and J.Walter Joseph, Paper presented at SAE Fuels and Lubricants Conference, October, 1980. Courtesy of SRS Archives, negative 17912-4.

NEPA was just the first in a whole series of environmental laws and regulations that began to affect American industry throughout the 1970s. Major environmental laws such as the 1976 Resource Conservation and Recovery Act (RCRA), the 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the 1992 Federal Facility Compliance Act (FFCA), the Clean Air Act (CAA), the 1972 Federal Water Pollution Control Act, and the 1977 Clean Water Act (CWA) were all passed. These laws provided legal means to ensure that the government and industry were circumspect in their activities, and that public input on proposed federal undertakings was gained. State regulatory controls followed. The South Carolina Department of Health and Environmental Control (S.C.DHEC) would be the first state agency to have jurisdiction over a federal facility.

IMPACT ON THE NUCLEAR INDUSTRY

The environmental movement had a special resonance for the nuclear industry, if only because it brought a number of problem issues to the foreground. Environmentalism highlighted at least three basic concerns important to the industry: the safe production of

nuclear materials, the safe disposal of nuclear waste, and the search for new sources of fissionable materials. The first of these concerns, the safe production of nuclear materials, was already grounded in the controversy over confinement versus containment, an issue debated within the nuclear community before it became a public issue in the 1970s.

The second problem, dealing with the safe disposal of nuclear waste, was more intractable. As early as 1948, the AEC recognized that the problem of nuclear waste was critical and still largely unresolved. Even though high-level wastes were buried in tanks located at each of the nuclear materials production facilities, it was understood that this method of disposal was temporary. The cumulative storage of nuclear waste, especially at older sites like Hanford, threatened to curtail future AEC production unless a permanent solution could be found.[4] Despite sporadic attempts to deal with this problem, the issue was no closer to resolution decades later, when nuclear wastes had accumulated not only at Hanford, but also at Savannah River and numerous civilian power reactors. At Savannah River, for example, low-level radioactive waste was kept in seepage basins in the 1950s, because that was an economical solution to the problem of radioactive waste.[5] High-level liquid radioactive wastes, generated from the production of plutonium and tritium, were stored in specially constructed metal tanks that started to leak as early as the 1960s.[6] The solution at Savannah River for high-level wastes, and later for the nation, came in the form of stabilized durable glass, with the inception of the Defense Waste Processing Facility. By the 1970s, with a rising concern about radioactive wastes, the issue of permanent disposal began to be addressed by the Argonne National Laboratory, which considered, among other solutions, the processing of nuclear waste to produce electricity.[7]

Less pressing, perhaps, but still of concern to the industry, was the issue of new fissionable material. If the nuclear industry, especially the civilian power industry, was to take off—as was beginning to happen in the 1960s—it would have to be assured of a steady and dependable supply of fissionable materials. This meant not just reprocessing nuclear waste, but locating and utilizing all available sources of uranium and other fissionable materials. This concern breathed new life into the breeder reactor program, which was promoted by President Nixon in the early 1970s.

IMPACT ON THE BREEDER REACTOR PROGRAM

In 1962, the AEC's report on Civilian Nuclear Power, made for President Kennedy, stated that nuclear energy would be needed to supplement the more traditional fossil-fuel sources of energy in the near future. It also said that the best way to ensure that nuclear energy could fulfill that task, would be to perfect breeder reactors, an idea that had been explored fitfully since the late 1940s. Even though essentially no electrical energy had been produced by breeder reactors since that time, breeders were seen as an important component in the future conservation of nuclear energy, and an important part of the solution to the national energy-supply problem.[8]

By the early 1970s, it was accepted that the most promising type of breeder reactor was the "fast breeder," which could create heat for electricity as well as generate fissionable material from "fertile" material.[9] At that time, there were three basic kinds of breeder

reactors under consideration: gas-cooled, molten-salt, and liquid-metal-cooled. Each had its advantages, but the one considered the most promising, and the one selected for further research and development, was the liquid-metal-cooled fast breeder reactor.[10]

This was the breeder reactor mentioned by name in Nixon's Energy Message to Congress on June 4, 1971. Not only was this the first message by a president to Congress on the topic of energy, it was the first mention of a specific reactor type.[11] In the message, Nixon called for a "commitment to complete the successful demonstration of the liquid-metal, fast breeder reactor by 1980."[12] Authorized by Congress the following year, the liquid-metal, fast breeder-reactor (LMFBR) program, was set up for completion over a 20-year period. The jewel of the program was to be an LMFBR demonstration reactor, to be built near Oak Ridge, on the Clinch River in Tennessee.[13]

As proposed the Clinch River plant was an unprecedented joint venture by both the AEC and a consortium of private utility companies. Slated to be built by Commonwealth Edison Company of Chicago and the Tennessee Valley Authority, the Clinch River LMFBR was designed to operate with fissionable material surrounded by fertile material, all made of ceramics encased in stainless steel tubes, to protect against the high heat of the power reactor.[14]

Not directly a part of the breeder reactor program, but certainly important to the nuclear industry, was the Natural Uranium Resource Evaluation project, or NURE, which began in the 1970s. This program was designed to locate uranium deposits all over the nation by taking subsurface core samples every 10 miles square, with intervals eventually increased to 100 miles. Drilling went down to two or three thousand feet. Soil and rock samples were then examined at Savannah River, where C Reactor Area was the site of the National Neutron Activation Facility, under the management of Bob Folger.[15]

THE OIL CRISIS AND THE END OF THE ATOMIC ENERGY COMMISSION, 1973–1975

U.S. domestic petroleum production peaked in 1970 when more than half of the world's oil wells were located within its boundaries. Despite the subsequent opening of new and expensive oil fields, it has been in decline ever since.[16] This development certainly played a role in the renewed interest in breeder reactors, not to mention the intensified search for new sources of oil. This concern was transformed into a national crisis by events in the Middle East. In October 1973, Egypt launched a surprise attack against Israeli forces in the Sinai in what came to be called the Yom Kippur War. When the U.S. began sending aid to Israel, the Organization of Petroleum Exporting Countries, or OPEC, dominated by the Arab nations, raised the price of oil by 70 percent, then 130 percent, until a complete embargo against the United States was in place.[17]

As suppliers of more than half the world's oil in the 1970s, OPEC was at the peak of its power, and its embargo had an immediate impact.[18] Nixon, whose presidency was already suffering from the Watergate scandal, suffered further with the Oil Crisis of 1973–74. Automobile owners had to purchase gas on an even-odd day arrangement, and oil prices were placed under national regulation. Nixon's presidency ended with his resignation in August of 1974, but the oil price controls he implemented lasted until 1979,

through the presidency of Gerald Ford and well unto that of his successor, Jimmy Carter. It is now widely assumed that those price controls helped foster and sustain the economic malaise of the 1970s.[19]

The oil crisis of the early 1970s also had an impact on the governmental agencies most closely associated with energy. This impact fell first (and foremost) on the Atomic Energy Commission, which had long controlled or at least directed the nation's nuclear energy program. In the wake of the oil crisis, there was a growing demand for a government agency to deal not just with nuclear energy, but the whole range of energy problems and possible solutions. The AEC, with its tradition of secrecy—and its exemption from Civil Service laws—was not considered the vehicle for this task. The Energy Reorganization Act of 1974 was an attempt to correct this situation by broadening the scope of the old AEC, as well as making the new agency more accountable. By the terms of the new act, the AEC was disbanded in 1975. In its place two agencies were established: the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). The first was designed to provide direction for the nation's entire energy program, only part of which was nuclear energy. The second was designed to provide more accountable regulation of the commercial nuclear reactors and activities. The Nuclear Regulatory Commission exists today, but ERDA lasted only two years. In 1977, it was again reorganized into a new Cabinet-level agency, the Department of Energy (DOE).[20]



Photograph of Space Museum's truck with display highlighting the Apollo 15 mission and Astronaut Col. James B. Irwin parked in front of 703-A at Savannah River Plant in 1976. Note lettering on main administration building reflecting the change in name from the AEC to United States Energy Research and Development Administration – Savannah River Plant. Courtesy of SRS History Project.

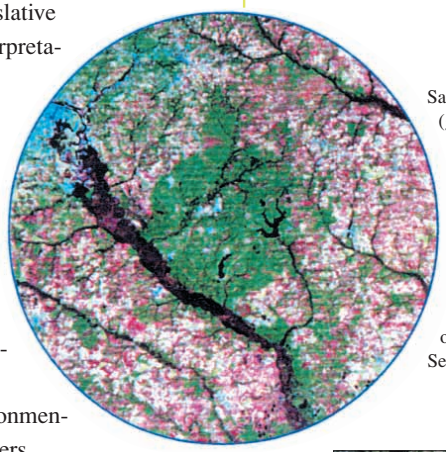
The reorganization of the AEC into first ERDA, and then the Department of Energy, had both positive and negative aspects. The veil of secrecy had become almost a reflex with the AEC. When production reactors were closed at both Hanford and Savannah River in the 1960s and early 1970s, there was little forewarning or explanation; neither was considered necessary. This would not be the case with either ERDA or the Department of Energy, which would be more responsive to pressure groups. In addition, the new agencies had to answer to more Congressional committees, and were subjected to more Congressional oversight than had been the case with the AEC. On the negative side, however, decisions were made at a much slower pace, which often led to gridlock when it came to technological action or innovation.[21]

SRS AS NATIONAL ENVIRONMENTAL RESEARCH PARK

Environmentalism at Savannah River was not something that was simply forced on the facility after the passage of the first environmental law. As noted earlier, groundbreaking studies initiated by Academy of Natural Sciences, the University of Georgia, the University of South Carolina, and the plant's Health Physics Department had already established a clear environmental study path.[22] In 1972, in the wake of the first environmental laws, the entire facility of Savannah River was designated the first National Environmental Research Park (NERP) by the Atomic Energy Commission.

Both the legalistic and philosophical underpinnings of the National Environmental Research Park (NERP) program at the

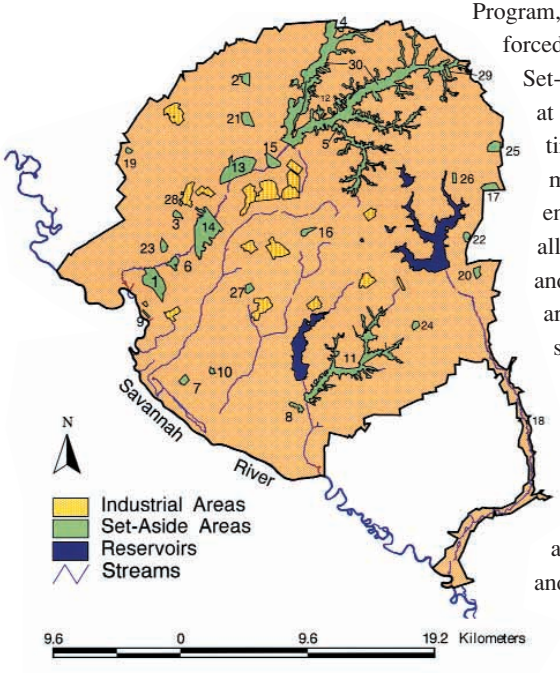
Savannah River Site trace their origins to a series of legislative acts of the late 1960s and early 1970s and their later interpretation by the judiciary. Foremost among these acts is the National Environmental Policy Act (NEPA) of 1969. Other legislation which has also made a contribution in this regard includes the Endangered Species Act and the Sikes Act (9PL93-452). The latter legislation specifically directs the Secretary of Energy and the Secretary of Defense to consult and cooperate with the Secretary of the Interior in the development of fish and wildlife management/utilization programs on lands under the control of their respective agencies. These and similar laws have made it incumbent upon the DOE to consider environmental resource management and conservation issues in matters regarding the use of land resources under its control.[23]



Satellite image of the SRS (green area in center) and developed surrounding region (pink area). This image shows the site as green space, something which is often not recognized because of the site's industrial use. Courtesy of the USDA Forest Service, Savannah River.

One of ten recommendations submitted by the Office of Science and Technology to President Nixon, concerning management of federal lands in 1970, advised federal agencies to accelerate their efforts to set aside locations for ecological research and wildlife preservation. This recommendation led to the designation of the Site as a NERP, where the effects of human impacts on the environment could be studied.[24]

Characterized as protected outdoor laboratories, NERPs are places in which ecologists, engineers, and land mangers can work collaboratively to better understand how our activities and our energy technologies affect the natural environment. NERP status also offers protection to special habitats where native species are found or where endangered species, both plant and animal, in need of protection are found. Thus, the Set-Aside Program, discussed earlier, was further reinforced. There are now 30 DOE Research Set-Aside areas, embracing 14,000 acres at the site, that are protected from routine site operations and land management. These areas function as reference points or controls within the overall NERP for environmental research and monitoring. The study of these land areas has yielded over 200 doctoral dissertations and a series of technical reports on the Sites' plant and animal life, ecological communities, and distinctive habitats.[25]





Savannah River Site as National Environmental Research Park (NERP). Thirty DOE Research Set-Aside Areas, involving more than 14,000 acres, are contained within the Savannah River NERP. The Set-Aside Areas are protected from routine site operations and active management is not permitted. This allows the Set-Aside Areas to serve as natural reference areas or controls for environmental research and monitoring efforts. These areas also provide baseline areas for comparing the effects of human activities and valuable information on how contaminated areas should look and function after they have been cleaned up. The concept of the research Set-Aside Area dates back to 1951, under the leadership of first AEC manager, Curtis Nelson. Source: Charles Davis, Set-Aside Areas of the SRS, Savannah River Ecology Laboratory's *An Album of Research at the Savannah River Site: Past, Present, and Future*, September 1998.

Environmental study extended to the cultural environment as well as the natural. Archaeological research and historic-preservation compliance efforts staffed by the University of South Carolina's South Carolina

Institute of Archaeology and Anthropology (SCIAA) began on the Savannah River Site in 1973. After several years of conducting archaeological survey and excavation for SRS planning and continuing development projects, SCIAA staff members were established on the SRS, in 1978 as the Savannah River Plant Archaeological Research Program, an on-site cultural resources management program directed by Glen T. Hanson. Ron Jernigan of the DOE was instrumental in its establishment.



Archaeological tour at SRS brings state's archaeologists, both professional and avocational, out to the SRS for a look at archaeological excavations, September, 1984. The four men behind signboard are Glenn Hanson, Richard Brooks, George Lewis, and Dr. Bruce Rippeteau, director of University of South Carolina's South Carolina Institute of Archaeology and Anthropology. Ron Jernigan, DOE, stands behind Richard Brooks. Courtesy of SRS Archives, negative 40142.

After a number of one-year contracts, the University of South Carolina signed the first of a series of five-year cooperative agreements with the Department of Energy in 1987, making the (renamed) Savannah River Archaeological Research Program (SRARP) the full-time, permanent onsite cultural resource management program for the SRS. That cooperative agreement established the three-fold mission of the SRARP, which includes archaeological research, historic preservation compliance, and public education. The program is directed by Dr. Mark J. Brooks, under the overall direction of Dr. Bruce Rippeteau, Director of the South Carolina Institute of Archaeology and Anthropology.

In addition to the Annual Review of Cultural Resource Investigations, which has been produced yearly since 1989, the SRARP has completed a Technical Report Series, a Research Series, and an Archaeological Heritage Series. In keeping with its commitment to research, the SRARP has provided financial support, technical expertise, and access to archaeological data for seven doctoral dissertations and six master's theses, and its staff



Archaeologist Glen Hanson interprets excavated prehistoric site, 1984. Archaeological research and historic preservation compliance efforts, staffed by the University of South Carolina's South Carolina Institute of Archaeology and Anthropology (SCIAA), began on the SRS in 1973. Five years later, SCIAA was established on the SRS as the Savannah River Plant Archaeological Research Program, under the direction of Glen T. Hanson. DOE's Ronald Jernigan shepherded the establishment of the program. Courtesy of SRS Archives, negative 40142-8.

has produced numerous scholarly books and articles. Established partially in response to the National Historic Preservation Act of 1968, SRARP's objectives were to inventory and understand prehistoric and historic archaeological sites within the boundaries of the Savannah River Plant as well as within the CSRA as whole. The program has been one of the most productive archaeological research programs in the Southeast.

THE OIL CRISIS AND SUBSEQUENT ENVIRONMENTAL IMPACT ON SAVANNAH RIVER

The oil crisis of 1973–74 and the subsequent reorganization of the nation's nuclear weapons facilities brought many more changes, first in the conservation of energy, and then, more permanently, in the breadth of environmental research and regulation. As a direct result of the oil crisis, there were power cut-backs at all three operating reactors at Savannah River. In mid-1974, the reactor cooling-water flow was reduced by 40 percent to help reduce electrical consumption and lower operating costs. The increased cost of coal was also a factor. Full flow was not restored until April of 1975.[26] This energy conservation measure, however, was just the beginning. The years after 1974 brought renewed interest in environmental issues and, finally, greater regulation of the facility itself.

One indication of the growing concern for environmentalism is preserved in the official Savannah River Laboratory histories, which record the achievements of the Savannah River Laboratory for every year since its inception. In January of 1974, for the first time, "Environmental Activities" was set aside as a separate history volume.[27] The new volume covered waste management concerns, such as the leakage of high-level radioactive waste from the waste storage tanks, in addition to tritium releases and other radioactive pollutants, information that had previously been delegated to the "General" volumes of the histories.[28] The new volume also had what were called "environmental assessments," with a section entitled "AEC Procedures for Preparation of Environmental Statements—Operations." These outlined the AEC's own revisions to the environmental code, 10 CFR 11.[29]

As part of the increase in studies of the local environment, the Laboratory for Microbial Ecology was opened at Savannah River in 1974. The purpose of this laboratory was to study the development of microorganisms in the man-made environment of the Savannah River facility. The impetus behind this development was the knowledge that even a slight increase in the temperature level of the natural environment of the American Southeast could engender the proliferation of disease-bearing organisms—a potential problem as long as the Savannah River reactors remained in operation.[30]

Environmental regulation also kept pace with these developments. In December of 1974, the Environmental Protection Agency issued the first sanitary NPDES permit for the Savannah River.[31] While this was largely *pro forma*, it was a harbinger of things to come. In subsequent years, there would be an increase in environmental regulation on federal lands, and Savannah River was not exempt from this trend. In 1976, the Resource Conservation and Recovery Act (RCRA) gave the EPA authority to enforce environmental laws on all Department of Energy weapons-production sites.[32] As a result, regulatory agencies began to weigh in on the previously "closed" controversy over the relative merits

of confinement and containment at nuclear reactors, as well as the need for towers to cool reactor effluent water, a feature that was already standard for commercial power reactors.[33]

Despite a promising collaboration in the early 1970s, environmental regulation and the nuclear community, due to a shift in environmental-perception, did not share the same agenda, and this became clear during the mid– to late–1970s. Environmental regulators soon moved beyond a balanced concern for the environment and the search for new energy sources, and began to micromanage commercial and DOE facilities solely for the benefit of the environment. The nuclear community, long sustained by public awe of atomic power, now began to find itself under attack by a public that increasingly feared the atom and its residual effects. By the late 1970s, the average environmentalist was anti-nuclear, and environmental regulators were responsive to that shift.

There is no better example of this change than the story of the Barnwell Nuclear Fuel Plant. Now identified as the Barnwell County Industrial Park, the Fuel Plant was situated on 1600 acres carved out of the eastern edge of Savannah River Site, adjacent to the town of Snelling, in Barnwell County.[34] The plant had its origin in the early 1960s, when the federal government decided to close its nuclear waste-processing facilities to waste generated by civilian power reactors. The task of processing nuclear waste was then assumed by private and public utility companies, which in turn led to a number of storage problems that soon required government attention.[35] A solution popular in the late 1960s was the creation of private plants near AEC facilities for the purpose of processing commercial nuclear waste. At Savannah River, correspondence dealing with the transfer of land from the AEC to Barnwell County, for the purpose of creating this sort of facility, appears to have begun in 1968.[36] In 1974, the first "Environmental Activities" volume of the Savannah River Laboratory history mentioned that the Barnwell Nuclear Fuel Plant still had a "construction permit" and was not yet complete.[37] When the Barnwell Nuclear Fuel Plant was finished in the mid- to late-1970s, the major contractor, Allied General Nuclear Services (known by its acronym AGNS), was poised to take spent fuel from civilian power reactors and process that fuel for re-use.[38] At that time, the facility was one of three such reprocessing sites in the United States.[39]

The Barnwell plant was never operated. One of the drawbacks of reprocessing spent nuclear fuel is that it becomes more like weapons-grade material, something not really feasible with a "once-through" system of uranium fuel. Fear of nuclear contamination and the possible spread of nuclear weapons, eventually overrode the desire for making commercial nuclear facilities more economical. In 1977, by executive order, President Carter prohibited the reprocessing of spent nuclear fuels, an order that effectively ended the Barnwell Nuclear Fuel Plant.[40] Despite this setback, the Barnwell site, under the auspices of Chem-Nuclear Systems, Inc., was used to bury low-level nuclear waste. In fact, in the 1970s, it was one of only three such sites in the entire country.[41]

Carter, an "environmental president," was the first to promote alternative sources of energy, such as solar and wind power. The exploration of such avenues was, in fact, one of the main reasons for the establishment of the Department of Energy in 1977. This exploration did not extend to the nuclear industry. In addition to banning the reprocessing of spent nuclear fuels for commercial reactors, Carter put a stop to the breeder-reactor demonstration program started by Nixon. Plagued with huge licensing problems and overwhelmed by environmental studies, the Clinch River breeder-reactor demonstration plant

essentially ground to a halt in 1977, even though Congress continued to fund the project for some years afterwards.[42]

In the early 1980s, President Reagan would attempt to revive both the commercial reprocessing of spent fuels and the breeder reactor program; however, by this time interest had flagged both in Congress and within the U.S. commercial nuclear industry.[43] The

Environmental Activism and Public Comment

I don't know that there was an epiphany that, Oh my goodness, there's a bomb plant in my back yard. I'm old enough to have grown up doing the drills where we hid under our desks to save us from nuclear attack. So I've grown up in the shadow of the bomb. And I was aware that (SRS) was a bomb production facility. I think there was just a general growth and awareness about nuclear issues in the late 1970s.

-Brett Bursey, environmental activist

Across the country in the mid-to-late 70s, there was a kind of a growing grass-roots kind of thing looking at nuclear power and nuclear waste….And that kind of expanded, in my perception at least, into looking at the Department of Energy sites themselves.

-Tom Clements, Nuclear Control Institute.

During the 1970s, SRS was the scene of a number of organized anti-nuclear protests. As public perceptions of nuclear energy changed, concerns were raised about the site and its mission as the nation's sole producer of weapons-grade plutonium. Anti-nuclear feeling in the CSRA was heightened by the construction and licensing of the nearby Allied General Nuclear Services in Barnwell where plutonium was to be recycled. And activists were further concerned about Georgia Power's plans to build a nuclear plant in nearby Waynesboro, Georgia.

In answer, scattered protests occurred throughout the decade but the largest occurred in 1979. Approximately 1,500 people attended the three-day protest that included seminars and organized marches, as well as a performance by Graham Nash of the rock music group Crosby, Stills, and Nash. Allied General Nuclear Services facility and Chem-Nuclear's low level radioactive waste dump were also targeted, in addition to SRS. The third day of the 1979 protest culminated with 162 arrests for trespassing, of which 30 occurred at SRS. The details of the arrests had been prearranged between the activists and law enforcement and DOE's James Gaver, now director of Savannah River's external affairs, acted as intermediary. Gaver remembered that, "from the very beginning in dealing with these various organizations, I think they,



right off the bat, knew that we respected their right to voice their opinion and they respected our concerns about protecting the federal property and our workers." The 1979 protest was not the last. Three years later, the Savannah River Six were arrested for trespassing on the federal property, as part of an anti-nuclear demonstration in front of the DOE administration building. And a petition, given in 1992 by activists concerned about the shrimp industry and tourism downriver from the site, was another source of controversy.

Public protests of the 1970s and 1980s have disappeared for the most part as environmental activists have turned toward public hearings to air their concerns or to offering input into draft environmental statements. Other tools have developed for public input into environmental decision making, such as environmental impact statements that contain the predicted environmental effects of a Federal undertaking. The 1990s also saw the development of the Citizen Advisory Board. The Savannah River Site (SRS) Citizens Advisory Board (CAB) is composed of 25 individuals from South Carolina and Georgia, who reflect the cultural diversity of the population affected by SRS. The purpose of the CAB is to provide advice and recommendations to the U.S. Department of Energy, the U.S. Environmental Protection Agency Region IV, and the South Carolina Department of Health and Environmental Control, on environmental remediation, waste management and related issues.

Sources: Tom Corwin, War Against Weapons, *The Augusta Chronicle*, SRS Past and Present, November 28, 2000, http://www.srs.gov/general/people/srs-cab/srs-cab.html.

demonstrated abundance of natural uranium certainly played a role in this shift of opinion, but the biggest change would be the accident at Three Mile Island. Even though it was the worst accident to befall the U.S. nuclear industry, its most disastrous impact was in public relations.

THREE MILE ISLAND AND ITS IMPACT

The partial meltdown of the No. 2 power reactor core of the Three Mile Island plant outside Harrisburg, Pennsylvania, on March 28, 1979, is generally acknowledged to be the worst disaster in the history of the U.S. nuclear power industry. Even though the containment structure around the reactor did its job, and there was no significant release of radioactive materials into the environment, it was quickly realized that it would take months, if not years, to clean up the reactor area.[44] What was not clearly perceived in the nuclear community was the negative impact this accident would have on the public perception of the industry. Even though no one was injured in the accident, it underscored the dangers of nuclear energy and, by 1979, it was a lesson the general public was ready to accept.

Three Mile Island was not the first major accident at a commercial nuclear reactor in the United States. That first occurred at Brown's Ferry Reactor, outside Decatur, Alabama, on March 22, 1975. On that occasion, a technician, looking for a gas leak with a candle, caused a fire that burned for seven hours and caused 100 million dollars worth of damage.[45]

The Brown's Ferry Reactor Fire was not well publicized—and it did not directly involve a nuclear reactor. Three Mile Island, four years later, was different. The film *China Syndrome*, with Jane Fonda, Michael Douglas, and Jack Lemmon, had been released just 12 days before the accident. With Three Mile Island in the headlines, the film proved to be a hugely popular depiction of a reactor meltdown eerily similar to what actually happened in Pennsylvania. That same year, Ralph Nader and John Abbotts published *The Menace of Atomic Energy*, in which they predicted that the tide had turned against nuclear energy.[46] The book proved to be remarkably prophetic. Blindsided by the accident, and left without a governmental vehicle capable of adequately defending the industry, the nuclear community battened down the hatches, complied with an increasing array of environmental regulations, and waited for the passage of a storm that would not go away.

The impact within the industry was also great. Many of the energy concerns and conservation programs conceived in the early 1970s, were simply abandoned by the late 1970s and early 1980s. Due to environmental regulations and a lessening demand for nuclear energy that was apparent even in 1979, there was less concern about the uranium supply or the discovery of new uranium sources.[47] This spelled the end of projects like NURE, and effectively put an end to any real demand for the reprocessing of spent nuclear fuels for commercial reactors. It also spelled the end of the breeder-reactor program at Clinch River. Even though the Reagan Administration favored the program in the early 1980s, Congress now refused to fund it. Design changes had to be made in the wake of Three Mile Island, and the use of sodium as a coolant required extra safety features. By the time the project was formally terminated in 1983, over 90 percent of the plant design work had been completed, and a comparable percentage of the site preparation work had been done.

Without even beginning construction, the Clinch River Breeder Reactor had cost $1.6 billion.[48]

Three Mile Island also had an impact on the remaining production reactors. Up to that point, reactor safety had concentrated on the prevention of major accidents, with an acceptance of certain low-level risks as a requirement of the job. In the wake of Three Mile Island, however, more thought was given to low-probability accidents, and to ways of reducing reactor power levels, as well as levels of radioactivity. With this new emphasis, "Loss of Coolant Accidents" (LOCA) became a major concern of the 1980s.[49] With LOCA raised to greater significance, there was a corresponding rise in the importance of Emergency Cooling Systems or ECS. The idea behind the Emergency Cooling System was that even after shutdown, the ECS could still supply cooling water to a reactor in the event of an emergency. Throughout the nuclear industry, and certainly at Savannah River, Emergency Cooling Systems were added to reactors or were augmented in the years after 1979.[50]

At the other end of the nuclear process, Three Mile Island also focused attention on the problem of radioactive waste, a dilemma that had never been permanently resolved. There were two types of radioactive waste, low-level and high-level, and both had their unique problems and potential solutions. The Low-Level Radioactive Waste Policy Act of 1980 made every state responsible for the low-level waste produced within its borders. Even though the solution to most low-level waste involved burial, progress in implementing this law was so slow that Congress was forced to amend the act to give several states more time to comply.[51]

The problems associated with high-level waste, especially those of the defense industry, were greater and more intractable. Here, simple burial was not adequate, even though the idea of "geological disposal" of high-level waste had been proposed in underground salt deposits and at Yucca Mountain, Nevada, since at least 1957.[52] Storage in high-level radioactive waste tanks was the preferred method of disposal, but this was recognized to be a temporary solution, and never more so than when the first serious leaks began to compromise the tanks in the early 1970s.[53] By the end of the decade, it was acknowledged that there would have to be some sort of "Defense Waste Processing Facility" to provide a more permanent solution to the problems of storage.

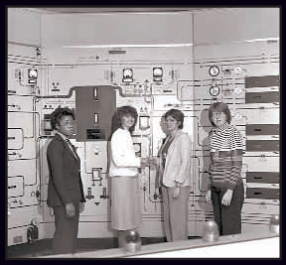
The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, also known as the "Superfund" legislation, helped provide the resources to clean up radioactive waste sites around the country. The money came with strings attached. The EPA, and the states under authority delegated by the EPA, were given more authority to regulate DOE weapons production sites.[54]

This law was followed two years later by the Nuclear Waste Policy Act of 1982, which President Reagan signed into law in January 1983. Robert Morgan, manager of SROO between 1980 and 1988, played a significant role in carrying out this act, which required the Department of Energy to establish a long-term site for the permanent disposal of the waste generated by nuclear power plants. The efforts mandated under this act were to be funded from a fee generated by the commercial production of power that was placed in the Nuclear Waste Fund. Between 1983 and 1984, Morgan helped develop the Nuclear Waste Policy Act of 1982.[55] Nine candidate repository sites were identified, and site characterization studies undertaken.[56] When Morgan returned to Savannah River in 1984, he used this experience to shape the future mission of the Savannah River Site.

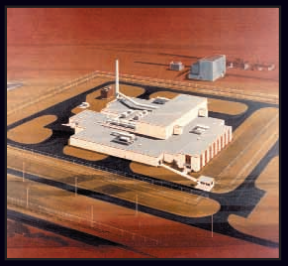


SRP Manager, Robert L. Morgan provided a complex-wide leadership role in increasing production that is considered to have accelerated the end of the Cold War. He was also the signer of the groundbreaking 1985 Memorandum of Agreement between DOE-Savannah River and South Carolina Department of Health and Environmental Control that pledged that the plant would follow state environmental laws as a matter of law or cooperation. This was a significant juncture in environmental regulatory compliance at Savannah River. Courtesy of Savannah River Site Photographic Services.

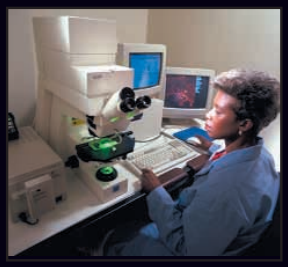





SAVANNAH RIVER PLANT
COMMITMENT TO SECURITY





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CAUTION
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Secretary of Energy
Hazel O'Leary







DAYS TILL RADIOACTIVE OPERATIONS
PROGRESS HIGHLIGHTS
ATTABOYS
DWPF
DWPF START-UP TEAM
WELCOME SECRETARY O'LEARY
COMMENCING RADIOACTIVE
OPERATIONS MARCH 1996




Ruth Patrick
SCIENCE EDUCATION CENTER




MARK II

Savannah River Site
50th
Anniversary

PART 5

Transition to Savannah River Site (1980–2000)

CONTENTS

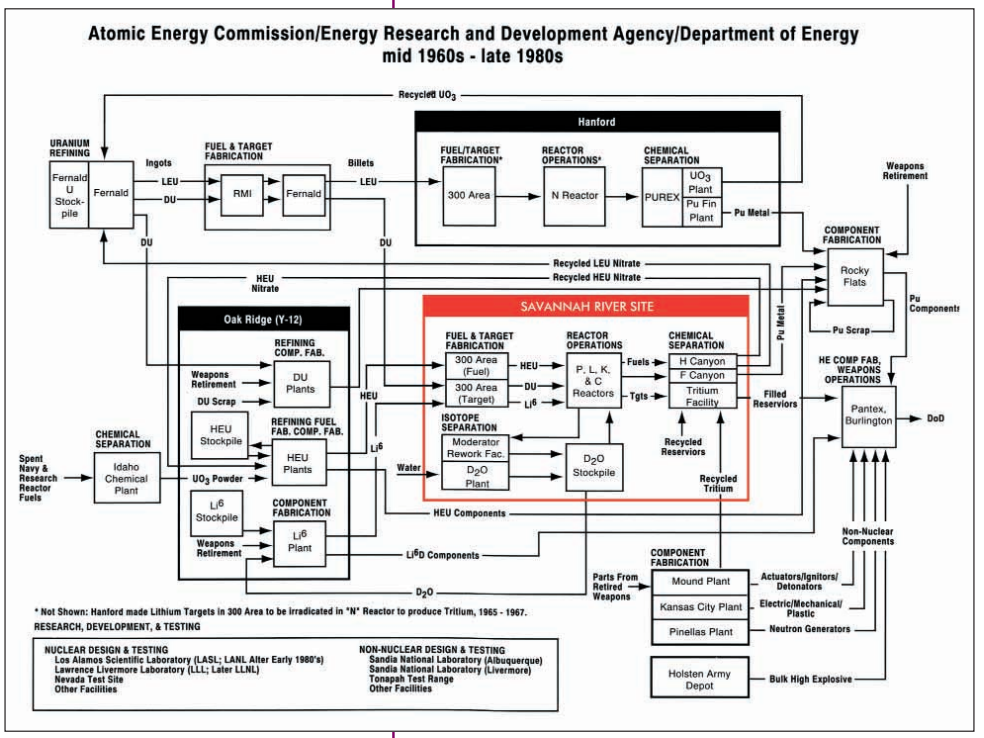
Chapter Nineteen
Transition

Chapter Twenty
Savannah River Site at Fifty:
Stewardship and Legacy

Conflict and transition were the hallmark of the 1980s. At the start of the decade, the Plant launched a building program and the restart of L-Area reactor. By the close of the decade, L-Area Reactor program was shut down, the remaining operating reactors were on standby, and Du Pont had elected to not renew its contract with the Department of Energy. Overarching all of this internal change was the ending of the Cold War. Savannah River Plant became Savannah River Site, reflecting its new role within the nation's changing defense requirements.

From 1989 to the present, the Savannah River Site has been operated by the Westinghouse Savannah River Company (solely between 1989–1996) and by Westinghouse Savannah River Company and its contract partners: Bechtel Savannah River Inc., Babcock and Wilcox Company (BWX Technologies), and British Nuclear Fuels Ltd., from 1996 to the present. The Westinghouse years have bridged the transition of the plant to a site. Although the recycling and reloading of tritium is a continuing mission, waste management, environmental restoration, and economic development have moved into the forefront under WSRC's management. The roles of the U.S. Forest Service and the University of Georgia's Ecology Laboratory have also expanded during the Westinghouse decade. Finally, a strong emphasis on technology transfer and regional economic development has developed, deepening the Site's ties with its local community. Part Five chronicles the development of the Site and its new identity in its fiftieth year.

19 Transition



Flow of materials through the nuclear weapons complex, mid 1960s through the late 1980s. Source: U.S. Department of Energy Office of Environmental Management. *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences* (Washington, DC: Department of Energy, 1997).

The 1980s were a decade of change. The Cold War heated up at the beginning of the decade, and then abruptly ended at its close. In the early part of the decade, Savannah River had to accommodate renewed demands for more nuclear weapons-grade plutonium and tritium, which led to the program to restart the L-Area reactor, on standby since 1968, as well as other initiatives. This was the first time in U.S. nuclear history that a production reactor had ever been brought back into operation after an extended shutdown period. Beginning just a year after the accident at Three Mile Island, the restart effort was complicated by the need to comply with new environmental laws, Department of Energy regulations developed in response to these laws, and increasingly adverse public opinion. Environmental scrutiny intensified in the wake of the disastrous Chernobyl accident of April 1986. In the months and years that followed, the nuclear defense programs came under heightened scrutiny as the Cold War reached its conclusion.

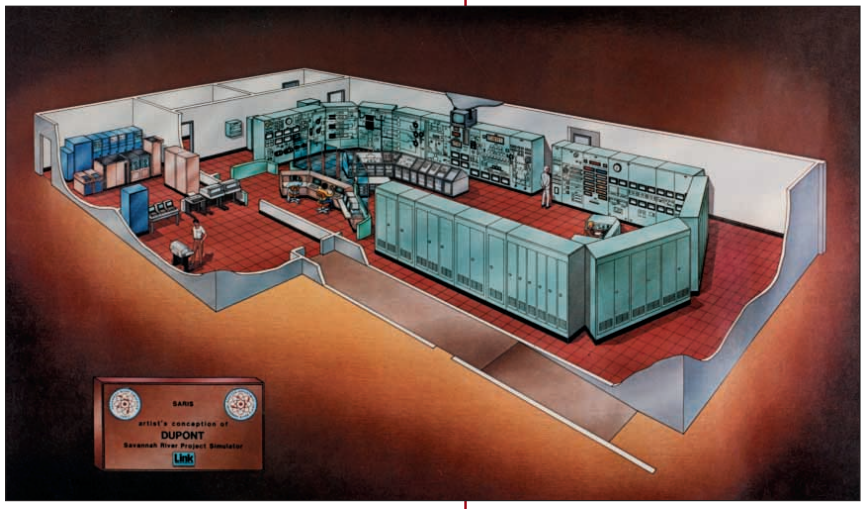
These external changes and pressures put increasing stress on Du Pont throughout the 1980s. The end of an era came in 1987, when Du Pont announced that it would not seek to renew its Savannah River contract. When the facility was turned over to Westinghouse Savannah River Company in April 1989, all of the production reactors had been shut down and the facility had a new name and mission. Now designated the Savannah River Site, its primary goal of production, site restoration, and cleanup expanded to include the permanent disposal of decades of nuclear waste.

THE IMPACT OF THREE MILE ISLAND

It was during the early 1980s that the full impact of the Three Mile Island accident became known, and this had repercussions for both the nuclear power industry and for the operation of the Savannah River production reactors. Lessons learned from Three Mile Island were incorporated into DOE orders that focused on reactor safety and environmental protection required for nuclear facilities. During this period, the Clinch River Breeder Reactor project expired, largely as a result of safety issues and concerns.[1] As Crawford Greenewalt noted in 1983, the incident at Three Mile Island brought a virtual halt to the development of new nuclear power plants in the United States. Nuclear power provided 13 percent of the nation's electrical energy in 1983, and that number was scheduled to rise to 21 percent by 1985, but it was not likely to rise higher. Greenewalt admitted that nuclear energy was not popular at the time, but prophesized that it would again be appreciated as a source of cheap energy, "when the shoe pinches."[2]

The impact of Three Mile Island resulted in changes to the Savannah River production reactors. In 1981, the Confinement Heat Removal System (CHRS) was installed to minimize any radioactive release from the carbon filters in the event of a reactor core meltdown. The CHRS would flood the minus-40-foot elevation floor with water from the disassembly basin to cool any molten core debris. This was designed to reduce the temperature of the exhaust air reaching the carbon filters of the confinement system. Without this feature, it was feared that the radioactive iodine trapped by the filters might become airborne as a result of the high temperature of the effluent air exiting the reactor building.[3]

Other reactor features were upgraded. In 1982, the high-level flux monitors were replaced by solid-state instruments.[4] More important was the implementation of the Diagnosis of Multiple Alarms system (DMA). Developed at the Savannah River Laboratory, the DMA was a computer-based diagnosis of malfunctions in the reactor operation, designed to aid operators in dealing with unusual reactor conditions. Since operators at Three Mile Island were confused by the multiple alarms and thus failed to act fast enough to prevent core meltdown, the DMA was designed to quickly determine the cause of the various alarms and advise reactor operators of the best response. Installed in 1982, the DMA system went online in 1984.[5]



Artist's conception of reactor control room simulator named SARIS (Savannah River Simulator) that was designed, built, and installed by the Singer Link Corporation in C Area. Construction began in 1983 on this facility that was used to train new reactor operators and supervisors and to periodically re-train experienced personnel in an effort to improve reactor safety. SARIS was programmed to accurately duplicate an operational reactor systems down to the background sounds. This enabled operators to train for routine operations as well as how to handle non-routine events. Clark Temple was the simulator project manager in 1983. Source: Groundbreaking Held for Reactor Training Facility in C Area, *Savannah River Plant News*, May 5, 1983.

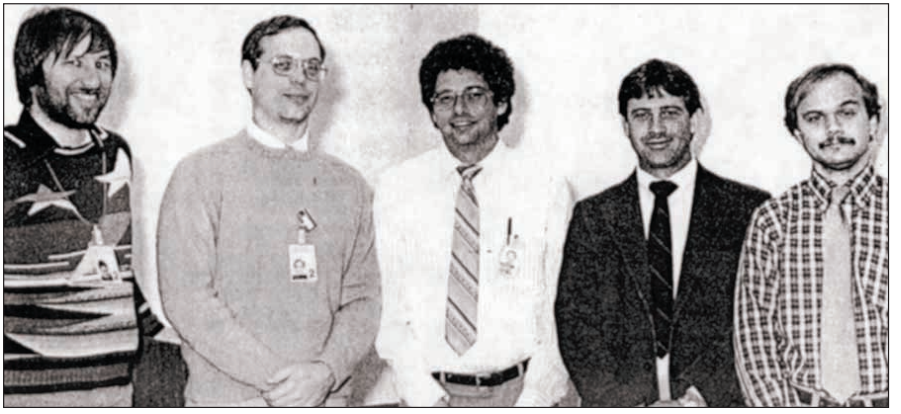
ENVIRONMENTAL CLEAN UP AND THE DEFENSE WASTE PROCESSING FACILITY (DWPF)

New laws and regulations put greater effort on the environmental cleanup programs at Savannah River. Environmental monitoring in 1981 by Savannah River personnel identified two non-radioactive industrial chemicals in shallow groundwater under the M-Area

seepage basin. When the monitoring tests identified the problem, South Carolina Department of Health and Environmental Control (SCDHEC) was notified and a plan for groundwater cleanup was defined. Between 1958 and 1979, the basin, constructed using industry standards, received wastewater from degreasing operations in the adjacent fuel fabrication facility. About 2 million pounds of trichloroethylene and tetrachloroethylene, both chlorinated degreasing solvents similar to those used in the dry cleaning industry, were released into the basin. The basin overflowed at times spreading the contamination into an adjacent natural seepage area and Lost Lake, a Carolina bay. The groundwater cleanup operation began in 1981 at the combined affected areas known as the M-Area Hazardous Waste Management Facility (HWMF). A prototype facility began in 1982 to remove these organics by a process known as air stripping in which air was used to strip the chemicals from the groundwater. Treatment consisted of pumping and treating the water from the basin, the removal of a sludge layer of heavy chemicals which was then dewatered, stabilized, returned to the basin and compacted. Contaminated soils from Lost Lake and the affected surrounding



M-Area seepage basin during groundwater cleanup operation. The basin was certified closed under RCRA guidelines in 1991. Courtesy of SRS Archives, negative 89-2070-15.



DOE and DHEC representatives meet with newly-formed site spill team in 1985 to begin training in oil spill retention and cleaning procedures, and to plan future training. The team was formed by a new initiative to respond to petroleum, chemical and other hazardous material spills. Staffed with members from CSWE-T&T, Health Protection, and Safety and Fire Protection, the team effort was lead by Pen Mayson. From left, Lou Goidell and Gary Hoover, DOE; Kim Cauthen, Aiken DHEC representative, Ted Pennington, site spill team leader and Tommy Sammons, Columbia, DHEC representative. Source: "New Team Learns DHEC Way in Spill Cleanup," *Savannah River Plant News*, Volume XXXII, No. 4, February 28, 1985.

area were excavated, effectively removing contamination and allowing regrowth. The excavated contaminated soils were backfilled into the basin that was then capped with dense clay, a synthetic liner, and layers of gravel/sand, topsoil and grass. The settling basin was certified closed in 1991 under the Resource Conservation and Recovery Act (RCRA) at an approximate cost of $5.8 million.

Other basins, set aside for chemical settling or low-level radioactive waste disposal, were also targeted for cleanup during this period.[6] The F and H Effluent Treatment Facility (ETF), a product of the late 1980s, was built to start this process. Built at a cost of $55 million, its construction and operation was approved and permitted by SCDHEC and the EPA. This facility, which went into operation in 1988, treats low-level radioactive wastewater from the F- and H-Area Separations and Waste Management Facilities by eliminating chemical and radioactive contaminants (heavy metals, organic chemicals, corrosive chemicals, cesium, and other radioactive contaminants) from the wastewater prior to its release into Upper Three Runs Creek, a branch of the Savannah River. Operation of the ETF allowed Savannah River to meet environmental regulations embodied in the Resource Conservation and Recovery Act and the National Pollutant Discharge Elimination System under the Clean Water Act. A biological baseline study of Upper Three Runs Creek was conducted by the Environmental Sciences Division of the Savannah River Technology Center prior to ETF startup to provide comparative data on environmental impacts. To date, no impact has been noted.

By 1981, the largest and most significant of the waste programs across the production complex that dealt with problems posed by the permanent disposal of high-level radioactive waste materials was the Defense Waste Processing Facility (DWPF) at SRP. Long-stored in huge carbon steel tanks, high-level radioactive waste had been a concern. At Savannah River there were over 30 million gallons of high-level waste stored in 51 tanks located in the Separations Areas.[7]

Borosilicate Glass. Courtesy of SRS Archives, negative DPSPF 32015-2.



The search for a permanent solution to the problem of high-level waste had begun as early as the 1960s, when leaks were discovered in high-level waste storage tanks. Bedrock storage had been considered but abandoned because of the danger of contamination to the Tuscaloosa Aquifer. The eventual goal was to bury the high-level waste in such a way that the material would be immobilized so that it could not leak into the environment. Several stabilizing matrixes were considered, including synthetic rock, various ceramic forms, cement, and glass.[8] Tests showed that glass appeared most promising. With vitrification, the radioactive particles within the high-level waste were atomically bonded to the glass, and the end result, often referred to as a "glass log," could also be recycled if a better method of disposal were to arise.[9] By the 1970s, Du Pont had begun to develop the vitrification process as a means of permanently disposing of high-level waste.[10]

By the early 1980s, the vitrification process proposed for the DWPF called for the immobilization of Savannah River high-level liquid waste in borosilicate glass.[11] Progress was pushed further along in 1982, when the Nuclear Waste Policy Act called for all commercial and DOE high-level waste to be disposed in federal repositories and mandated the creation of a permanent waste disposal facility.[12] A crucial step in the vitrification process, the development of "in-tank precipitation" using sodium-tetraphenyl borate, was demonstrated in 1983. This final step led to the funding of DWPF, at a cost of just under one billion dollars.[13]

The groundbreaking ceremony for the DWPF took place on November 4, 1983 and construction continued throughout the 1980s.[14] Designed by Bechtel and built by Morrison Knudsen, the DWPF has reinforced concrete walls, three feet thick, and was designed so that all operations could be remotely conducted. The facility also has a powerful ventilation system, with air exhaustion through a huge underground sand filter.[15]

Groundbreaking and Construction of the Defense Waste Processing Facility









1. Over 500 guests and dignitaries were on hand for the groundbreaking of the DWPF pilot facility, on November 8, 1983. 2. Du Pont's Crawford Greenewalt, Frank Kruesi, and two others meet for tour of DWPF pilot facility and later for groundbreaking ceremonies. 3. Design study models that were placed under the tent explained the processes involved. The model DWPF Glass Melter in Remote Cell is explained to Crawford Greenewalt. Courtesy of SRS Archives, negatives 37807-1, 24, 18. 4. Aerial of S Area showing the Defense Waste Processing Facility (DWPF) under construction. The clearing and grubbing of the 44-acre site began in 1982, while actual construction began in 1983. All photographs courtesy of SRS Archives.

Although the DWPF was first expected to be complete in 1989, with the first radioactive start-up scheduled for January 1990, the facility did not actually begin operation until March 1996. The six-year delay was largely the result of various commissioning procedures and numerous safety checks.[16] As a result, the operational story of the Defense Waste Processing Facility is discussed in the following chapter.

INCREASED REACTOR PRODUCTION

> Early in the decade new production records were set. At the end all reactors were shut down.[17]

Despite the increased environmental pressure of the early 1980s, Savannah River reactor production began a sustained increase for the first time since the 1960s, reaching a peak in 1984 and 1985, before dropping back in 1986 and 1987. One measure of productivity is the number of reactor subcycles per year. In 1980, there were 13 reactor subcycles, a total comparable to previous years. At that time, there were only three production reactors in operation at Savannah River: P, K, and C. By the following year, 16 subcycles were completed, and there appeared to be a complete halt in the production of californium.[18] In 1982, there were 17 subcycles, and in 1983 there were 18.[19] Twenty-one subcycles were completed in 1984. Among the products of these years were tritium, neptunium, and plutonium-238, -239, and -242.[20] During these years, the use of Mark 22, the main tritium producing assembly, was expanded from its original use in K-Area Reactor. In December 1983, the first Mark 22 charges designed for C-Area Reactor went critical. Two years later, in January 1985, C-Area reactor attained a record high-power rating with Mark 22 charges: 2829 MW.[21] The production of fuel and targets in the 300 Area was also greatly affected by the increases in production and the need to match the higher-power reactor operations in their output. Fabrication processes in M Area were conducted on a 24-hour-a-day, 7-days-a-week work schedule.

Part of the increase in reactor operations was the result of a change in the irradiation level of Savannah River plutonium. In 1982, plutonium irradiation levels were dropped from six percent to three percent plutonium-240, a figure that would be maintained until at least 1988. This allowed the plutonium made at Savannah River to be blended with material from the only other production reactor then in operation, N-Area reactor at Hanford. Since N-Area reactor was both a power and a production reactor, it operated more efficiently with long fuel cycles. As a result, it produced plutonium with a longer reactor exposure creating 9 to 12 percent plutonium-240.[22]

By the end of 1985, there were four reactors in operation at Savannah River, the first time this had been the case since 1968, when L-Area reactor was placed on standby. After a five-year restart program that began in 1980, L Reactor was brought back online in October 1985. By the close of that year, 20 reactor subcycles had been completed. Using Mark 16B-31 and Mark 22 charges, the reactors were producing tritium, neptunium-237, and plutonium-239.[23]

This increase in production led to improvement in facilities and an overall site upgrade. New construction occurred in the process and administration areas to house new programs and personnel. Older facilities were repaired, and technical upgrades were made to operating systems and equipment. New security provisions and other physical changes were made with the installation of Wackenhut Inc. as the onsite security force. To begin to refurbish the Site's facilities, a five-year Restoration Program was established, funded at $350 million, which was to be dovetailed with a $300 million Productivity Retention Program by Du Pont. The Restoration Program did not include capital funds needed for new construction such as the DWPF, but was the source of funding for L-Restart and other upgrades.

Meet Rosa



In 1982, four young women became the first female supervisors in the history of the Site's Reactor Department to assume responsibility for supervising reactor control operations. Barbara Jennings, one of this cadre of women, observed that If you want to learn the nuclear business of Savannah River, the Reactor Department is where the action is. To get to where the action is took three decades. Women historically figured into the nuclear business of Savannah River in diverse roles and fields of endeavor that allow for the employment opportunities that women at SRS enjoy today.

During the 1950s and early 1960s, the great majority of women associated with the plant were wives. Unsung heroes, they established their families and planted roots in their new communities despite being initially labeled as "bum plant workers" and even worse, Yankees. Housing was scarce and the schools were stretched to capacity as the operations workforce arrived. Moving to the South was an experience for some, as was the incredible heat. Most stayed and carved out new lives forming the nucleus of the SRS community. This generation of SRS women is also notable for their protection of the mantle of secrecy that their job's demanded. Mrs. Letitia Mason, the wife of Savannah River's Field Manager for Construction, knew Du Pont had selected her husband for a secret project and that a family move was in the offing. She learned where and when over the radio on November 28, 1950, when Mary Walker, Mr. Mason's secretary, called to alert her to the broadcast by the AEC announcing the selection of a site in South Carolina. Bob Mason was already in Augusta under an assumed name until the public announcement. On a daily basis, these wives supported the SRP community not knowing what their husbands did "out at the plant."

The first female employees were primarily employed as secretaries and clerical help within a range of administrative positions. Du Pont's Mary Walker, noted above, was one of the first employees to arrive in the plant area. With her typewriter in tow, she arrived at the Richmond Hotel in Augusta in November 1950 to provide the clerical support for the announcement team. By 1955, Du Pont employed 750 women at the plant primarily as secretaries, administrative and general clerical workers, cafeteria workers, and in maintenance. Others worked within non-traditional roles as analysts in Works Technical, mathematicians, draftspersons, in design work and printing, and as technicians within the production areas such as Health Physics, where they processed pocket meters.

In 1972, Rosa Burnette, a widow with two children, and Loretta Barnett, also a mother of three, became the first female operators in production. Both women had been employed in the cafeteria prior to accepting positions with Du Pont. Loretta Barnett's first assignment was in H Area. Rosa Burnette was first assigned to Traffic and Transportation where she worked at the Stores loading dock in A Area until she qualified for a production position.

"I was in Stores, on a cylinder truck, rolling cylinders two at a time. And you would go to the different areas to deliver them, the men would be actually standing on top of the building looking at us, because women never did this before…."

Mrs. Burnette's first job as an operator was in Raw Materials, where she assembled aluminum-cladded fuel billets. She described her overall experience in production as an operator as working within a family. Mrs. Burnette worked in separations and other production areas before she retired in 1993. Many women would follow in her footsteps on the production lines and in work roles that had previously been typically reserved for males.

Science and ecological research, medicine, and library science brought professional women to Savannah River. One of the first professional women at the plant was Dr. Elizabeth Baumann, an analytical chemist, who engaged in electroanayltical chemistry studies at the Savannah River Laboratory. Other female scientists and researchers would slowly join Dr. Baumann within the Laboratory. Today, Dr. Susan Wood is the Laboratory's director. The Medical Department also offered professional women employment onsite. Nurses, such as Mary Hannah, were hired early on to begin the employee health program. Ecological research brought Dr. Ruth Patrick to Savannah River in 1950, and she has remained a powerful figure at the Site throughout its history as a groundbreaker in her discipline and for her gender. Dr. Patrick is a recognized authority on wetland research and has received a number of awards for her achievements, including the John and Alice Tyler Ecology Award, considered to be the highest honor within her field. The Ruth Patrick Science Center at USC-Aiken, named in 1991, is a testimony to her scientific achievements in the state, and Dr. Patrick was inducted into the South Carolina Hall of Science and Technology in 1996.

University of Georgia professor and SREL's senior ecologist, Dr. Rebecca Sharitz graduated from the University of North Carolina with a Ph.D. in botany and ecology in 1970. Dr. Sharitz came to Savannah River in the early 1970s, and has worked onsite in her research areas: plant community ecology, wetlands ecology, environmental restoration, and the biology and conservation of rare species. As an educator and ecologist, she has provided students and colleagues with a female role model in science and has advanced the ecological profile of SREL on a regional and national basis. Dr. Sharitz was awarded the Meritorious Teaching Award from the Association of Southeastern Biologists in 1997 for her profound impact on students.

Source: Oral Interview with Mrs. Rosa Burnette, May 14, 1999. SRS History Project. "Meet Loretta and Rosa: First Female Operators," *Savannah River Plant News*, July 7, 1972; "Women of Du Pont," *Savannah River Plant News*, October 14, 1955. "Million H.P. Pencils Read; 4,500 are Processed Daily," *Savannah River Plant News*, February 18, 1955. "Women Assume Supervisory Duties in Plant Reactor Control Rooms," *Savannah River Plant News, 1982*.

Women in the Workplace





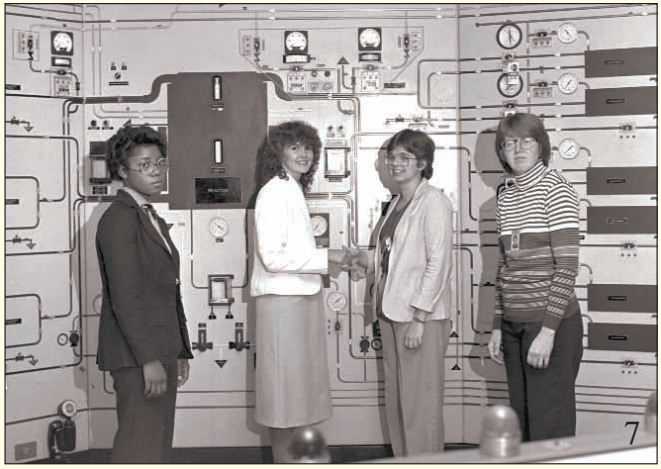








1. Clerical workers, circa 1955. Courtesy of SRS Archives, negative 7071-18. 2. Dr. Rebecca Sharitz, SREL, at Par Pond, 1972. Courtesy of SRS Archives, negative 15723-6. 3. Helen S. Bond, Construction Division Truck Driver, 1974. Courtesy of SRS Archives, negative 18509-1. 4. M. Sanders, Health Physics, preparing employee in Whole Body Counter, 1960. Courtesy of SRS Archives, negative 6832-10. 5. Female operator measuring mandrel temperature at extrusion press in 321-M. Courtesy of SRS Archives, negative DPSPF 43682-30. 6. Dr. Ruth Patrick at Flowing Streams Laboratory, 1972. Courtesy of SRS Archives, negative 15536-6. 7. First female reactor room control supervisors. (From left) Jessie Hill, nuclear engineering graduate of the University of Tennessee; Cheryl Cott, chemical engineer graduate of the University of Missouri; Jeri Trickett, chemical engineering, West Virginia University, and Barbara Jennings, chemistry graduate from the University of Pittsburgh, were the first women to assume responsibility for supervising reactor control operations at Savannah River. Each was certified after a nine-month training program. Courtesy of SRS Archives, negative 33924-1.

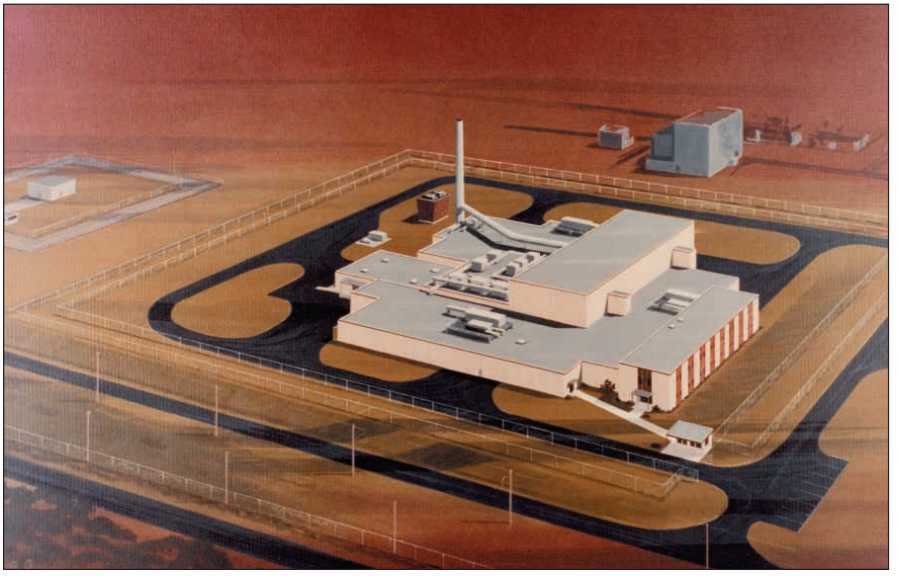


The process areas were not the only focus of upgrades and new construction in the 1980s. The main administration area was expanded under a long-range building program that aimed at replacing trailers with administrative facilities. A 1982 article in the *Savannah River Plant News* (December 2, 1982) stated that 100 trailers housed 800 DOE and Du Pont employees. The Du Pont Project Department was charged with obtaining permanent buildings (30-year life expectancy) to replace the trailers over time, depending on the availability of funding. Between 1980 and 1989, nine buildings were added to the Upper 700 Area to improve the work environment and better provide office space for the increasing SROO and Du Pont staffs. Building 703-A, the main administration building, was upgraded with new conference rooms and added computer space. As a result of these changes, the main administrative area received a completely new look.[24] SRL's building inventory was also enlarged with the construction of a pair of two-story buildings, adding office and laboratory space. The design and building materials used in this construction was based on obtaining the most space for the available money. The buildings were considered "Local Practice Commercial Standard Office Buildings" and were let to bid as "Design-Build" projects at significant cost savings.



According to the *Savannah River Plant News*, 100 trailers housed 800 DOE and Du Pont employees in 1982. A building program was undertaken by the Projects Department to provide sufficient office space within permanent buildings. Ben Rusche and crew, SRL trailer, 1972. Courtesy of SRS Archives. Negative 16316-1.

New construction also occurred in F and H areas. The construction of H-Area's B production line (HB-Line), a $70 million addition of two new levels built on top of 221-H, was begun in 1980. It was built in three phases and designed as three process lines. Construction began on the scrap recovery facility, then the neptunium oxide facility, followed by the plutonium oxide facility. The HB-Line, when built, was the sole producer of plutonium-238, a power source for the nation's deep-space exploration program. The



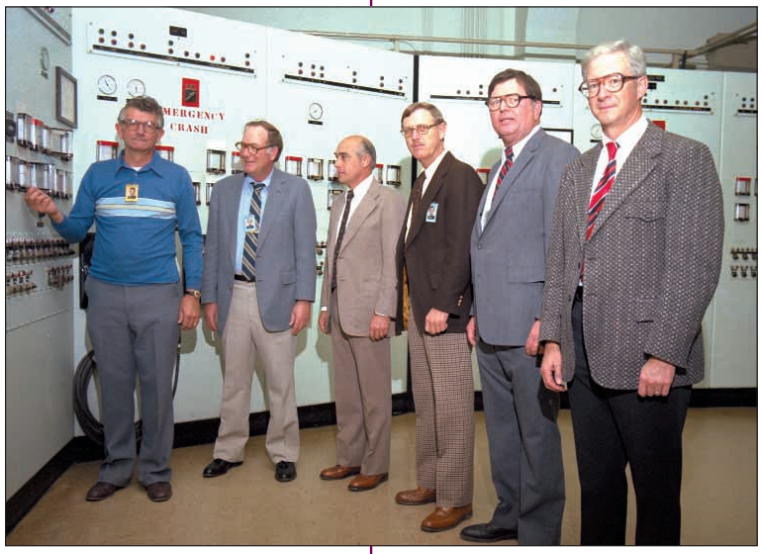
Artist's conception of Naval Fuels Facility that was constructed at the request of Admiral Rickover to provide fuel components for the U.S. Navy's nuclear propulsion reactors. Source: SRS History Project.

Scrap Recovery Line (also called Phase I) recycles plutonium scrap for puification and concentration to a solid form. The Phase III or Plutonium-238 Oxide Line produces plutonium-238 oxide from nitrate solutions. It also produced neptunium oxide and recovered plutonium-238, plutonium-239, and uranium scrap. Phase I and III of the HB-Line supplied plutonium-238 for the Cassini Mission. Phase II, the Neptunium-237/Plutonium-239 Oxide Line, was designed to produce solid oxide material from neptunium-237 or plutonium-239 nitrate solutions.

The Naval Fuels Program initiated in the 1980s was aimed at converting uranium feedstock into useable fuel in support of the Navy's nuclear propulsion program. Facility 247-F, a 90,000-square-foot facility constructed between 1982 and 1985, housed the processes involved in this conversion. Built at the request of Admiral Rickover, this facility provided fuel components for the Navy's nuclear propulsion reactors until it was shut down by request of the Department of Defense.

The last of the heavy-water production units (412-D) was shut down in 1982. The area was in operation for slightly over 29 years, and had produced a sufficient amount of heavy water for the three operating reactors, a reserve stock, and deuterium for use in weapons components. Notably 37 percent of the current Heavy-Water personnel in 1982 had remained in D Area since startup. Plant Manager John Granaghan, on hand for the occasion, noted that while a contingent of employees would stay on, the majority would be shifted over to the L-Area reactor restart program, as well as other project assignments on site.[25]

The addition of L Reactor marked the high point of Savannah River production during the 1980s. In the three years that followed, reactor production would decline dramatically,

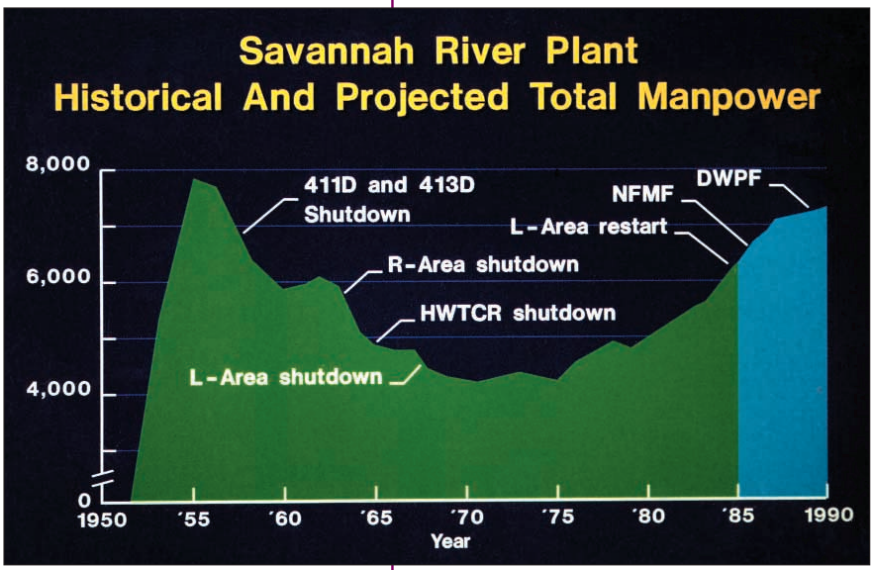


Tom Ansley, operator in D Area, far left, turns valve to shut off process water in SRP's last heavy-water production facility on January 8, 1982 From left to right, Production General Superintendent Joe Womack, Works Engineering General Superintendent Ben New, Senior Supervisor Don Bowman, Plant Manager John Granaghan, and Assistant Production Manager Dixie Hendrick. Courtesy of SRS Archives, negative 33403-13.



Area Superintendent Harvey Allen, left, addresses D Area employees on last day of production in 412-D control room. Courtesy of SRS Archives, negative 33403-2.

from 17 subcycles in 1986 to 9 subcycles in 1987.[26] C-Area reactor was not restarted in 1986 after an unsuccessful attempt to repair a tank leak. The gradual end of the Cold War itself, which had been the impetus behind the U.S. nuclear weapons material production, decreased the need for nuclear material production. By the end of 1988, all of the Savannah River reactors had been temporarily shut down to study safety issues in the wake of Chernobyl. Despite fitful attempts in the early 1990s to resuscitate L and K, with the end of the Cold War and heightened environmental concerns, the Savannah River reactors were out of production.

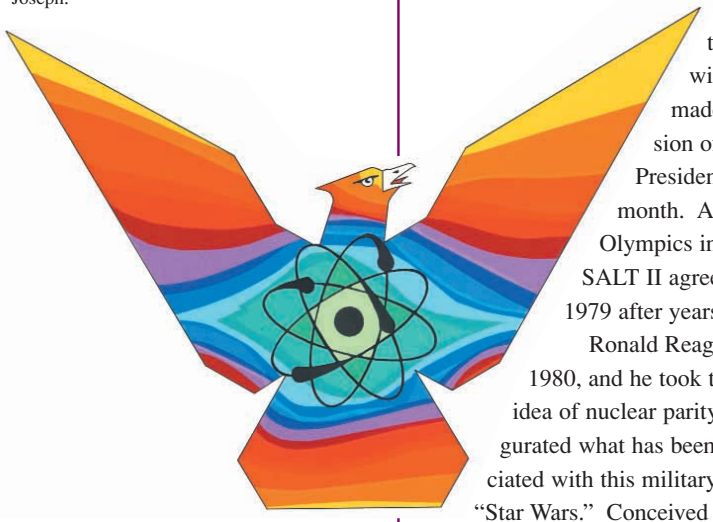


Historical Profile of Operations employment from 1950 to 1985 and projected employment from 1985 through 1990. Changes in missions and shutdowns are shown that affected the workforce over time. Source: SRS History Project.

THE L REACTOR RESTART PROGRAM

In the years that followed the Limited Test Ban Treaty of 1963, R Reactor was shut down in 1964, and L Reactor was placed on stand-by in 1968. With increased power levels, C-, P-, and K-Area reactors were able to meet the production goals originally established for the five SRP reactors and R- and L-Area reactor's production was not needed. Although the three Savannah River reactors remained in operation throughout the 1970s, all but one of the reactors at Hanford were also taken out of production during this period. The Vietnam War was ongoing, but it was also the era of détente, formally espoused by Secretary of State Henry Kissinger and at least informally accepted by presidents Johnson, Nixon, Ford, and, in the early years of his administration, Carter. The centerpiece of détente was the idea of nuclear parity between the United States and the Soviet Union.

A technicolor phoenix was appropriately chosen as L Reactor Restart Program's logo. Courtesy of J. Walter Joseph.



Beginning in the mid-1970s, the reality of détente began to fall apart. In 1975, the U.S. lost all influence in Vietnam with the fall of Saigon, and the Soviet Union and its Cuban ally made their presence felt in Sub-Saharan Africa. The Soviet invasion of Afghanistan in December 1979 proved to be the last straw for President Carter, who called for a U.S. military buildup that same month. As a result of Afghanistan, the U.S. boycotted the 1980 Summer Olympics in Moscow. More significantly, the U.S. failed to ratify the SALT II agreement, which had been signed by Carter and Brezhnev in June 1979 after years of negotiation.[27]

Ronald Reagan won the presidency in an electoral landslide in November 1980, and he took the new direction even further. Reagan formally rejected the idea of nuclear parity and pushed for a military and nuclear build-up.[28] This inaugurated what has been called the Neo-Nuclear Age of the early 1980s.[29] Also associated with this military renewal was the Strategic Defense Initiative (SDI), known as "Star Wars." Conceived in 1981, and revealed to the public in 1983, SDI pushed the

idea of national defense into a whole new realm, and threatened to make the Soviet nuclear arsenal obsolete.[30]

The ripples caused by the Carter–Reagan shift in the late 1970s and early 1980s were clearly felt in the DOE Defense Program facilities. As early as 1980, under Carter, Hanford's N-Area reactor went back to producing weapons-grade plutonium.[31] However, more production was needed. Throughout this period, there was discussion of the need for a New Production Reactor (NPR) for tritium. Almost every aspect of the NPR engendered controversy, from the site location, to the costly Environmental Impact Statement. Even the reactor technology, whether heavy water, light water, or gas, was up for consideration. Although the need for the NPR was debated until the end of the Cold War, the controversy and production needs had the more immediate effect of spurring a related program that was considerably cheaper and more immediate, the restart of L Reactor at Savannah River.[32]

The L Reactor Restart Program began in 1980. Its goal was to restart L Reactor by October of 1983. This was a major initiative budgeted at $214 million, employing a peak workforce of 800 for the renovation efforts, and projected to employ an operating workforce of 400 to run the reactor. It was also the first time that a reactor on standby had ever been refurbished and restarted after being out of service for more than a decade. The symbol chosen for the program was, appropriately enough, the phoenix.[33] The L Reactor Restart Program, directed by Walt Joseph, soon found that the reactor needed new heat exchangers and replacement of all small diameter carbon steel cooling pipes. The Restart Team also had to remove deposits of aluminum-nitrate from the reactor tank and nozzles, eliminate the old asbestos insulation, and add safety upgrades that had been installed on the other reactors.[34] In June 1983, the restart program was $10 million dollars under budget, ahead of schedule, and possessed an admirable safety record of 2.5 million hours without a single lost-day injury among the Restart workforce.[35]

The greatest problem, however, was not technical but environmental. The accumulation of environmental requirements governing DOE facilities came down hard on the L Reactor Restart Program, as did those who opposed any expansion of nuclear facilities, whether for production or power. A lawsuit was filed in a Washington DC federal court by the National Resources Defense Council, the Energy Research Institute, the League of Women Voters, and several individuals in November 1982. This lawsuit requested that the DOE prepare an Environmental Impact Statement (EIS) on the impact of L Reactor operations on the environment, specifically the discharge of hot water into Steel Creek and the remobilization of 14 curies of cesium-137 from Steel Creek to the Savannah River.

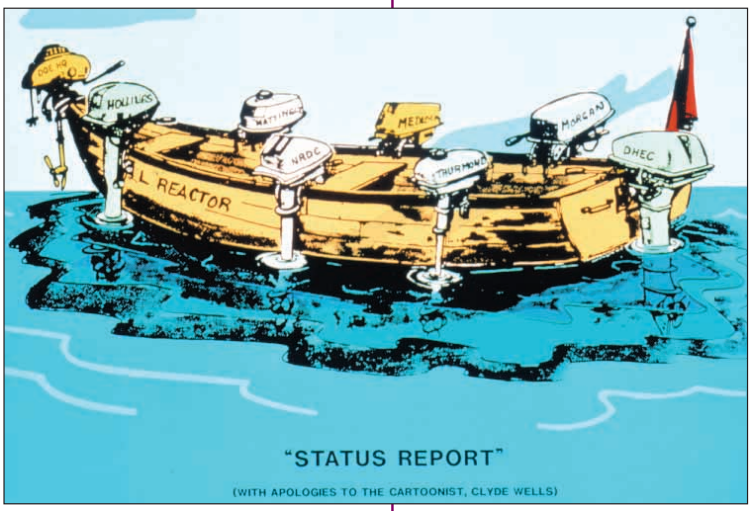
The lawsuit was lodged against DOE because the environmental groups disagreed with an earlier finding of no significant impact (FONSI) forecasted for L Reactor operations in an Environmental Assessment (EA) prepared by the NUS Corporation for DOE. They also protested that there had been no public input into the decision making. The findings in the EA stated that the rise in Savannah River's temperatures, as measured by previous L Reactor operations, would be one to two degrees F and that the river tempera-



Replacement heat exchangers for L reactor were fabricated in Japan at a cost of $1 million each for the 12 needed. Courtesy of SRS Archives negative 33433-8.

ture would be well under the 90º F maximum temperature required by the State of South Carolina. Also the cesium-137 dose to a person drinking Savannah River water just downstream of the Site was found to be 1/20,000 of the EPA standard. Given these findings, the DOE contended that the EA with a FONSI fulfilled their regulatory responsibilities and that an EIS was unnecessary. In January 1983, the State of South Carolina entered the suit as an intervener, and in May, U.S. Senator Ernest F. Hollings stated that he would introduce legislation to block L Reactor restart funds until an EIS was compiled.[36]

Further complicating matters were ongoing negotiations between DOE and South Carolina Department of Health and Environmental Control (SCDHEC) on obtaining an National Pollutant Discharge Elimination System (NPDES) permit that would regulate all site-water discharges. The previous permit, issued by the EPA, allowed direct discharges of the reactor cooling water to the site's streams. In 1983, NPDES permitting was conducted at the state level, not by the EPA, which had delegated its responsibilities to individual states. After negotiation, the State of South Carolina agreed to remove itself from the1982 lawsuit on the signing of a Memorandum of Agreement with DOE in which DOE agreed to study thermal mitigation for SRP discharges, to undertake a health study of SRP populations, to continue expanding the SRP groundwater program, to provide the state with radiation emission data, to provide available reactor safety documents, and to operate L Reactor within state permit limits and DOE statements. After signing the agreement, L Reactor startup was able to proceed on schedule.[37] A detailed monitoring system that met the regulatory requirements of the NPDES was established on the site. One source notes that 70 NPDES monitoring stations were in place on the Site in 1987.[38]



Cartoon showing groups and individuals involved with decision making on the L Reactor Restart project and its progress through political, regulatory, and public waters. Source: "Du Pont and Atomic Energy: From the Brandy Wine Creek to The Savannah River." Paper presented by J. Walter Joseph for AICHE Meeting, 1983.

In response to criticism on the lack of public input on the project, Senator Strom Thurmond conducted a session of the Senate Armed Services Committee in North Augusta in February 1983 to elicit public response on the environmental consequences of the restart program. The public turnout at the session was large enough that Senator Thurmond recommended that DOE provide a 90-day comment period to allow the public to fully express their concerns. In accordance, DOE held additional public meetings in Augusta, Aiken, Savannah, and Beaufort throughout May 1983, and the statements made at these meetings were submitted into the record and transmitted to Congress. By this time, the L restart controversy had fragmented into opposing camps. Most local business, community leaders and citizens favored the restart, while those opposed were the more distant regional forces tied directly to environmental groups.[39]

The groups opposed to the program argued from a number of angles. Some were upset that L Reactor would not be equipped with a containment dome, as was now required for all commercial power reactors by the Nuclear Regulatory Commission. More direct was concern over the environmental impact to Steel Creek, a tributary of the Savannah River that would once again receive hot water effluent discharge from L Reactor.[40] In 1981 and 1982, the Savannah River Ecology Laboratory released two

reports dealing with the impact of L Reactor on the ecosystem of Steel Creek. The Laboratory's general conclusion was that the "Steel Creek stream corridor and floodlands must be considered… a sacrifice zone for virtually all higher life forms."[41] This was essentially the position taken by Academy of Natural Sciences limnologist, Dr. Ruth Patrick. Dr. Patrick appeared at the North Augusta hearing in 1983 to state that the renewal of the reactor would have minimal impact on the Savannah River, implicitly recognizing that Steel Creek itself would have to be used as a buffer.[42]

This position was acceptable in earlier decades, when wetlands and simple distance were used to minimize impacts on the Savannah River itself. By the 1980s, however, it was no longer perceived as environmental best practice. There was now concern over the thermal effect on Steel Creek itself. It was noted at the 1983 hearing that L Reactor would discharge 250,000 gallons of slightly radioactive water per minute into Steel Creek at a temperature of 200º F, a violation of U.S. and South Carolina water standards for any commercial reactor.[43] By 1983, environmental groups were calling for an artificial lake that would mitigate the effects of the high-temperature effluent water from L Reactor.[44]

Before the end of 1983, it was recognized that "L Lake" would have to be constructed adjacent to L Reactor as thermal mitigation to meet NPDES requirements. Construction of the lake began in 1984 and was completed the following year.[45] By the time L Reactor went critical, on October 31, 1985, the controversy over Steel Creek and L Lake had delayed the reactor restart by two years.[46] In the three years that L Reactor operated, before all the reactors were shut down in 1988, the operation of L Reactor was often limited by the environmental requirement to limit the temperature in L Lake to 90º F in the summer months.[47]



L-Lake Construction. L-Lake provided a once-through 1,000-acre cooling pond for L-Area reactor's hot water effluent. Courtesy of SRS Archives, negative 400115-12.

CHERNOBYL AND ITS AFTERMATH

On April 26, 1986, Unit 4, a graphite-moderated and water-cooled reactor at the Chernobyl Nuclear Power Station, 80 miles north of Kiev, suffered a series of explosions that are recognized as the worst nuclear reactor accident to date. As a result of a low-power test in which operating personnel disregarded established safety procedures, the reactor overheated to the point that the control rods could not be inserted when the supervisor ordered a "scram." The fuel elements burst apart, causing the cooling water to turn to steam almost instantly, which in turn blew the top off the reactor tank and the building around it. The explosions dispersed huge quantities of radioactive particles into the atmosphere. Two persons were killed in the explosions and another 29 died soon after from radiation exposure. Hundreds more were sickened, as Soviet authorities struggled to evacuate and clean the area.[48]

The impact of this disaster was felt throughout Europe, and it had repercussions within the Soviet Union that contributed to the end of the Cold War itself. Those repercussions will be explored in more detail later in this chapter. Chernobyl also had an impact on the DOE nuclear reactors that was more momentous than Three Mile Island.

The most immediate impact was on the dual-purpose N-Area reactor at Hanford. A graphite-moderated reactor, as was Chernobyl, N Reactor was closed for extensive safety checks. Like Chernobyl, N Reactor had no containment vessel to protect the environment and probably would not then have been licensed if subjected to current NRC requirements. Even though the reactor was basically sound, it was not restarted.[49] The closing of N Reactor was followed by the temporary shutdown of the High Flux Isotope Reactor at Oak Ridge.[50]

Chernobyl would influence the DOE's decision to shutdown C Reactor. Small leaks had occurred in the lower portion of the C Reactor tank as a result of stress corrosion cracking. The leaks were repaired in 1968. In 1984, another small leak was found in the C Reactor tank, which caused the reactor to be shut down the following year for a thorough examination. A number of cracks were discovered, the most serious of which were at the knuckle joint. Efforts to repair these cracks were unsuccessful, and in September 1986, the reactor was placed on "cold stand-by" by order of the Department of Energy.[51] This effectively ended the operation of C Reactor, which was never restarted.

These developments, however, did not satisfy the anti-nuclear lobby, which turned up the heat on all aspects of the DOE complex in the wake of Chernobyl. This attention created an environment in which the media began a more intensive search for problems within the industry, especially within the aging DOE facilities that served the military needs of the Defense Department. There was also a marked increase in the number of films, television shows, and articles critical of DOE facilities and the companies that managed and operated them. Prominent on the list of DOE operator–contractors was Du Pont.

CHANGING REQUIREMENTS FOR THE DEPARTMENT OF ENERGY COMPLEX

In the first two decades of Savannah River's operation, relations between Du Pont and the Atomic Energy Commission, while occasionally strained, were still based on mutual respect and amiability. Du Pont had a proven track record in the wartime operation of Hanford, and the AEC permitted substantial autonomy. As a result, the AEC only had around 150 employees at its Savannah River Operations Office, and supervision was not overly intrusive.[52] Additionally, in the 1950s and 1960s, there was little or no outside pressure from environmental groups disposed to scrutinize the arrangement or look for flaws in the operation of the plant.

This began to change in the late 1970s, with the demise of the Atomic Energy Commission as an independent federal commission. Whatever the flaws of the earlier arrangement, the AEC and Du Pont's Atomic Energy Division shared similar goals and aspirations for nuclear energy. This was not always the case with ERDA, a Federal administration, and its successor, the Department of Energy, a cabinet-level department with a multifaceted role spanning the range of energy sources from fossil fuels, to solar and wind power, to a politically driven concern for gas prices. Not always, but certainly sometimes, nuclear energy was relatively neglected, and this trend continued as various advocacy groups and the general public itself began to turn away from the promise of the atom. And there did not appear to be anything that could be done to alleviate the situation. In the early days, Du Pont may have been far ahead of the environmental curve, as wit-

nessed by the collaboration with the pioneering work of scientists like Dr. Ruth Patrick, but that was not the case in the 1980s. By then, changing laws and expectations led the Savannah River Operations Office to correct perceived deficiencies in safety procedures and radioactive waste disposal.



Welcome to Wackenhut (WSI). The selection of the Florida security firm from a field of 19 bidders was announced on August 12, 1983. Tasked with providing a full range of security protection and law enforcement, Wackenhut would initially employ 460 uniformed security inspectors as well as an additional 50 employees in management and support positions. Source: "Wackenhut Selected for Security Contract," *Savannah River Plant News*, Volume XXX, No. 10, August 25, 1983. Courtesy of SRS Archives, negative 37808-2.

WACKENHUT SERVICES COMES ON BOARD

Security became a major issue at Savannah River in the early 1980s. With the taking of American hostages in Iran in 1979 and the general rise of terrorism in the Middle East, the security arrangements at U.S. nuclear facilities came under closer scrutiny by the National Security Agency. Industrial guard forces at most facilities were capable of thwarting simple threats, but were inadequate to protect facilities and nuclear materials from dedicated and trained terrorists.[53] In 1980, the government conducted a mock raid on Savannah River with government agents, who infiltrated the plant with forged documents, took hostages, and seized control of one of the reactors.[54] The relative ease of this raid led to a Congressional hearing on security and it soon became obvious that security at Savannah River would have to be improved.[55]

(Below) SROO acting manager Dick Denise (left) and George R. Wackenhut, president and chairman of the board of the Wackenhut corporation met in August 1983 to discuss terms of Wackenhut's $40 million contract for security services over a two-year period. Courtesy of SRS Archives, negative 3361-1.



Even though Du Pont had been responsible for all aspects of the Savannah River operation, including its security, the company was not interested in developing the capability to deal with the terrorist threat. The Department of Energy thus contracted with Wackenhut Services Inc. to provide security services for the site in 1983. Du Pont continued to provide security projects and safeguards for special nuclear materials. In the business of securing industrial and national sites from the Alaska pipeline to the Kennedy Space Center, Wackenhut immediately made plans to upgrade the plant's security force employed by Du Pont at Savannah River.[56] Soon after the transition, security was tightened around the reactors, the separations areas, and the fuel manufacturing area

with the addition of perimeter fencing and many internal security improvements. Major capital improvements and operational changes required close collaboration between SROO, Du Pont, and Wackenhut. Helicopters, machine guns, and flak jackets became the security norm at Savannah River.[57]

CHANGE AND FRUSTRATION

The security issue was a major challenge for the Department of Energy and Du Pont, and it was a harbinger of things to come. There had always been a tension between Du Pont and the Savannah River Operations Office, but this had been a creative tension when the need for nuclear materials was paramount. As that need declined, as AEC headquarters became more politicized, as the older generation of workers was replaced by a new generation, and as environmental scrutiny made everyone's job more difficult, this frustration became more intense for SROO and Du Pont.



Savannah River Plant Staff, 1989.
First Row (Left to Right): Otto M. Morris, William C Reinig, James W. Wade, Joseph L. Womack, Lowell Hibbard, Robert Maher, John T. Lowe, Albert H. Peters, Jr, Lucien M. Papouchado, Ira B. New, Jr., John D. Clayton, and Charles E. Ahlfeld.
Second Row: Gary Hayes, Jr., William R. Jacobsen, Thomas A. Moore, John A. Porter, Michael F. Sujka, Joseph F. Ortaldo, Thomas E. Leipold, J. Walter Joseph, Jr., James W. Crichton, Maurice M. Anderson, and Donald C. Nichols.
Third Row: Gerald F. Merz, William D. Findley, James E. Haywood, James O. Hightower, Unknown, John S. Roberts, Lendon E. Weisner, Jr., Richard F. Mayock, Harold J. Groh, Thomas W. Greene, and Thomas F. Thome Courtesy of SRS Archives, negative 50717-3.

In April and May 1982, Du Pont at Savannah River underwent a management reorganization that moved away from a traditionally "functional" approach to one that was more responsive to "program management." This shift began approximately in 1979. The adoption of the program management approach was perceived as an enabling tool for Du Pont to handle the greater load of new programs required of the facility in this decade, and to conduct the training that new recruits required. Much of this reorganization was overseen in Wilmington by Frank Kruesi, Technical Director, and Jim Conaway, Manufacturing Director, and was coordinated at Savannah River by the plant manager, John Granaghan. Under the new organization, the Savannah River Manager of Operations was Al Peters, and under him were the program managers for Reactors, separations, and waste management. In the case of reactors, the Program Manager was Joe Womack, and under him were five superintendents: Lowell Hibbard for reactors; Gerry Merz for Reactor and Reactor Materials Technology; Tom Beliveau for Reactor Works Engineering; Bob Swingle for Raw Materials and Heavy Water; and Walt Joseph for the L Startup Project Team.[58]

Much of this reorganization was an attempt to come to grips with the gradual change in the overall mission of the Department of Energy. Throughout the 1980s, there was a shift in the DOE mission from weapons manufacturing to cleaning up the weapons complex, and this was true despite the re-emphasis in the early 1980s on weapons-material production as witnessed by the L Restart effort. This new emphasis was recognized in 1987, when the DOE Headquarters itself went through a reorganization that allowed it to better concentrate on defense waste programs and site cleanup.[59]

Du Pont had never been completely at ease with its involvement in the nuclear industry, even in the early days. This dissatisfaction grew as the nuclear industry and weapons material production received increasingly bad press beginning in the 1970s and intensifying in the 1980s. Savannah River had never had a close fit with Du Pont's corporate culture, which was devoted to the pursuit of new products. Du Pont performed the early nuclear work out of a sense of patriotism, and was certainly interested in the promise of

Commercial Interest

Du Pont's commercial interest in the nuclear field was limited at best until the early 1960s. From 1957 through 1962, Du Pont and Savannah River had participated in studies of potential commercial reactors, but did not wholeheartedly jump aboard the power reactor bandwagon. The company's interest in commercial developments lay elsewhere, in potential products closer to its traditional marketable goods. Participation in the plutonium-238 and transplutonium production projects at Savannah River indicates management was looking towards the materials rather than the energy that reactors could produce.

In 1961, Crawford Greenewalt wrote to AEC Commission Chairman, Glenn Seaborg, expressly reversing earlier statements on commercial aspects of the nuclear industry. This change of heart among the Du Pont management reflected broad attitudes of that era. At the time, public fear of nuclear energy was nearly nonexistent, and interest in radioisotope uses in medicine and industry were waxing, as were heat source applications in space exploration.

By Spring 1963, Du Pont had acted on its newly expressed interest in the commercial nuclear sector in a variety of ways, but found little that warranted more than minimal or routine efforts. One person in the Development Department was then spending almost all his time following the nuclear industry to watch for potential areas of investment, but had seen nothing of great interest. A committee investigating the potential of thermal nuclear power generation could not recommend further pursuit for the company. Collaboration with another company in their nuclear energy related work had twice been considered and turned down. The construction of a high flux reactor for the production of heavy element isotopes was briefly considered then dropped.

Du Pont had found some markets for its know-how in the nuclear and military industry. The company had developed processes to use explosives to compact beryllium and graphite and to clad metals for use in reactor vessels; they also provided general expertise related to nuclear material and reactor construction and operation. During the early 1960s, Du Pont's Central Research Department and Radiation Physics Laboratory were exploring the effects of radiation on chemical processes and materials. The former had a new building housing two Van de Graff generators, and the latter had a variety of linear accelerators for this work.

Of more relevance to Du Pont commercial activities was the Atomic Energy Commission's Plowshares program of the 1960s, which attempted to develop nuclear explosives suitable for use in construction and mining. The Du Pont Explosives Department followed the work closely, but no practical atomic explosives were ever developed—in part because their use was unlikely to be accepted by the public. At Savannah River, use of explosives to create transplutonium elements was studied, but found problematic because the great amount of material that would need to be processed to recover the products.

Between the mid-1960s and the 1980s, about 100 power reactors were built in this country. Only one was heavy-water cooled and moderated like the Savannah River reactors, and that was an experimental unit in operation briefly at Parr, South Carolina. Thus Du Pont's expertise in reactor operation was with a type of reactor that was not attractive to the power industry, as heavy-water reactors were expensive to build and operate.

By the late 1960s, while many of the commercial power reactors were being built, public perception of risks associated with the nuclear industry were fast tilting toward the negative. Environmental concerns and regulations further hampered development of the nuclear power industry in the 1970s, encouraged by and encouraging greater public apprehension about the safety of nuclear energy. Du Pont did not pursue any lingering interest in power generation that it may have had into this period. Also, through the 1970s, it became apparent that none of the products irradiated in the reactors at Savannah River would find markets suitable for commercial development by the company anytime soon. Du Pont's testing of the commercial nuclear industry waters did not proceed beyond public sector involvement by anything more than a few hesitant steps.

Source: Crawford H. Greenewalt to Glenn Seaborg, October 17, 1961,1--2, Acc. 1957, Series VI, Box 62, Folder 16, Hagley Museum and Library. Glenn T. Seaborg to Crawford H. Greenewalt, November 21, 1961, 1, Acc. 1814, Series III, Box 30, Folder 16, Hagley Museum and Library. Glenn T. Seaborg to Crawford H. Greenewalt, November 21, 1961, 1, Acc. 1814, Series III, Box 30, Folder 16, Hagley Museum and Library.

Shifts In Management Style

During the initial years of management at Savannah River, Du Pont followed the functional management system described in the earlier chapter discussing the company. At the corporate level two shifts occurred in managerial organization, one in 1972 and a second in 1978; neither impacted operations at Savannah River.

In 1979, a shift in management policy did occur that had an effect on Savannah River. Forecasts of increased construction with authorization of major new facilities prompted a change from functional to what Du Pont called a program management organization, first instituted in L Area as an outgrowth of an effort to enhance liaison between Wilmington and Savannah River personnel and between construction and operations managers during the upgrade of L-Area reactor. The then-limited changes involved reorganization of the Wilmington AED Process Section into the Project Management office, assignment of project liaison personnel in major SRP departments and Wilmington, and organization of the L Reactor Startup Team to provide close design and construction follow-up of the L Reactor reconditioning. Ideally the onsite liaison personnel for a new project would be the future top operating staff. The new organization gave operations managers more generalized authority, placing the management focus on target products. This was to encourage greater coordination among the various groups involved in production, moving the focus away from individual functions of production, which could encourage isolation of production units and less efficiency. The new system was an adaptation of practices Du Pont had successfully applied to some of its commercial plants.



The L Reactor Startup Team was the first management group to be placed under Du Pont's "program management" organizational philosophy. The program management structure was applied plant-wide in 1982. Courtesy of SRS Archives, negative 34872-3.

The concept of more generalized authority for management of operations was generally applied to the entire plant in the spring of 1982. Under the new system, three product teams, each headed by a Program Manager, were responsible for all production at the Site. And each program Manager was in charge of Production, Works Engineering, and Works Technical departments for their particular program. The new organization consolidated these entities into what was hoped to be a more coordinated structure at upper management levels, while leaving the lines of authority intact for most of the wage roll employees and their supervisors. This change came at a time when many of the persons with Hanford experience had retired, taking with them early organizational experience and know-how. The new managers typically had learned their skills in commercial operations. The new structure may have been inefficient initially or appeared to be so to those accustomed to the earlier organization. Departments like Health Physics no longer had a direct line to the plant manager since their findings now passed through a production manager, although, as always, safety issues did have the ear of management when needed.

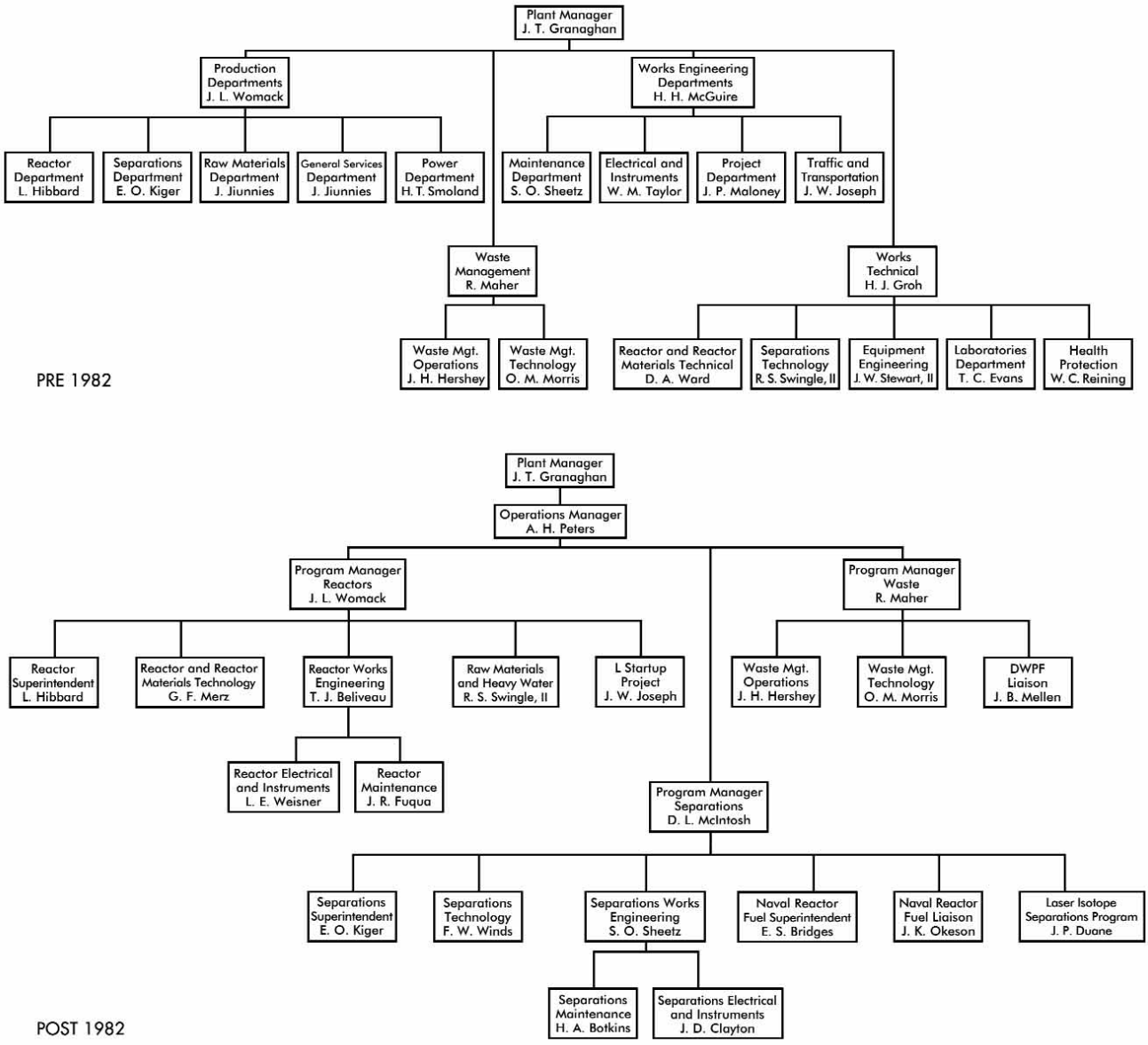
This management structure, in effect through 1989, was too briefly used to assess its impact. However a similar reorganization of SRL was quickly seen to be detrimental. At the end of 1978, the director of the Technical Division, in Wilmington, announced a reorganization of the Savannah River Laboratory along "programmatic lines." The Laboratory director position was eliminated, and three staff positions were created to manage laboratory work. These were Special Programs, Process Research and Development, and Laboratory Manager (in charge of services, planning general operations, and information). The former Laboratory Director was offered one of these positions but left the plant in protest over the changes and did not return.

Ostensibly, a change to a program management organization, one effect of the change was to move decision-making power over broad program pursuits to Wilmington since there was no longer a single person in change of the Laboratory in South Carolina. Prior to this, a single director of the Savannah River Laboratory had reported to the director of the Technical Division for approval of programs, but the latter had little authority to broadly determine Laboratory work. With local management power divided, the Technical Division director could then apportion as he saw fit. Greater preference was given to waste issues, organized under Special Programs. The shift in funds to waste programs under the Special Programs group reduced monies available to the Process Research and Development group. This meant in turn reduced funding for reactor oversight and cooperative activities previously undertaken by Laboratory personnel. Some have felt that this reduction may have contributed to reactor safety problems experienced in the 1980s. At the very least, it did increase competition for funds and personnel in the Laboratory, and heightened tensions there.

The Technical Division director who initiated this change was transferred late in 1979, and by early the following year the new director had reversed the problematic division of management authority. An announcement in January 1980 stated that the programmatic functions-Special Programs and the Process Research and Development-were consolidated under a new Laboratory Director. Even though short-lived, this change shows that shifts in management responsibilities could have great impacts on the work undertaken, and that such shifts as the change to the program management concept had to be carefully considered by the plant operator.

Sources: John T. Granaghan to staff, with attachments, April 19, 1982, Savannah River Site; and W. P. Martin to P. L. Roggenkamp, Personnel History of AED and SRL Management, May 1, 1987, Savannah River Site.

Reorganization Chart, 1982



Prior to 1982, Production, Works Engineering, and Works Technical departments were on an equivalent level in the management hierarchy. Under the new project management structure in 1982, the applicable Works Engineering and Works Technical departments were moved under Production, giving production concerns the focus of the management structure and routing all other work through the new program managers.

the transplutonium programs in the 1960s. However, when those programs failed to find a niche in the open market, and when the production of weapons materials was clearly no longer critical to national security, Du Pont realized that its continued presence at Savannah River was not in the company's best interest.[60]

Congress was increasingly dissatisfied with the arrangement as well. The latitude given Du Pont in the original AEC contract did not sit well with Congress, which put pressure on DOE Headquarters to standardize arrangements with its various management and operations contractors. One senior DOE official complained in the 1980s, "we don't have a contract with Du Pont, we have a treaty with Du Pont."[61]

The breaking point was the issue of liability. In the original contract, Du Pont had insisted, and the AEC had accepted, that the company would not be held liable for damages in the case of an accident or some other form of litigation that might result from its operation of a nuclear facility. At the time, this was seen as reasonable, and even the government received some support in this regard through the Price–Anderson Act of 1957, which established liability limits and certain no-fault insurance provisions for reactor accidents.[62] By the mid to late 1980s, however, DOE began to suggest that Du Pont's liability arrangement might have to be altered. Du Pont, which did not run Savannah River for a profit, was not eager to assume this responsibility.



Du Pont plant manager John Granaghan, along with Ernie Ruppe (seated), Petrochemicals vice-president, and Savannah River's Public Affairs manager Jim Felder, field questions at a press conference on Du Pont's decision to not renew its contract at Savannah River in October 1987. Courtesy of SRS Archives, negative 47340-20.

DU PONT'S DEPARTURE

Given the above, it was not surprising when Du Pont announced in October 1987 that it would not accept another extension of the Savannah River contract when the existing contract expired in 1989. Richard E. Heckert, Chairman of Du Pont, stated that the reason was two fold, that the government no

> …as in 1950, Du Pont has no interest in operating such a facility for profit…. What has changed is that now there are a number of major companies fully capable of operating nuclear facilities such as Savannah River and who do so as a core business. In 1950 we were uniquely qualified for the job. From the beginning, Du Pont has operated Savannah River with total protection from liability, which we believe is appropriate given the nature of the task and essential in the case of Du Pont. We are not willing to put our shareholders' assets at risk for a business which we operate without profit.
>
> Regardless of the outcome of the current Congressional debate over renewing the Price–Anderson Act, we believe that an increasing number of elected officials and some segment of the public favor the elimination of protection from liability which is critical to us. – Du Pont Chairman Richard E. Heckert, excerpted from 1987 announcement.
>
> Source: "Du Pont to Leave SRP in 1989," *Savannah River News*, Volume XXXIV, No. 23, November 12, 1987.

longer appeared willing to guarantee the work, and that Du Pont was no longer uniquely qualified to do it.[63] A parallel announcement was made by John Granaghan, Manager, at Savannah River.[64]

Since the mid-1980s, DOE and its contractors had been under examination in Congress for allegations of poor safety practices at various nuclear facilities. In hearings before the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce, Savannah River was noted for its poor fire-prevention procedures. It was stated that in certain parts of the reactor buildings, fire control was nothing more elaborate than a standard garden hose.[65] Congress wanted sprinkler systems installed in the reactor buildings, and this was a government expenditure that SROO and Du Pont management had resisted for the simple reason that the all-concrete reactor buildings could not burn.[66]

The concern over fire-prevention procedures was eclipsed by a news story reported on the front page of the *New York Times* in 1988. A report, "SRP Reactor Incidents of Greatest Significance" compiled three years before, which detailed and categorized 30 significant incidents in the history of the five Savannah River reactors, was released to the public. Most of the incidents in the 1985 report had been summarized in an earlier ERDA document. An internal memorandum initially, the report's purpose was to show that the serious reactor incidents at the Savannah River Plant were largely confined to the early years of operation, and that the safety precautions of later decades had greatly reduced the incidence of error.[67] It was composed at a time when reports of a similar nature were being compiled for other sorts of mishaps; one such report, for example, compiled in June 1985, documented the occupational exposures of workers to chemicals at Savannah River from 1952 through 1984.[68] In 1988, the report on reactor incidents was released in an effort to show that nuclear work was, in fact, becoming safer. This was not, however, the way the report was received, and the national media immediately interpreted the 30 "incidents" as "accidents."[69] The Department of Energy acknowledged that the incidents had been duly described on each occurrence by Du Pont's staff and that DOE and its predecessor agencies were aware of their occurrence. The outcry over the disclosure led to another series of congressional hearings over perceived problems at Savannah River, and the 1985 report was entered into the Congressional Record.[70] Media attention reached a peak in late 1988, with investigative reporting spearheaded by the *New York Times*.[71]

The fact that the Savannah River reactors had all been shut down in 1988 was almost lost in the public debate. Although this shutdown was initially intended to be temporary, it soon became permanent. In March 1987, administrative limits were placed on the power levels at K, L, and P reactors due to lingering uncertainties over the Emergency Cooling System (ECS). Even though these limits were relaxed somewhat later that same year, it seemed increasingly clear that the three reactors would never again be brought to full power.[72] The following year, all three were shut down due to continuing concerns over the ECS, as well as the possibility of a "loss of pumping accident" (LOPA) or a "loss of coolant accident" (LOCA). K Reactor was the first to go, in April 1988, followed in rapid succession by L in June and P in August.[73] The ripple effect of these shutdowns passed through other areas of Savannah River as well. The production of fuel tubes ceased in Building 321-M that same year, as did production in Building 313-M.[74]

By the time Westinghouse Savannah River Company assumed the facility from Du Pont in April 1989, all of the reactors were shut down, and the U.S. had ceased the pro-

Reactor Shut Down









"When we started using these reactors down here, the commercial nuclear business hadn't been invented yet. We had five reactors going—and commercial power reactors were just a gleam in the scientist's eye. So everything we did was pioneering—there was no real road map for us."

- Gerry Merz

Source: "Reacting to Change," *The Augusta Chronicle*, November 6, 2000.



duction of weapons-grade fissionable material altogether. The Site was officially included on the National Priority List and became regulated by the Environmental Protection Agency. In the same year, the Department of Energy formally announced that its primary mission had changed from weapons production to a comprehensive program of environmental compliance and cleanup. In a signal that it was making a break with the past, the facility's name was changed from the Savannah River Plant to the Savannah River Site.[75]



At the close of the decade all five of Savannah River's reactors were shut down. P Reactor had earned the designation of "World's Safest Production Reactor" with its impeccable safety record spanning almost three decades. (Opposite) Aerial views of the five reactor areas taken between 1989 and 1991. Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 182.

(Opposite) Reactor Area Aerials:

1. Reactor Aerial, 1991. Courtesy of SRS Archives, negative 92-1029.

2. Reactor Aerial, 1991. Courtesy of SRS Archives, negative E GG 7091-32.

3. Reactor Aerial, 1991. Courtesy of SRS Archives, negative 7090-47.

4. Reactor Aerial, 1989. Courtesy of SRS Archives, negative 89-2083-16.

5. Reactor Aerial, 1989. Courtesy of SRS Archives, negative 89-2074-7.

THE END OF THE COLD WAR, 1985–1991

The controversy over "Star Wars," not to mention conflicts in Afghanistan and Nicaragua, kept the Cold War fairly warm in the early 1980s. There was also a confrontation over missile deployment in Europe. It was in this context that the L Reactor Restart Program was initiated and completed. By the mid-1980s, however, Soviet society was beginning what would turn out to be a permanent thaw. Yuri Andropov, Brezhnev's successor, died in 1984 after only a couple of years in power, and was eventually succeeded by Mikhail Gorbachev in 1985. Within a year, Gorbachev became the first Soviet leader to openly admit the weakness of his country's planned economy. More remarkably, he was the first Soviet leader to admit that elements of the old Communist doctrine were wrong or, at the best, outdated.[76] By the late 1980s, Gorbachev was well into the programs now associated with his name: *glasnost* (openness) and *perestroika* (economic and political restructuring of the old Soviet system).

The nuclear accident at Chernobyl played a role in this development. After first denying the accident, Soviet authorities soon made a complete turn around, with relatively open disclosure of the problem and solicitations for foreign assistance. The relatively new approach to Chernobyl paved the way for new approaches to other problems. In December 1987, the U.S. and Soviet authorities signed an agreement to eliminate all land-based intermediate-range nuclear missiles from Europe.[77] More was to follow in almost dizzying succession. In the fall of 1989, the Berlin Wall, symbol of the Cold War in Europe, was dismantled, permitting a rapid reunification of Germany. Communist regimes collapsed throughout Eastern Europe. Within two years, in 1991, the Soviet Union itself would collapse, leaving the former giant split into its various constituent republics. Gorbachev, now jobless, was forced to bow out to Boris Yeltsin, the president of Russia.

In the decade that followed, there would be additional problems with Russia as its economy continued downward, but there would no longer be the threat of an ideologically fueled nuclear war between the two great superpowers of the Second World War. Now it was the time to take stock of the vast nuclear arsenals in both countries, and initiate a general cleanup of forty years of nuclear production. Savannah River Site, under the auspices of the Westinghouse Savannah River Company, was already poised to head in that direction.

20 Savannah River Site at Fifty: Stewardship and Legacy

Savannah River reached a turning point between 1987 and 1989. Within this three-year period, Du Pont announced its withdrawal from the plant, the last of the Savannah River reactors were shut down, and a new contractor, Westinghouse Electric, was selected to operate the plant. The next decade would begin on untried ground as Westinghouse began to establish an identity on site and in the larger community. The ending of the Cold War mandated changes in old missions and new directions for the forty-year-old production site with the primary emphasis on environmental management rather than production. The Department of Energy and Westinghouse Savannah River Company, unfamiliar partners, would be joined in pursuit of these new directions that stemmed from the legacy of the past missions and would begin, in concert, to define the site's livelihood for the future.



Glass melter crew and equipment at TNX, 1991. Courtesy of SRS Archives, negative 91-1602-3.

By the close of the century, SRS's mission would be defined as the safe and secure stewardship of the nation's nuclear weapons stockpile, nuclear materials, and the environment. Expanded, this means that SRS will meet the needs of the enduring U.S. nuclear weapons stockpile; will store, treat, and dispose of excess nuclear materials safely and securely; and finally will treat and dispose of legacy wastes from the Cold War and clean up environmental contamination.[1] The site mission of 2000, compelled by the social, political, and economic context in which it was formed, is vastly different from the production mission that characterized the site's first four decades. In 2000, waste management, environmental cleanup, nuclear weapon stabilization, nonproliferation, and the development and application of related technologies via technology transfer have joined production as pathways to the Site's future.

WESTINGHOUSE SAVANNAH RIVER COMPANY BECOMES PRIME CONTRACTOR

Previously, Savannah River had been operated for a one-dollar profit and the reimbursement of allowable costs over the course of several contract extensions by Du Pont. This changed dramatically at contract change. The new contractor would operate the plant

for profit, with annual profits expected to be somewhere between $25 and $40 million. The two corporations that placed competitive bids for running Savannah River were Westinghouse Electric and Martin Marietta. Westinghouse was joined by Bechtel National, Inc., while Martin Marietta teamed up with EG & G, Stearns Catalytic Division, and United Engineers and Construction.[2] On September 8, 1988, the Department of Energy awarded the contract to Westinghouse Savannah River Company, a subsidiary of Westinghouse Electric created for the purpose of running the plant.[3]

Both Westinghouse and Bechtel had a history of nuclear work with DOE. Westinghouse's nuclear roots are over a half-century deep. Westinghouse Electric Corporation entered the nuclear field in 1948, when the firm signed a contract to construct a thermal submarine reactor propulsion plant based on an Argonne design. Between 1948 and 1989, the firm became a major leader in the field, constructing over 170 commercial reactors, in addition to their government contracts under which they operated other sites within the DOE complex. Westinghouse assumed authority for operating Hanford in partnership with Kaiser in 1987 and DOE's Fernald Feed Materials Production Center in Ohio in 1985. Westinghouse's primacy at Hanford was more the result of a consolidation than a transition—the firm was already on site at Richland as one of eight DOE contractors. When six of the eight contractors left Richland in 1987, Westinghouse became operating and management contractor and Kaiser became prime engineering contractor.[4]

With their nuclear experience and as a presence already known to DOE, Westinghouse in 1989 could be likened to the Du Pont of 1950 in its qualifications to run Savannah River. It had demonstrated success with the Department of Energy and maturity within the nuclear field. Bechtel was also a veteran firm with extensive experience in nuclear power. Under the Westinghouse–Bechtel agreement, Bechtel's role was to act as prime construction and engineering subcontractor. At contract signing, Westinghouse Savannah River Company became the operators of South Carolina's largest manufacturing site and the state's largest industrial employer. Fortuitously, the question of contractor liability for the new contractor was settled even before the contract was awarded. It became clear that a renewed version of the Price–Anderson Act would pass Congress, guaranteeing liability protection for the new Savannah River contractor–operator.[5]



Barbara Kish and Julie McLeod Kirby with the SRS Sign Shop show signs with new name and logo, 1991. Courtesy of SRS Archives, negative 91-1448-4.

When Westinghouse officially took over the plant on April 1, 1989, it moved quickly to establish a new identity for the production plant by changing the name from "Savannah River Plant" to "Savannah River Site." While the name change reflected the presence of several "plants" within the site, it also suggested that the era of production, if not over, would have to make way for other missions—especially the cleanup effort that was required after almost four decades of nuclear materials production. Around 36 metric tons, or 40 percent of the plutonium in U.S. stockpiles, were made at Savannah River between 1953 and 1988, and the waste materials generated by this production were still on hand.[6] Although the Defense Waste Processing Facility was nearing completion, there were still

Savannah River and the Community

The Savannah River Operations Office encouraged community interaction from its inception. As noted in earlier chapters, the United Way, begun locally by Senator Strom Thurmond and known initially as the Community Chest, has been a major focus from 1952 onward for the site. Savannah River's contributions to the community-based organization since 1952 total $32,865,723, and in 2000, Savannah River represented about 40 percent of the donations to the regional campaign.



Students with the AEC Summer Employment Program pose with SROO Manager Nat Stetson, 1974. Courtesy of SRS Archives, negative 18219-1.

Education and educational outreach has been a priority for DOE, Du Pont, and Westinghouse and its contract partners. Under Du Pont, field trips to the plant by local secondary school students took place on the birthday of Thomas Edison to encourage the teaching of science in high schools. Other early outreach programs included the Savannah River Laboratory's agreement to help Clemson College initiate a program in nuclear engineering. In the late 1950s, professors from the college spent time in training at the Laboratory; later, graduate students worked at the Laboratory as part of their course requirements. Similar arrangements with other schools were established to allow graduate and later undergraduate students to work in plant operations. The first student to complete a cooperative program at the plant was Lynwood Croom, a University of Florida electrical engineering student who completed the work–study portion of the program in 1958. At that time, 11 students in various physics and engineering programs were involved in work study programs at the plant. In addition to the University of Florida, the students came from Georgia Tech, Auburn, and Georgia State.

When peaceful uses for atomic energy received greater emphasis under Glenn Seaborg's direction of the Atomic Energy Commission, an expanded educational role for Savannah River was begun. The program initially targeted the University of South Carolina, Clemson, the University of Georgia, Emory University, and Georgia Tech. Professors were able to work in the Laboratory, graduate students were presented scholarships from the Atomic Energy Commission and some also worked in the Laboratory. Du Pont personnel in the Laboratory contributed to and conducted lecture programs and seminars at local institutions of higher learning. In the summer of 1967, more than two dozen graduate and 100 undergraduate students participated in summer work programs at the Plant and Laboratory. Most were from South Carolina and Georgia, but others came from as far away as New York, Wisconsin, Michigan, and Texas. An effort to broaden still further the cooperative programs began in 1970, when specific invitations to universities with predominantly African-American enrollment were extended. Colleges joining the program at that time included the Tuskegee Institute of Alabama, the Tuskegee and North Carolina Agriculture and Technical State University, the South Carolina State College at Orangeburg, and Voorhees College.

Beginning in the 1970s, outreach and cooperative programs shifted to include greater focus on environmental studies. The Savannah River Ecology Laboratory was an important component of environmental research cooperative programs, and when Savannah River became the nation's first National Environmental Research Park, selected areas were designated for research and efforts taken, to encourage local and visiting environmental scientists to use these areas to conduct research aimed at developing a better understanding of ecological principles. SREL continues this tradition today, as does Savannah River Forest Station through its Savannah River Field Station and other programs that offer educational advancement in ecological and environmental studies. Savannah River Archaeological Research Program is also dedicated to public outreach, specifically in the area's cultural history.

Education became a focus offsite under Du Pont, and this program was reinforced by Westinghouse's commitment to become a corporate partner with its community. The Ruth Patrick Science Education Center (RPSEC) at the University of South Carolina-Aiken was conceived over a dinner attended by the USC–Aiken chancellor Dr. Robert E. Alexander and Du Pont staff members. A partnership between the university and Du Pont was brokered to further science and math education in the CSRA. Du Pont contributed $250,000 towards the center that includes the Du Pont Planetarium. The center offers science courses and workshops that teach about the environment, chemistry, and nuclear science for teachers. It is also the home base for the Traveling Science Demonstration Program that allows materials to be checked out for use in area schools. Westinghouse was on hand to help with the costs of



Groundbreaking for addition to Ruth Patrick Science Education Center at USC–Aiken, 1997. Dr. Patrick addressing Secretary of Energy, Federico Peña; current WSRC Manager, Joe Buggy; WSRC President, Ambrose Schwallie; and others. Courtesy of SRS Archives, negative 97-1558-3.

enlarging the center with a donation of $250,000, and DOE provided $1.4 million to finance the addition that was named Westinghouse Hall. Dr. Jeffrey M. Priest, director of the RPSEC, noted that tens of thousands of students benefit each year by visiting Westinghouse Hall, or by having access to the center's scientists, or from the loans of scientific materials that allow science teachers to improve scientific education in their home schools.

In addition to its support of the RPSEC, Westinghouse has provided in excess of $2 million to scholarships, student internships and research, specific department support, and the arts and cultural programs to USC-Aiken. Funding in the neighborhood of $1.5 million was also provided to the school for scientific and environmental research. Aiken Technical College has benefited from Westinghouse's commitment to its community in the areas of technical training, grants toward construction of the Dale Phelon Information Technology Center, and in financially supporting academic and continuing education programs and student scholarships.



Student Tour, SRTC, 1992, in Robotics Laboratory, 1992. Courtesy of SRS Archives, negative 92-1711-20.

At the elementary and high school level, the Site is responsible for a plethora of educational programs in Aiken, Allendale, Barnwell, and Bamberg counties in South Carolina and Richmond County, Georgia. The CSRA Science and Engineering Fair held annually, grants given for science supplies, the CSRA College Night attended by about 4,000 students, and the DOE Savannah River Regional Science Bowl are all examples of ongoing programs that show Savannah River's commitment to its community.

Source: "First Co-Op Finishes Stint Here, Heads Back for Final Classroom Work," *Savannah River Plant News*, September 26, 1958. "Education Research Program Planned for S.C., Georgia," *Savannah River Plant News*, April 19, 1963. 108 "Undergrad in Summer Work," *Savannah River Plant News*, June 30, 1967. "Negro Colleges Add to SRP Co-Op Program," *Savannah River Plant News*, June 12, 1970. Loren Schneider, "Contributions - The Positive Impact on the Community," *Aiken Standard*, November 27, 2000.

problems associated with the various processes that would have to be resolved. In meeting this challenge and others, Westinghouse also agreed to conform to standards and rules set by DOE. At a basic level, this meant adhering to the general standards preferred by the Department, specifically those established by the International Organization for Standardization, or ISO.[7] The company made it clear that it would run the facility in accordance with DOE's preferences and in a cooperative fashion. In addition, Westinghouse promised to support and pursue areas of common interests with local universities: Clemson University, Medical University of South Carolina, and the University of South Carolina at Columbia and at Aiken. Technology transfer, a distinguished scientist program, graduate courses in disciplines linked to waste, health, and environmental issues were all targeted. They further pledged to use minority businesses, continue work on environmental problems, and to "continue our tradition of active and supportive involvement with local communities, universities and organizations to maintain and enhance the role of both the Savannah River Plant and Westinghouse as a 'good neighbor.'"[8]



Ambrose Schwallie, WSRC President, 1991–1999. Courtesy of the SRS Archives.

"I was most impressed at the dedication to safety and safety culture. I was also impressed with the quality and caliber of the people at the site. The technical excellence out there is tremendous as well as the work ethic of the people at SRS. I also realized what a national asset SRS was and turned out to be. That ground out there served a tremendous role in the history of the country. It's a great site and I've probably never become so emotionally attached to a job or a piece of property in my whole career. "

Source: Sandy NeSmith, "Westinghouse Era," *Aiken Standard,* November 27, 2000.

James S. Moore was named president of the new company and leader of the management and operation of the Site. Prior to this, Moore was vice president and general manager of the parent corporation's Government Operations Business Unit that handled all of Westinghouse's government operations. He served as manager of SRS for a two-year period. Ambrose Schwallie, who started out as executive vice-president at the Site, succeeded Moore in 1991. Schwallie began his career with Westinghouse in 1972, working as an engineering manager within Westinghouse Corporation's Advanced Energy Systems. In 1979, he managed the core reactor design of the Clinch River Breeder Reactor at Oak Ridge. Notably, Schwallie had orchestrated the successful contact proposal that led to the designation of Westinghouse as the new prime contractor in 1988. His tenure as manager at SRS lasted a decade. In 1999, he was designated president and chief operating officer of the government operating unit of Washington Group International, of which WSRC is a wholly owned subsidiary.[9]

At the outset, all of Savannah River Plant's employees were offered employment, and an additional 37 key positions were offered to members of Du Pont's upper management. According to one report, Westinghouse would add twenty-two upper management positions to this while Bechtel National added six. For the first three years of the new contract, there were some difficulties as a largely "Du Pont" work force integrated themselves into Westinghouse's corporate culture.[10] A working relationship between Westinghouse and DOE also had to develop simultaneously. The complexity of these changes was only deepened by the context in which they were to occur. All of these growing pains were reported upon by the media; by the 1990s, Savannah River Operations was a media presence, and its missions and changes in them were open for public input.

The shift in the main mission at Savannah River from nuclear–materials production to site cleanup and remediation was partially a cause of some of the problems. The path from one to the other was not smooth, and for a number of years in the early 1990s, Westinghouse was required to do both simultaneously—and to more exacting safety standards. By 1991, the Savannah River work force had swelled to a peak of 25,800 persons, and the facility had an annual budget of $2.2 billion, twice what it had been two years earlier.[11] And while work progressed on both fronts, criticism of the facility heightened,

especially as Savannah River prepared to restart K Reactor for tritium production. After the Soviet Union dissolved in 1991, the public outcry against the restart program became too great, and DOE decided to eliminate the program. It took a number of years before new missions would be sorted out.

FIRST HURDLE—K REACTOR RESTART

When Westinghouse took over the Savannah River Site, there was the intention of starting at least some of the original five reactors. Even though the reactors had been shut down in 1988 due to various safety concerns, it appears that the Department of Energy wanted the reactors shut down so that restart could be done with a new contractor–operator. Although the Cold War was winding down, DOE was still concerned about the nation's nuclear arsenal. Plutonium, which has a half-life of some 24,000 years, was in no need of replenishment in an era of relaxing tensions. The same, however, could not be said for tritium. An essential ingredient for hydrogen bombs, tritium has a half-life of 12 years. Without renewal, virtually the entire U.S. supply of this gas could decay over a single lifetime. Counter-balanced against this need, however, was growing public and political pressure not to restart any of the original five SRS reactors, no matter how urgent the need for tritium. It was in this context that an attempt was made to restart K Reactor for tritium production in the early 1990s.

Westinghouse completed its first safety review in April 1989 noting that K, L, and P Reactors all had restart potential, although the main focus of study was K Reactor.[12] In 1990, a top official at Bechtel averred that the push to restart the three production reactors was the "Number 1 priority on the site."[13] In May of that year, James Watkins, the Secretary of Energy under President Bush, announced that K Reactor would be returned to service by December, and that P and L would follow in March and September of 1991, respectively.[14] Despite this enlarged focus, work remained concentrated on K, which did not reopen in December. L Reactor was relegated to a back-up source for tritium in 1990, while P Reactor was shut down permanently in February 1991.[15] In the meantime, K Reactor was upgraded to meet more stringent safety regulations, especially those related to loss of pumping accidents.[16]

One of the main reasons for the delay of the K Reactor restart was the demand for a facility to treat the effluent hot water. Just as L Reactor, 10 years earlier, had not been allowed to restart without the addition of L Lake, so K Reactor was not allowed to reopen without a cooling tower, similar to those required for commercial power reactors. It was announced in June 1990 that a cooling tower would be constructed to comply with South Carolina water quality standards pursuant to Consent Order No. 84-4-W with SCDHEC. This order mandated thermal mitigation for all the Savannah River reactors (C, K, and P Reactors) as well as other facilities. Like similar towers, it was designed to take the reactor effluent water at a temperature of 170º F and reduce the temperature to 90º F, as required by South Carolina law.[17] With a projected construction period of two years, the K Reactor Cooling Tower was initially estimated to cost around $79 million.[18] By January 1992, with the tower still under construction and the facility scheduled for completion by the fall of that year, the cost had risen to $90 million. By the time of completion, the K Reactor Cooling Tower was 447 feet high, with a base diameter of 345 feet.[19]

Even though it was to be connected to K Reactor in December 1992, the cooling tower was never actually used, since K Reactor itself never progressed beyond a test run.



By 1992, it was obvious that the K Reactor restart project faced an uphill public relations battle. In late December 1991, a leak in one of the K Reactor heat exchangers released 150 pounds of tritiated water into the Savannah River, a relatively minor contamination that was picked up by sensors on the Savannah River. Despite SRS denials of any imminent danger, public utilities downstream from the Site closed their intake valves until the contaminated water had passed.[20] This accident released a groundswell of political opposition to the reopening of K Reactor itself. Unlike previous protests, this not only included environmental interest groups, but also many local South Carolina and Georgia politicians who previously gave their unanimous support for Federal undertakings at SRS.[21] To help defuse the situation, the Department of Energy announced in February that K Reactor would only act as a reserve, to be tested and then shut down until needed for future tritium production.[22]

K Reactor was raised to criticality on June 8, 1992; however by then it was understood that the reactor would be operated only for a test run.[23] Even though there were plans to restart the reactor in the spring of 1993, international and domestic political events worked to keep the reactor closed.[24]



K Area Cooling Tower under construction (Top). K Area after construction of cooling tower (Above). Note stacks of Georgia Power nuclear facility, Plant Vogtle, to the west across river in Georgia. Courtesy of SRS Archives, negatives 93-1340-17 and 91-2203-20.

Although the nation needed tritium for hydrogen bombs, there was a decrease in the need for bombs, as the Cold War finally came to a close in the early 1990s. In August 1991, Communist hardliners led a push against increasingly reformist leaders in Moscow. Not only did the uprising fail, but it also backfired, leading to the final dissolution of the Soviet Union and the rise of Boris Yeltsin as President of Russia. In the United States, there was soon a "peace dividend" to be awarded at home. President Bush announced unilateral nuclear cuts in September 1991, and it was clear that DOE contractors were increasingly interested in facilitating the "nuclear clean-up" work.[25] In January 1992, during the controversy over the tritiated water released in the Savannah River, the Department of Energy announced a shift in focus from defense to environmental clean up. Plutonium-production activities at Rocky Flats were halted, and plans to restart K Reactor were reconsidered.[26]

The next year would bring even greater changes. In November 1992, William J. Clinton defeated George Bush's bid for reelection, and the new administration, which took office in January 1993, was not sympathetic to the nuclear status quo. The Clinton administration almost immediately cut funding for atomic reactor research and in other areas.[27] At SRS, the workforce was pared from a high of around 25,800 in 1991, to 22,000 by 1994, with plans to reduce the number of employees systematically in the years to follow.[28]

No one personified these changes more than the new Secretary of Energy, Hazel O'Leary. By the end of 1993, O'Leary was calling into question the veil of secrecy that had previously been the hallmark of the nuclear weapons complex. She called for a revision of the Atomic Energy Act of 1954 to permit a greater openness of information[29] and the declassification of many previously secret DOE documents.[30]

All of these changes spelled the end of the SRS production reactors. In April 1993, the Department of Energy sent a letter to Westinghouse to shut down L Reactor without possibility for restart. K Reactor was to be placed on "cold stand-by," with no planned provision for restart.[31] That same year, the R, P, L, and C Reactors were declared "excess" by DOE, with no further production mission.[32] In November 1993, Secretary of Energy O'Leary announced that K Reactor would not be restarted.[33]

CONTRACT RENEWAL

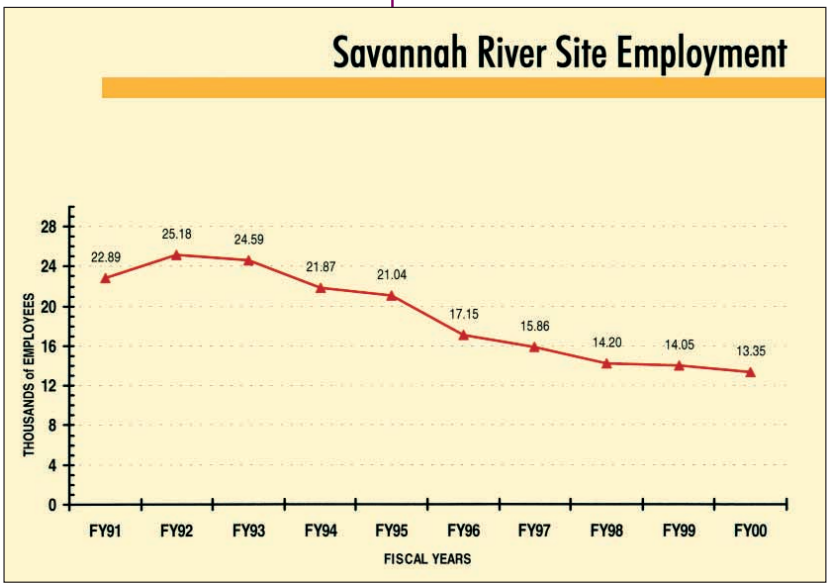
Difficulties during the transitional first years of the contract, intense public pressure on SRS not to resume reactor operations, and scrutiny from Washington compelled DOE to announce that it would seek an open selection process for the new Savannah River contract, with bids submitted in 1995 and the contract to be awarded the following year. Only one bid was made, and that bid was submitted by the existing contractor, Westinghouse Savannah River Company. The new Westinghouse proposal, based on experience at the Site, differed from the previous bid. An enlarged team of subcontractors had been assembled with each bringing specific expertise to help the main contractor meet the demands of what was turning out to be a new set of missions and a developing scope of work.[34] By the mid-1990s, there was less discussion on resuming reactor operations, and this change translated into less media attention for the site. Also stakeholders in the site's operation within the local community were now able to provide input into site operations through public meetings and public comment periods, easing the tension once felt between the site and its community. By 1995, given all these factors, the facility had largely made the transition from the old missions to the new, and it had a set of experienced subcontractors charged with specific responsibilities to carry out the work that was projected.

Print to Digital

In the 1990s, site communications moved from print to digital media. The first local area network at the site was installed in 1982, serving only the main Savannah River Laboratory building. The first site-wide network was installed in 1986 and 1987, geographically one of the largest in the country at the time. At the end of Du Pont's tenure and under Westinghouse, every office was wired to have at least two computer data connections. The extensive site computer network, called SRSnet, now provides the means of direct, daily messaging to supervisors and all employees who have computers in their workspaces, and made offsite employees in Aiken, North Augusta, and Augusta an integrated part of site communications. Information distribution was further enhanced in 1996, with the implementation of the Savannah River Information Network Environment, or ShRINE, through which all employees have access to telephone directories, newsletters, forms, site manuals, and other information necessary to the workplace.

Although electronic mail and the site's computer network have given employees digital access to much of the information that once was provided by letters, booklets, and memoranda, not all of the earlier modes of communication have been set aside. The plant newspaper, renamed the *SRS News* when Westinghouse became the prime facility contractor in 1989, continues to be published on a monthly basis.

For the contract that began in 1996, Westinghouse Savannah River Company, in addition to Bechtel, brought on board Babcock & Wilcox Company (later known as BWX Technologies) and British Nuclear Fuels Ltd.[35] The division of labor is roughly as follows: Westinghouse operates the nuclear facilities, the Savannah River Technology Center (the Savannah River Laboratory), environment, safety, health, quality assurance, and all formerly administrative functions. Bechtel Savannah River, Inc., is in charge of the environmental restoration project management, engineering, and construction work. Babcock & Wilcox Savannah River Company was introduced to handle facility decontamination and decommissioning, and British Nuclear Fuels was brought in to run the solid waste program. All of these firms operate under the aegis of the Westinghouse Savannah River Company, identified as the main contractor.[36]



Savannah River Site Employment, 1991–2000. Source: Doug Carnahan and Rich Keenan, *Savannah River Site Overview,* Westinghouse Savannah River Company LLC. Prepared for WGI, Denver, August 9, 2000.

Underneath the umbrella of Westinghouse, but independent of it, is the next tier of contractors. These consisted of Wackenhut, in charge of security; the Savannah River Ecology Laboratory, affiliated with the University of Georgia; and the Savannah River Natural Resource Management and Research Institute, which was effectively an arm of the U.S. Forest Service. By 2000, Westinghouse and its various contract partners had a total workforce of 12,300 people. Wackenhut has another 800, followed by 150 for the Savannah River Ecology Laboratory and another 80 with the Forest Service. With a supervisory force of around 500, the local office of the Department of Energy, DOE-Savannah River, rounds out the team. The complete work force at SRS now stands at 13,830.[37]

FUTURE PATHS

The reactor closings and negative publicity led to positive action within the nuclear community in the early 1990s, especially in the Savannah River Site area. Long protected by secrecy and unfamiliar with the demands of public relations work, the local nuclear community saw negative reaction to their livelihood progress as fear of low-level radiation appeared to become a national concern. To present a more balanced view of nuclear energy, a local group of concerned scientists established the Citizens for Nuclear Technology Awareness (CNTA) in 1991. This group's activities expanded over time, as the threat to nuclear programs increased across the board.[38] As part of the CNTA program in support of nuclear energy, Edward Teller was invited to the area in 1992, and his comments were recorded. Teller noted that France produced 75 percent of its electricity in power reactors, while the United States was still mired in the 20 percent range—virtually unchanged since Three Mile Island. Teller expressed his fear that in rejecting nuclear energy, the U.S. might also be turning its back on technology in general.[39] While Teller's comment con-

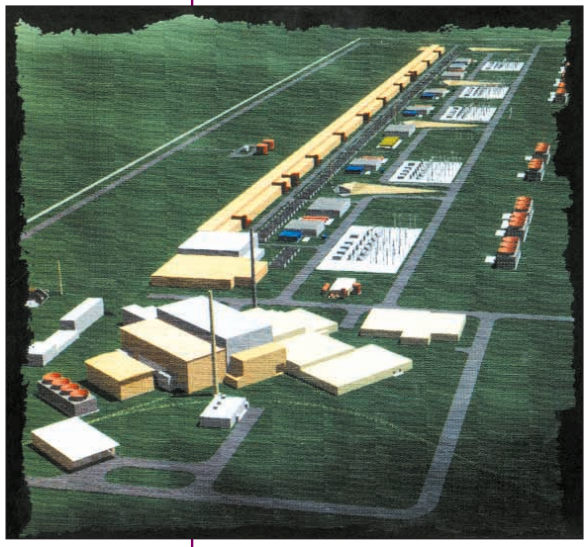


Citizens for Nuclear Technology Awareness Pioneers with Edward Teller at inaugural Teller Lecture, 1992. Dr. Teller is seated in center. Courtesy of CNTA.

cerning technology may have been overstated, there was no denying that the nuclear industry was in decline.

Despite such publicity, there was still the question of tritium production, and for many that solution was a new reactor. Tritium had not been produced for the U.S. nuclear weapons stockpile since 1988. Stockpile requirements were met through the recovery of tritium from dismantled nuclear weapons and from routine tritium reservoir exchanges from the existing stockpile. Throughout the 1980s and into the 1990s, there was much discussion over the need and location for a "new production reactor" or NPR. Built to modern specifications and with up-to-date safety features, it would be easier to commission than an older reactor that required upgrades. With K Reactor out of the picture, the NPR remained a theoretical possibility. By the late 1980s, a heavy-water NPR had been planned for Savannah River Site, and at that time, it was assumed that it would take 10 years to build.[40] In November 1991, it was announced that any future planning work on the NPR would be delayed for two years as a result of the end of the Cold War.[41] The following year, NPR plans were again postponed until at least 1995.[42] In May 1994, there was discussion of a dual reactor that could burn excess plutonium for electricity and also produce tritium for national security, a concept that was strongly supported by the CNTA.[43] In the end, the NPR never left the drawing board, in large measure because the very concept of a reactor had negative connotations to the American public.

Artist's Conception of Accelerator. Courtesy of SRS Archives.



In 1995, the Secretary of Energy focused on two options: the purchase of an existing commercial reactor or the purchase of irradiation services from a commercial light water reactor (CLWR) or the design and construction of an accelerator system. The possibility of producing tritium without a reactor was discussed as early as 1989 when a scientific panel proposed construction of a "linear accelerator," rather than an NPR, for the production of tritium.[44] Conceived as a tube, about a mile long, the linear accelerator remained under considera-

tion.[45] The accelerator had a number of advantages over a reactor. It would not require fissile materials, there would be no fission process and no spent fuel, and there would be a safety bonus as well, since there would be no possibility of a criticality accident.[46] SRS was the proposed site, should one be built.

In December 1998, DOE ended the debate by choosing to use an existing reactor, the commercial light water reactor option, for future tritium production. The accelerator is now considered a backup option; as a consequence only design and development work will be completed.[47] Instead, a program has been initiated to produce tritium using the Tennessee Valley Authority's Watts Bar and Sequoyah reactors. Tritium Producing Burnable Absorber Rods (TPBARs), supplied by DOE, are to be irradiated in the TVA reactors, after which the irradiated material would be shipped to SRS for extraction and processing. The Tritium Extraction Facility (TEF), expected to cost $400 million and scheduled for construction in H Area, will allow SRS to extract tritium-producing gases from the TPBARs. The gases will then be delivered to the Reservoir Loading Facility where they will be purified and readied for use to fulfill stockpile requirements.[48] The TEF, when completed, will consist of three structures: the Remote Handling Building (RHB), a Tritium Processing Building, and an administration building.



Shovels filled with red clay at groundbreaking of New Tritium Extraction Facility in July 2000. From left to right, Steve Sohinki (DOE-HQ Director, Office of Tritium Production; Dave Beck (Assistant Deputy Administrator for Military Application and Stockpile Operations; Carolyn Huntoon, Assistant Secretary for Environmental Management; Greg Rudy, DOE-SR Manager; Secretary of Energy Bill Richardson; John Gordon, Administrator, National Nuclear Security Administration; Madelyn Creedon, Deputy Administrator for Defense Programs; Joe Buggy, WSRC President; and Rich Viviano, SR Acting Deputy AM for National Security. Courtesy of SRS Archives, negative 00-1269-9.

The RHB will be located inside the existing tritium area at SRS just west of the Reservoir Loading Facility. The RHB will include a truck receiving area, cask decontamination area, TPBAR and waste preparation area, furnaces, hot maintenance areas, and associated extraction pumps and tanks. It will also include an overhead crane and remote–handling equipment. The purpose of the Tritium Processing Building is to provide preliminary purification of the extracted gases prior to transfer to the Reservoir Loading Facility.[49]

As noted, tritium stockpile requirements were met through the recovery of tritium from dismantled nuclear weapons and from tritium reservoir exchanges from the existing stockpile since 1988. Recycling the remaining tritium from existing weapons reservoirs allows reuse of the tritium, and SRS has the sole facility in the nation for recycling tritium from nuclear weapons reservoirs returned from service. Each reservoir, a stainless steel canister, contains three gases: the remaining tritium, non-radioactive deuterium, and helium-3. The latter is produced when tritium decays and it is this "poison" gas that needs to be separated from the useful isotopes, tritium and deuterium.[50]

The Replacement Treatment Facility, a one-acre underground, totally confined building, was constructed in H Area for this purpose. The new facility became operational in 1994. Within it, tritium gases are unloaded from old reservoirs, useful hydrogen isotopes (tritium and deuterium) are separated out and purified, and then mixed to the correct specifications for loading into reservoirs. A 400-watt laser is used to remove the gases from the reservoirs by cutting a hole in it, allowing the gas to expand into a receiving tank. Once separated, the tritium/deuterium gas is placed in metal hydride beds, metal containers with metal particles that absorb hydrogen isotopes when the particles are cold but release gases when heated. The transferred gas safely awaits enrichment in these beds. "Enrichment" used in this context actually means "separated" so they can be mixed in exact proportions. This is executed using the Thermal Cycling Absorption Process (TCAP) in which the gas is repeatedly placed into a cool TCAP column, where it is heated. The heavier isotope, tritium, gravitates to one end of the column, while the lighter deuterium remains at the other end; each is then drawn off and separately stored. Mixing of the gases occurs next, and several types of reservoirs result; mass spectrometry is used to test the exactness of the blend. A mechanical compressor system compels the gas mixture into a reservoir and the fill stem of the reservoir is then pinched, resistance-welded, and tested.[51]



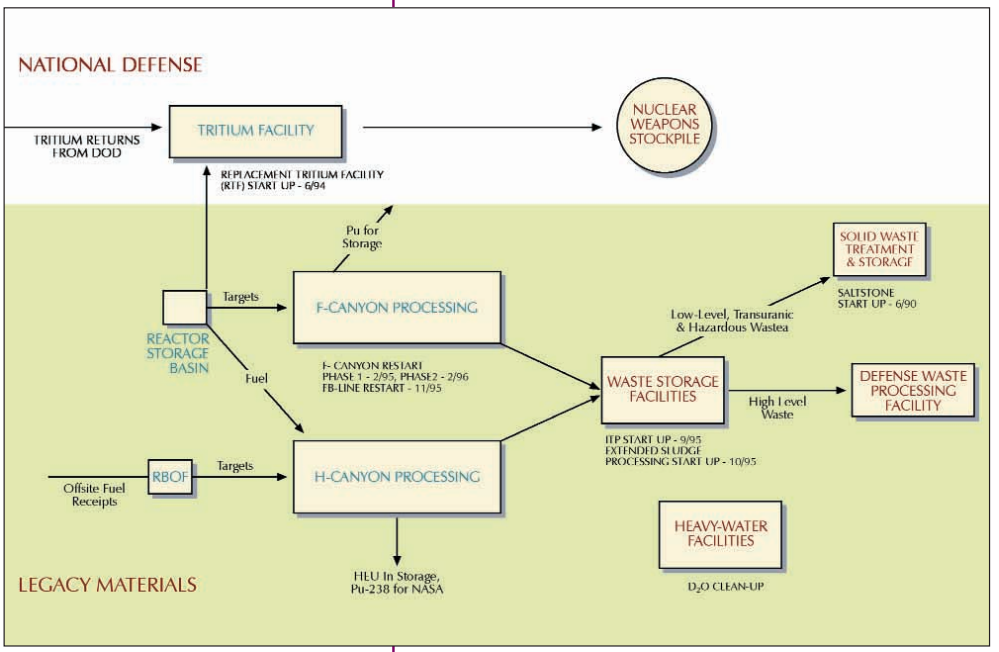
Replacement Tritium Facility Group, 1993. (Front Row from Left to Right) Glenn Gilbody, Maggie Hitt, Gary Thurnock, and Don Kinnsch. (Back Row from Left to Right) Tom Crouse, Brian Geyer, Joe Weatherly, and Roger Yancey. Courtesy of SRS Archives, negative 93-1189-1.

The new facility provides a much safer work environment due to the facility design. Process rooms are operated as "clean" radiologically controlled areas; all tritium work is completed in gloveboxes filled with nitrogen gas (nitrogen atmosphere reduces the possibility of the production of tritiated water); stripper systems that remove residual tritium from gloveboxes are in place; metal hydride beds allow the safe storage of the isotopes in a solid form; a laser system is used for unloading reservoirs replacing a mechanical shear-

ing system that was formerly used; and a dry pump system now operates in the building. The Replacement Tritium Facility is now one of four main buildings that house tritium facilities at Savannah River Site.[52]

NUCLEAR MATERIALS STEWARDSHIP

Spent nuclear fuels (SNF) is a generic term for fuel and isotope production targets that are taken from nuclear reactors after irradiation.[53] The sources of SNF are commercial power reactors, defense material production reactors, domestic and foreign research reactors, and naval reactors. SRS is one of two DOE sites that receive SNF and it does so in accordance with the May 1995 DOE Programmatic Spent Nuclear Fuel Environmental Impact Statement Record of Decision. Between 1964 and 1992, the Receiving Basin for Offsite Fuels (RBOF) was used as a holding facility for SNF. Under the Atoms for Peace Program, the U.S. provided nuclear technology to foreign countries to pursue peaceful applications in the fields of medicine, agriculture, or industry. The loaned technology was typically in the form of research reactor technology and the highly enriched uranium fuel needed to run the reactor. As the uranium used in these experimental venues could also be used to produce nuclear weapons, the U.S. stipulated that the used fuel elements or "spent fuels" would be returned to the U.S. for processing after use by foreign researchers. This was done in accordance with first bilateral agreements then under the Off-Site Fuels Policy in effect between 1964 and 1988.[54]



Savannah River Site Production Flow, 1995. Courtesy of WSRC.

When the latter agreement expired, the receipt of highly enriched uranium fuels was curtailed, and low-enriched uranium fuels were no longer received after 1992. This policy changed in 1996 at the behest of the U.S. Department of State and the International Atomic Energy Agency. Shipments of fuel from foreign research reactors (one shipment containing 4–8 casks) will arrive every four months until the end of the program in 2009. Fuels from domestic reactors (two shipments per month) will be received until 2035.

Built for this purpose, the RBOF is slightly larger than a baseball infield, encompassing an unloading basin, two storage basins, a repackaging basin, a disassembly basin, and an inspection basin. The walls are specially treated and the basin floor is covered with stainless steel plate; the total volume of all the basins and their linking transfer canals is 500,000 gallons of water. The fuels are shipped to the facility via railroad in heavily

shielded casks and are lifted into the unloading basin, which is 29 feet deep. Notably, spent fuels from SRS production reactors are about 14 feet long and 3–4 inches in diameter, while those from offsite are individually shorter but are packaged in containers that are 11 and 14 feet in length. The SNF created at SRS from its production mission is stored in L and K Reactors' disassembly basins. Also, as space is limited in the RBOF, L Reactor basin and water chemistry was modified to enable it to receive and provide short-term storage of research reactor fuel assemblies. It received the first shipment in January 1997.

The inventory of SNF at SRS includes about 1,400 production reactor assemblies; 3,400 assemblies of aluminum-clad research-reactor spent nuclear fuel; and 2,000 assemblies of zirconium/stainless-steel-clad research reactor spent nuclear fuel. Planned future disposition of these assemblies varies for each group. The SRS production reactor SNF will be processed onsite at the canyons through 2003 as directed by the 1997–1998 INMAN Environmental Impact Statement Record of Decision. The assemblies that are clad in aluminum will be processed through a new facility called the Treatment and Storage Facility and readied for disposal in a geologic repository. Finally, the third group of assemblies, uranium clad in zirconium or stainless steel, is scheduled to be sent to the Idaho National Engineering and Environmental Laboratory about 2010, where process modifications will be made to treat these assemblies. Aluminum-clad fuel stored at Idaho will be shipped to SRS for processing.



Spent Fuel Shipping Cask, 1981. Courtesy of SRS Archives, negative DPSTF 1-15039.

Despite its low volume within the SNF inventory, aluminum-based research reactor SNF offers particular technical problems for disposal that have to do with its diverse forms after manufacture, its corrosion rate, and level of enrichment. SRS researchers, after much analysis, have designated a demonstrated technology, the melt–dilute process, for a pilot study. This process, in which furnaces melt the SNF and dilute the uranium enrichment, is also the preferred technology for most of the research reactor SNF. L Reactor has been targeted for possible use after modifications for the Treatment and Storage Facility that would house the melt–dilute process.[55] The impetus for this work derives from a 1996 DOE commitment to implement a program for "identifying, developing and implementing a technology alternative to conventional chemical reprocessing for the stabilization and final disposition of aluminum-based research reactor spent nuclear fuel. The mission of the Alternate Technology Program is to develop a treatment and interim dry storage of the spent fuel in a manner that will be "road-ready" for disposal in DOE's planned geologic repository."[56]

Even though neither tritium nor plutonium has been produced since 1988, plutonium-processing facilities at SRS have been newly constructed and older facilities upgraded and

modified during the 1980s and 1990s to handle existing and future plutonium processing needs. SRS has the only production-scale plutonium glovebox facilities within the complex that have been routinely operated in the 1990s. As a consequence it is the only site with accredited plutonium operators and has a radiological-worker-training program in place.[57]



Rosetta Wiley poses in front of M Area safety mural "BEE SAFE." Courtesy of SRS Archives.

The New Special Recovery Facility (NSR) was constructed to reprocess plutonium from the Hanford N Reactor and scrap for weapons-grade material. Located on Building 221-F, near the B Line, the facility was constructed at a cost of around $86 million. In 1992, when the facility was almost complete, it was suggested that it might not be opened, if only because there was simply no need for the plutonium that it would provide. To date, the NSR has not been used.[58]

The HB Line (Phase I and Phase II) with its glovebox layouts on the roof of H Canyon discussed in the previous chapter, was built to produce plutonium-238 for the U.S. space programs. No new plutonium-238 has been produced since the closing of the last SRS reactors; however all of the plutonium-238 processed for the Space Program and for the nation's defense was handled at SRS.[59] Shut down in 1987, the HB-Line, was restarted in the 1990s. The HB Line is now used to stabilize solutions stored in H Canyon. To date, plutonium-238 and plutonium-242 stabilization campaigns have been undertaken, and the Phase II process line within the HB Line is to be used to stabilize plutonium-239 and neptunium-237.[60] In addition, major modifications were made to the FB-Line that is located in F Area on the top of F Canyon. When built, this process line converted plutonium-239 nitrate solution produced in F Canyon to a solid form, called a button. In 1997, this process line was used for a new plutonium packaging process called "bagless transfer." In this process, stabilized plutonium is put in strong, welded stainless steel cans rather than plastic; this technology, which allows for safer plutonium storage, was developed at SRS and it is the first use of this packaging within the DOE complex.[61] A summary of plutonium-processing history at SRS notes that 40 percent of the total plutonium-239 in the DOE complex was processed at SRS, and that figure rose to 90 percent after 1970.[62]

In accordance with a directive that resulted from the 1996 Moscow Summit between President Clinton and President Boris Yeltsin, excess weapons plutonium was slotted for conversion into materials that could not be reused in nuclear weapons. In 1997, a Record of Decision was made in which DOE agreed to pursue this disposition of surplus plutonium by converting it to a mixed-oxide fuel (MOX) and then using that fuel to generate electricity in commercial reactors.[63] This conversion entails the construction of three facilities. A pit-disassembly and conversion facility disassembles the cores of nuclear weapons and converts the plutonium inside to a powdered oxide. The MOX facility then takes the powdered oxide for use in the manufacture of nuclear fuel. The third component in the process is the immobilization facility that immobilizes the remaining plutonium oxide into ceramic material and readies it for long-term storage. At this writing, SRS is the preferred site for all three facilities.

Duke Cogema Stone & Webster was selected to design and construct the Mixed Oxide Fuel Fabrication Facility. This is a consortium of firms comprised of Duke Engineering and Services (DE & S); Cogema, a U.S. subsidiary of the French firm Cogema, which specializes in the design, construction, and operation of mixed-oxide fuel fabrication facil-

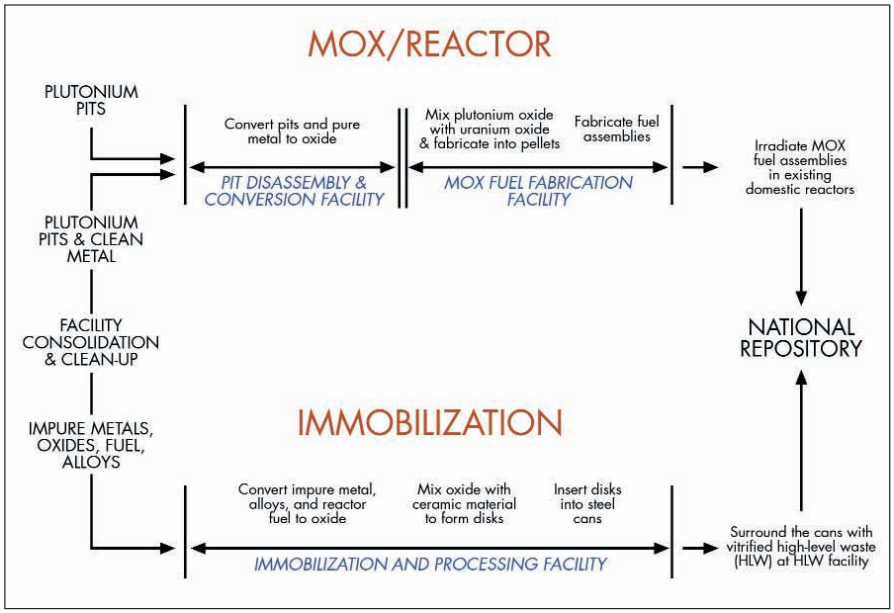


Diagram showing MOX process. Courtesy of WSRC.

ities; and Stone and Webster, specializing in plutonium design work. The MOX fuel provided by this team will then be available to Duke Power for use in its commercial reactors.[64]

This program has led to an adaptive re-use of K Reactor.[65] In the year 2000, K Reactor was established as the "K-Area Materials Storage Facility" (KAMS), to be used in the first phase of the MOX process. The many upgrades that SRS was required to make on 105-K for the restart program—from structural upgrades to security changes—made the selection of 105-K for the KAMS project an easy one. A Record of Decision made by Secretary of Energy Bill Richardson in January 2000 on the basis of the Surplus Plutonium Disposition Environmental Impact Statement designated SRS as a major player within the excess plutonium disposition program, of which KAMS is the initial step. In 2000, over 1,000 shipping containers of plutonium were received at K Reactor for storage from other sites within the DOE complex. Double that amount will be stored in K Reactor by the completion of KAMS Phase II. The plutonium, placed in welded canisters, and then nested in containers, will remain in its shipping containers until the processes for disposition outlined above are in operation.

ENVIRONMENTAL STEWARDSHIP

Environmental restoration, waste management, and facility disposition are key components within the site's environmental stewardship policy developed under DOE's 1989 Environmental Management Plan. While the pre-operational baseline studies are the foundation on which the current environmental programs are overlain, work in the early 1980s really set the site's program in action. The site's placement on the EPA's CERCLA's National Priority List in 1989 was followed a year later with a comprehensive site-restoration program.

ENVIRONMENTAL RESTORATION

Environmental restoration in this context encompasses the assessment and cleanup of inactive waste units and groundwater. This began onsite in 1981 with the identification of groundwater problems emanating from M Area settling basin. The cleanup involved and its ultimate closure under SCDHEC guidelines was chronicled earlier. The term "cleanup" refers to a number of strategies from complete removal of a substance or to its stabilization and containment. Simply put, the goal is to treat the substance so that it cannot impact human health or the environment.[66]

The Site's current restoration program was established in 1990. Under the program, 515 inactive waste and contaminated groundwater units were identified. These units range in size from a few cubic feet of soil to tens of acres, and the types of wastes include solid waste, radioactive waste, hazardous waste, and mixed waste (a mixture of hazardous and radioactive waste). On the basis of the inventory data, SRS, in conjunction with the USEPA and SCDHEC, maintains a priority list of waste sites that need cleanup, and evaluations on the best approaches to their cleanup given the risks they impose to human health and the environment. If, after investigation, a site is found not to pose a significant health or environmental risk, and USEPA, SCDHEC, and the public are in agreement with the finding, then no further action is taken.



In situ soil solidification remedial action began at the old F area seepage basin in 1999, and a media event was held at the site in August to commemorate the milestone. Here, the project manager explains the grouting process to a newspaper reporter. Source: Sandy DeWald (NFN).

Several federal regulations stipulate how waste is managed at SRS. The Resource Conservation and Recovery Act (RCRA) provides a method for tracking and managing hazardous wastes from their point of origin to their disposal and requires corrective action for releases of hazardous waste from active or inactive waste units. The Comprehensive Environmental Response Compensation and Recovery Act (CERCLA) and the Superfund Amendments and Reauthorization Act establish liability, compensation, cleanup, and emergency response for hazardous substances released to the environment. The Federal Facility Compliance Act calls for the creation of schedules for mixed waste treatment that are acceptable to both the state and to the Federal regulatory agencies involved. The National Environmental Policy is also a key regulation, requiring that the site evaluate the potential environmental impact of Federal activities and explore alternatives. The Clean Air Act and the National Pollutant Discharge Elimination System are also applicable.

Underneath these regulations, 33 of SRS's waste sites have been completely remediated, and an additional 39 sites are in progress. Current fieldwork is focused on *in situ* soil stabilization and the placement of low-permeability soil covers over the old F Area Seepage Basin, L Area Oil and Chemical Basin, and F Area Retention Basin. Large-scale groundwater cleanup systems are in place and operating in A, F, H, and TNX areas and in C Area Reactor Seepage Basin, the Mixed Waste Management Facility, and the Nonradioactive Waste Disposal Facility.

SRS has used a number of innovative techniques to accelerate these programs and to perform them with greater efficiency. The groundwater cleanup in A/M Area was expedit-

ed by vacuum extraction technology used since 1995 that removed solvents from the soils above the groundwater, eliminating the possibility of further contamination. BaroBall™, designed by Savannah River Technology researchers, was also used in A/M Area to remove contaminated soil vapor from the subsurface and to eliminate further contamination. The Dynamic Underground Stripping (DUS), a product of Lawrence Livermore National Laboratory that uses steam-injection and soil-vapor/groundwater extraction, was placed into service in A/M Area. The DUS allowed SRS environmental personnel to take Dense Non-Aqueous Phase Liquid contamination from the subsurface, and bring it up to where it could be treated. C Area's Burning/Rubble Pit was the site of three remediation strategies: the placement of a low-permeability soil cover, sparging and soil vapor extraction. This was the first time air-sparging (forcing air into contaminated groundwater to evaporate the solvents) and soil-vapor-extraction equipment were combined at SRS to accelerate the contamination removal process.[67]

The 55-acre Nonradioactive Waste Disposal facility was chosen for a major bioremediation program in 1999:

> Naturally occurring bacteria in the soil are capable of breaking down chlorinated organic solvents if they are stimulated with oxygen and additional nutrients. Engineers therefore installed two horizontal wells to feed air, methane, and other nutrients to stimulate microbial activity to destroy the contaminants. These 1400-foot-long wells have the largest screen zones in the country being used to supply nutrients for a bioremediation cleanup. Computer modeling has shown that remediation will reduce groundwater cleanup time for volatile organics from 15 years to 6 when compared with conventional pump and treat alternatives.[68]

This program and others such as the Monitored Natural Attenuation process that uses the indigenous microbe population in the subsurface to remediate groundwater are indicative of SRS attention to innovations that can accrue cost savings for the site as well as increase efficiency. By the close of 1999, 221 sites out of the 515 identified were either closed, in the course of being cleaned up, or found to need no further action. Since 1996, the SRS Environmental Restoration program has been credited with achieving a $50 million cost savings due to its use of innovative cleanup strategies and a healthy exchange of expertise between the site and others in the DOE complex.

WASTE MANAGEMENT

After decades of production, SRS is responsible for the management of high-level waste, low-level waste, hazardous waste, mixed waste, transuranic waste and sanitary waste that was generated as a result of the manufacture of plutonium, tritium, and other nuclear materials.[69] The types of wastes and their storage have been discussed earlier, as well as their site locations. In 1999, waste management functions were carried out in five areas: E, F, H, S, and Z. E Area which is situated between the two separations areas, is the locus of most of the Site's disposal and storage facilities. Waste generated from site

operations is stored or treated at: the Solid Waste Management Facility (E Area), the Effluent Treatment Facility (H Area), the high-level waste storage tanks assembled into "farms" in F and H -Areas, the Extended Sludge Processing Facility, the Defense Waste Processing Facility in S Area; the Saltstone Facility (Z Area), and the Consolidated Incineration Facility (adjacent to H Area). The Solid Waste Management Facility, the Extended Sludge Processing Facility, the Defense Waste Processing Facility, the Saltstone Facility, and the Consolidated Incineration Facility all became operational in the 1990s, some after extensive planning that occurred in the previous decade. The management of these materials in the 1990s is largely divided between Solid Waste Management and High Level Waste Management.

E Area's Solid Waste Management Facility is the repository for solid low-level wastes such as protective clothing, tools, and equipment that are contaminated. In 1994, concrete vaults were constructed for the permanent disposal of solid low-level waste. The composition of the concrete is specially formulated to discourage cracking. SRS is the first facility in the DOE complex to use such facilities, which represent a significant improvement over previous methodologies. Low-activity waste is separated from intermediate-activity waste and placed in separate vaults. Most wastes that are certified as low-level are stored or disposed of in the E Area vaults.



"0 Days Until Radioactive Operations," DWPF Startup Sign 1996. Courtesy of SRS Archives, negative 96-1120-44.

Prior to this, solid low-level waste was placed in the 195-acre Low-level Radioactive Waste Disposal Facility, referred to earlier as the Burial Grounds. After characterization of the waste types and radioactivity, the waste was sorted and packaged for disposal. Low-activity beta–gamma waste was packaged in steel boxes and placed in engineered trenches approximately 22 feet deep, that featured sloped sides to prevent cave-ins and slightly sloped floors to provide rainwater runoff into sumps at one end of the trench. The higher-activity waste within the low-level waste category was placed in separate trenches or in fiberglass-lined cylindrical holes or concrete trenches to offer better confinement. No new waste has been introduced into the Low-Level Radioactive Waste Disposal Facility. The groundwater in the area surrounding it will be monitored to identify radioactivity that may have migrated from the facility which will be closed under RCRA guidelines.

The Solid Waste Management Facility is also where transuranic waste is stored. Transuranic waste is defined as "radioactive waste contaminated with certain isotopes that have decay rates and activity levels exceeding defined standards. It contains manmade elements that are heavier than uranium, some of which decay slowly, thus requiring thousands of years of isolation."[70] Since the early 1970s, 11,289 unvented transuranic waste drums have been stored in E Area. Of that number, 8,809 were covered by earth and

2,480 were put under weather cover. A 1996 decision to retrieve the buried drums and to vent and purge them was carried out between 1996 and 1999. All of the drums have been repackaged in 55-gallon lined, vented, and unvented drums; casks and boxes are used for bulky equipment. Drums containing waste with higher radioactive levels of transuranic nuclides are further protected within concrete culverts that are overlayed onto concrete pads. Sloping of the pad allows for environmental sampling of the rainwater from the sump prior to the water's discharge. The transuranic waste is stored safely in readiness for eventual shipment to the New Mexico Waste Isolation Pilot Plant (WIPP).[71]

The Consolidated Incineration Facility (CIF) was designed to burn specific hazardous, low-level radioactive, and mixed wastes. Approved for construction in H Area, with an estimated cost of around $90 million, it was engineered to process four million pounds of waste per year.[72] Construction on this facility began in January 1993. The first trial burn and the start of radioactive operations occurred in April 1997.[73] It successfully and safely burned 2,437,000 pounds of radioactive waste in 1999, triple the amount treated in 1997.

The Effluent Treatment Facility (ETF) also in H Area treats the low-level liquid waste that historically was sent to seepage basins. This facility, discussed in the previous chapter, began operation in 1988 and processes about 20 million gallons of wastewater annually. Treated water from the ETF is channeled to a National Pollutant Discharge Elimination permitted outfall which captures all chemical and radioactive contaminants except tritium.

The greatest challenge for the nuclear community today is the treatment of the millions of gallons of high-level radioactive waste generated from hundreds, if not thousands, of reactor cycles and their subsequent purification in the separations process. This high-level waste has been stored in growing numbers of huge metal tanks, both at Hanford and at Savannah River, with the expectation that a process would be identified that would lead to its permanent disposal. It was not until the first tanks began to leak in the 1970s that serious attempts were made to find a permanent solution to this problem.

After years of study, the Defense Waste Processing Facility was conceived as a way to process this high-level waste, using a method that had found favor in the French nuclear community. This method of disposal, the vitrification process, bonded radioactive material with silicon to form "glass logs" that would then be leak-proof. Onsite process development and research began in the 1970s at the CNX/TNX Area. Actual construction of the Defense Waste Processing Facility, or DWPF, began in 1983, and it was completed at a capital cost of $1.276 billion and start-up operating costs that reached $1.2 billion. Delays, mostly dealing with process problems and safety practices, occurred throughout the construction and startup period. All were given publicity in the late 1980s and early 1990s.[74] At the time of radioactive startup in 1996 there were other problems, most notably with the build-up of benzene gas.

In order to understand the problems associated with the DWPF, it is essential to know more details about the process. In the 1940s and 1950s, when the first high-level wastes were stored in large carbon steel tanks, concern over how the wastes were to be disposed of was limited. The major concern at that time was how they could be stored in carbon steel tanks without causing corrosion. Since the waste was acidic, caustics like sodium hydroxide were added to neutralize the matrix. Over time, the neutralized material precipitated out as a sludge that formed on the bottom of the tanks. The liquid matrix above the sludge, known as the supernate, held the lighter elements in a radioactive salt solution.[75]



Simulated Savannah River Liquid Waste Samples, 1978. Courtesy of SRS Archives, negative DPSTF 1-14033-1.



Aerial view of DWPF Building, 1997. Courtesy of SRS Archives, negative 97-1527-1.

By 1988, there were an estimated 35 million gallons of high-level radioactive waste at SRS, stored in 51 large, shielded, underground tanks clustered into two tank "farms." The most radioactive elements within the tanks were found in the sludge, which comprised three million gallons of this total. The less-radioactive supernate, also known as salt waste because much of it is sodium nitrate and sodium nitrite, comprised 32 million gallons.

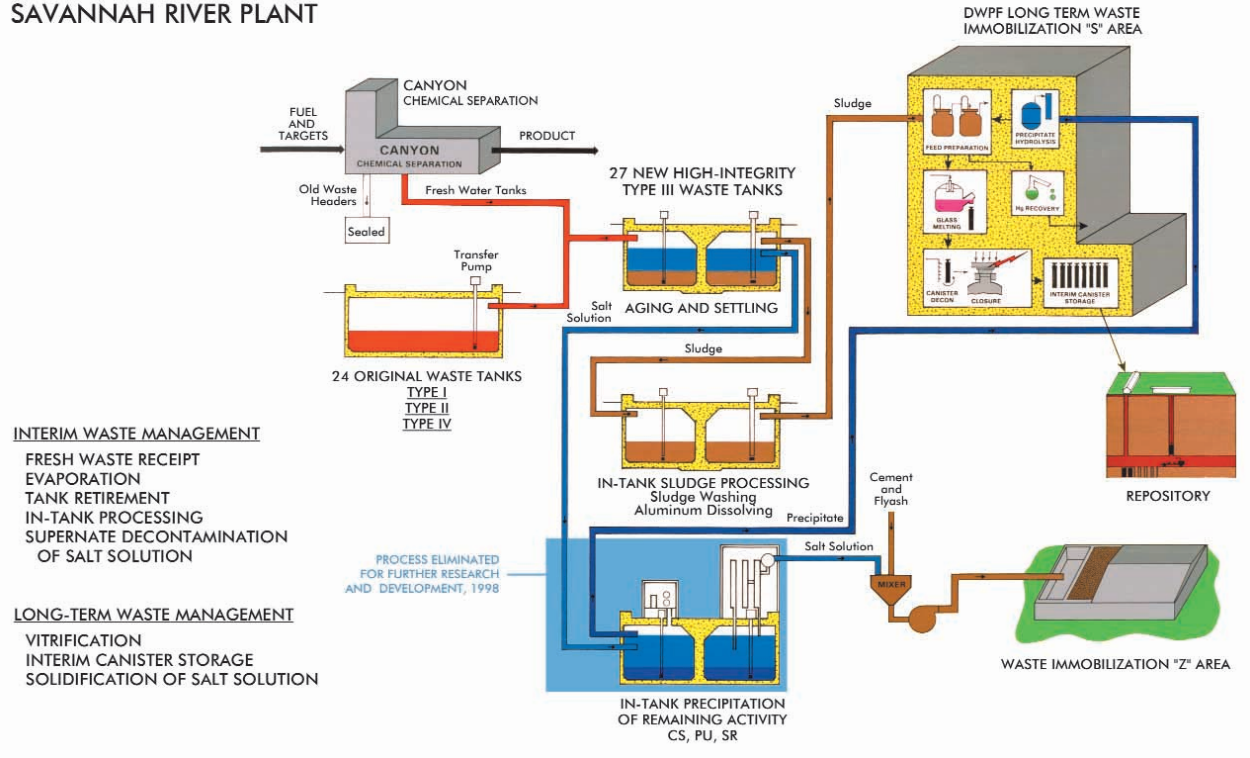
The sludge, because it contains the heavier, more radioactive, elements, was scheduled to go directly to the DWPF after pretreatment at the Extended Sludge Processing Facility. At this facility, the sludge is washed to curtail the concentration of sodium salt and then it is dissolved to remove aluminum for better glass quality at the DWPF. In 1999, the facility began to process the second of ten sludge batches that will need to be completed to vitrify all of the high-level waste sludge.

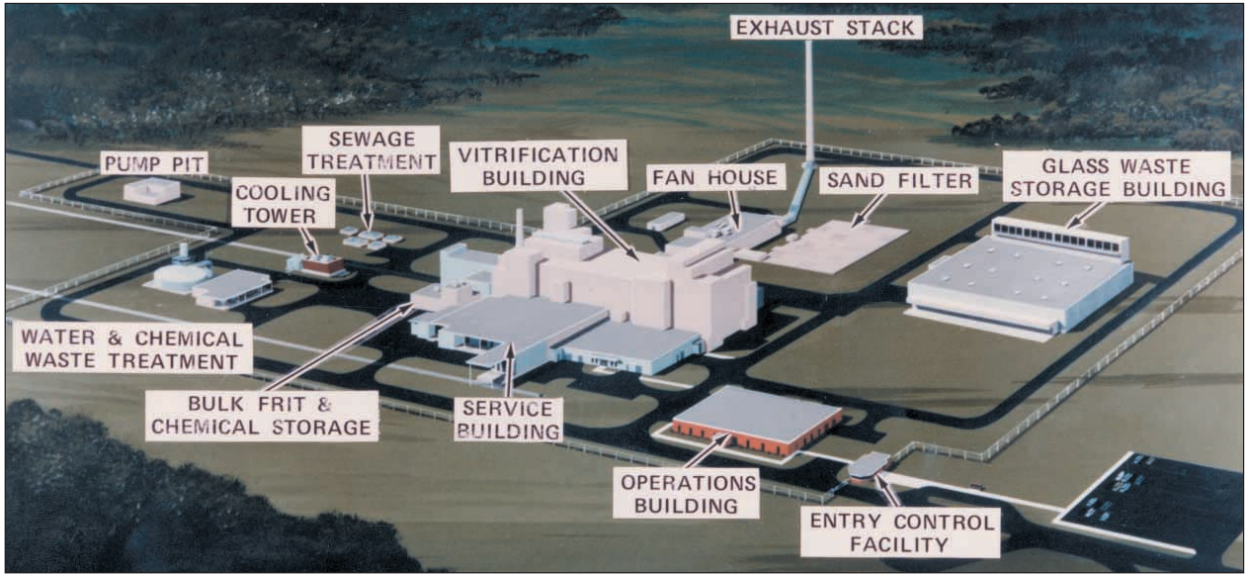
(Opposite Page) 1. Flow Chart of High-Level Waste Management Processes. Courtesy of SRS Archives, negative 91-1358-1. 2. Layout of S Area showing buildings and their function as planned. Courtesy of SRS Archives, negative 47984-1.

After processing at the Extended Sludge Processing Facility, the transformed sludge is transferred to DWPF for a "sludge only" vitrification. There, the waste, the sludge from the original waste and the highly radioactive material from the salt cake, is mixed with ground borosilicate (glass frit) and fed into a melter at 2100º F. The waste is poured into stainless steel canisters, ten feet high, two feet in diameter, and three-eighths of an inch thick, to cool. The glass-like solid that is produced envelopes the highly radioactive material and effectively seals it off from the environment. The canisters are then stored below ground in concrete vaults until a national repository is established.[76]

With the liquid salt waste, the process was a little different. Any cesium-137 and strontium found in the supernate would be sent to the DWPF to be processed exactly like the sludge. The removal of those two elements reduced the salt waste from the category of high-level radioactive waste to that of a low-level waste. At this lower level, the salt waste does not need to go to through the vitrification process. It can instead be sent to the Saltstone Facility, where it is put through a different process.[77] The SRS Saltstone Facility became operational in 1990.[78] In this process, the supernate is evaporated to a solid state identified as saltcake. After the cesium-137 and strontium are removed for shipment to the DWPF, the remainder of the saltcake is then mixed with cement, fly ash, and furnace slag,

HIGH LEVEL LIQUID WASTE MANAGEMENT
SAVANNAH RIVER PLANT





DWPF Interior Views





(Above) Interior of DWPF melt cell behind shielded glass, 1997. Courtesy of SRS Archives, negative 97-1273-9. (Right) Canister inspection within DWPF. Courtesy of SRS Archives, negative 97-1273-11.

to form a grout, that is pumped into one of these large concrete vaults, each of which is subdivided into cells or sections.[79] Within the cells the grout cures into a stable solid called "saltstone." When each of the vaults is filled, it will be capped with protective grout, and ultimately final closure will entail covering each vault with a clay cap and a stratum of earth over the cap. Between 1990 and 1998, the Saltstone Facility processed about 2.5 million gallons of salt solutions, transforming them into more than 4 million gallons of "saltstone."

The In-Tank Precipitation Facility (ITPF), a second pretreatment operation for DWPF, was designed to process the high-level waste salt to remove cesium and other radioactive materials. The facility went into operation in September 1995. It soon developed, however, that higher-than-expected benzene levels were encountered.[80] As a result, in August 1996, the Defense Nuclear Facility Safety Board recommended that the processing of the liquid salt waste be discontinued. In January 1998, it was determined that the ITP process could not cost-effectively meet safety and production requirements. A SRS engineering design team then studied approximately 140 alternatives to the ITP process and identified four promising alternatives: solvent extraction, ion-exchange using crystalline silicotitinate (CST), small-tank precipitation, and direct disposal in grout.[81] Extensive

research and development have been conducted on these alternatives, and the Department of Energy is expected to select a salt waste processing technology after research is completed.

The DWPF has successfully processed radioactive sludge since it began operation in 1996 and has produced over 1100 canisters. The facility will proceed with processing sludge until the "precipitate" from one of the salt processing alternative strategies is available.



Aerial of Z Area showing multisectional Saltstone Facility, 1989. Courtesy of SRS Archives, negative 89-2080-4.

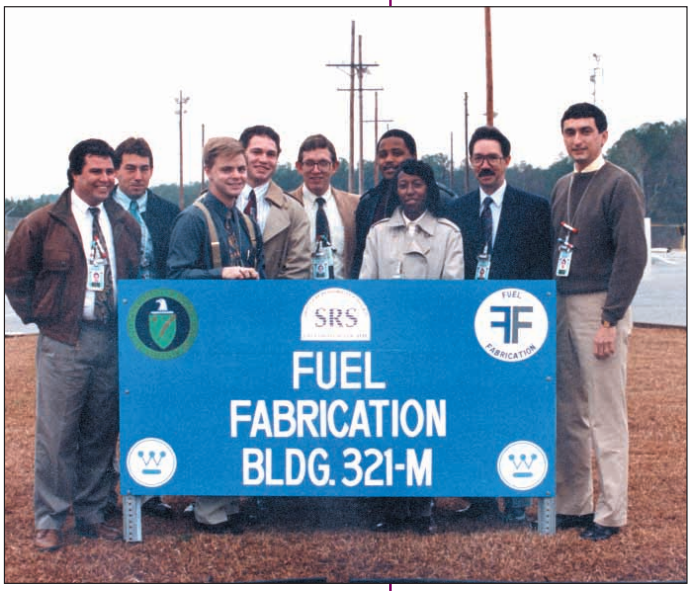
Two of the site's 51 high-level waste tanks, Tanks 20 and 17, both built in 1958 and first used in 1960, have been closed partially because of the successful operation of the DWPF. When the tanks were certified closed by SCDHEC in 1997, they marked a milestone in the site's history and the DOE complex. They are the first high-level radioactive waste tank closures in the nation. The measures involved in their closure were the product of close collaboration between the DOE, SCDHEC, USEPA, and SRS personnel and the public:

> Closure activities began years before the actual closing of the tanks. First, contaminated waste and sludge was removed from the tank to the extent practical (approximately 99.9 percent removed) while finalizing agreements and closure plans with state and federal regulators. Once these steps were completed, the closure activities began with workers pouring grout, a cement-type substance, into the 1.3 million-gallon tanks. The grout hardened, safely incorporating any residual radioactivity in the tank. Over the course of several weeks, the tanks were filled with grout to within a few feet of the top. Then the balance of the empty tanks was filled with very high cement.[82]

Work towards alternate technologies and better techniques continues, so that the rest of the high-level waste tanks can be emptied and their contents processed. In this regard, the tank farm evaporators perform heroically in reducing the waste in these tanks to 10 to 33 percent of their original volume. Used since 1960, they have allowed SRS high-level waste managers to reclaim about 100 million gallons of tank space overall, and about 2 million gallons of tank space in 1999 alone. "Without these evaporator, systems, SRS would have required 85 additional waste storage tanks—at $50 million apiece—to store waste over the site's lifetime."[83] To comply with Federal and state regulations, the program of waste-tank closures and high-level waste vitrification is to be completed by the year 2028. Even though the vitrified waste is currently stored at SRS, this is an interim arrangement. A permanent storage facility remains to be identified, although the most likely location appears to be Yucca Mountain in Nevada.[84]

FACILITY DEACTIVATION AND DECOMMISSIONING

This component of SRS's environmental management involves the deactivation of surplus facilities, placing them in safe storage, and readying them for final decommissioning. One hundred and thirty surplus facilities were identified in 1999; these range in type from historic facilities associated with the site's production mission, such as the reactors and test reactors, to smaller support structures and buildings. The 1990s witnessed strong strides in the decontamination and decommissioning of the original Savannah River facilities associated with the original production mission. Seven of the original process areas, the five 100 Areas, 300 Area, 400 Area, and B Area (originally the TC or Temporary Construction Area) have already experienced change or will in the future in response to the site's changing missions. The building stock in the Separations Areas has also been impacted.



(Left to right) R.V. Gann, Eric Plantz, Richard Newman, Mark Decosta, Charlie Varner, Teddy Crafton, Mary Fuller, James Wiederkerr and Nick Floyras pose for a staff photograph in 1992 prior to closing of Building 321-M. Courtesy of SRS Archives.

The Heavy-Water Area (D Area) has been completely decommissioned. The last of the three heavy-water facilities in D Area, 412-D, shut down since 1982, was dismantled by D & D teams between 1993 and 1996.[85] D Area has now become an industrial archaeological site. During this same period and in the years that followed, the SRS reactors and manufacturing areas have been scenes of similar work. Much of the Fuel and Target Fabrication Area (M Area) has already been dismantled. HWCTR, the experimental heavy water power reactor that operated in the early 1960s in the TC Area, began decontamination and decommissioning in 1994 and completed the process in 1997.[86]

Building 232-F, which began extracting tritium from reactor materials back in 1955 and was shut down three years later, when new facilities were required, was dismantled in 1994–1997, with grass planted over the site.[87] The original product vault, 217-F, has also been demolished. And work on the Naval Fuels Facility was initiated in 1999.

Non-radioactive buildings have been decommissioned. Foremost among these are the original powerhouses in the C and P areas. Other areas of work include the R Area water-



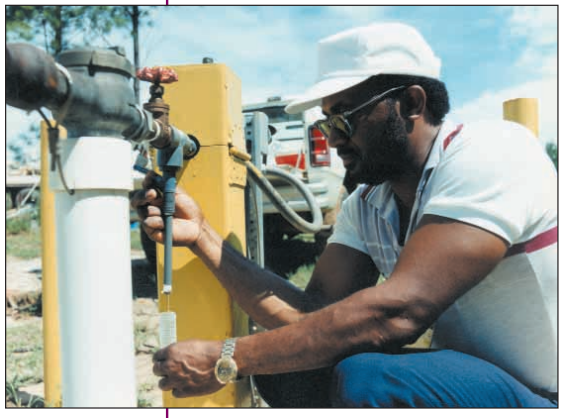
Original Tritium Building, demolished 1997. Courtesy of SRS Archives.

treatment plant, the L Area "hot shop," the R and C area helium-storage facilities, and the heavy-water distillation facilities in Areas P, L and C. Deactivation, and decommissioning teams, however, are not limited to work on structures; smaller items are also subject to cleaning. The Decontamination Facility in C Area is used to clean low-level radioactive contamination from small objects and portable items. This reduces the amount of material with low-level contamination that would otherwise have to be disposed of or stored.[88]

ENVIRONMENTAL MONITORING, PARTNERS AND PRESERVES

Monitoring of the site environment is carried out both on and off the site by members of EPD's Environmental Section in concert with the Division of Environmental Research of the Academy of Natural Sciences of Philadelphia.[89] The history of this collaboration was presented in Chapter 17. The monitoring program hinges on effluent monitoring and environmental surveillance, both radiological and nonradiological, and groundwater monitoring. Effluent monitoring is defined as the collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying contaminants, assessing radiation exposure to members of the public, and demonstrating compliance with applicable standards.

Environmental sampling, 1991. Courtesy of SRS Archives, negative 91-1712-20.



Monitoring takes place at the point of discharge, for example at an air stack or at the end of a pipe. In 1999, EMS personnel took approximately 4,200 radiological samples from 71 points of discharge upon which they performed the majority of the radiological analyses required. They focus on the detection of radioactive materials that could be released during site operations in the handling of plutonium, tritium, and other nuclear materials. The data are compiled within a monthly radioactive releases report and then summarized annually and published. The non-radiological airborne emissions of concern include sulfur dioxide, oxides of nitrogen, particulate matter, and toxic air pollu-

tants such as trichlororthylene, perchloroethylene, benzene, and hydrochloric acid. Data gathered from points of discharge are tabulated and then compared to assure that SRS is in compliance with permits issued by SCDHEC. An additional layer of monitoring is performed by the states of Georgia and South Carolina at offsite monitoring stations. This monitoring of ambient air is conducted to evaluate whether each state is in compliance with Federal ambient air quality standards. National Pollutant Discharge Elimination System outfalls provide sampling venues for nonradioactive liquid effluents.

Environmental surveillance is "the collection and analysis of air, water, soil, foodstuffs, biota and other media from DOE sites and their environs and the measurement of external radiation for purposes of demonstrating compliance with applicable standards, assessing radiation exposures to members of the public, and assessing the effects, if any, on the local environment." Unlike monitoring, surveillance pursues the identification of contaminants in the environment. Ten thousand radiological analyses were undertaken on 5,000 samples; 26,958 radiological samples were completed on groundwater samples taken from 1,224 monitoring wells. Mathematical modeling is used to estimate concentrations based on the data collected from sampling; measurement at the point of discharge, which should represent the highest amount, is used to calculate the amounts that will be dispersed in water, soil, or vegetation. Nonradiological surveillance takes place in the site's streams and in the Savannah River. Notably, the data from the outer areas are compared with outfall data to better detect the presence of materials that might harm the environment. The Environmental Report for 1999 states that approximately 6,300 nonradiological analyses for specific chemicals and metals were completed on about 1,200 samples; 134,123 nonradiological analyses were completed on groundwater samples.

The environmental monitoring efforts listed above for 1999 are a continuation of a program that began in the early 1950s. The records of the monitoring over time have been released for independent study by the Federal Centers for Disease Control and Prevention in Atlanta, Georgia, as part of the SRS Dose Reconstruction Study. The goal of the program is to determine the effects of the release of radioactive materials and chemicals since the site began operations. This program began as a result of the suit against the Department of Energy by the "Three Mile Island Public Health Fund," an environmental group interested in the effects of long-term exposure to low levels of radiation. As a result of this suit, in May 1990, DOE released the health records of some 200,000 people and employees within the nuclear industry.[90] That same year, at SRS, Westinghouse made public the first reports that detailed the radioactive releases known to have occurred at the site from 1954 through 1988. These were divided into atmospheric releases, liquid-to-stream releases, and liquid-to-seepage-basin releases.[91]

In 1990, DOE contracted with the CDC to measure and evaluate the radiation doses received by people within and around the Savannah River Site. Two years later, the CDC launched its SRS Dose Reconstruction project by awarding a $1.7 million contract for the first phase of work to Radiological Assessments Corporation of Neeses, South Carolina. Radiological Assessments Corporation (RAC) was commissioned to examine plant records to obtain relevant information, without any restraints from either DOE or the prime contractor.[92] RAC began examining the SRS records in January 1993, marking the first time that a DOE facility had opened its documentation to outside researchers.[93] By September 1994, the first phase of this project was well underway, with more than 133,000 records entered into a master data base.[94] The record search was completed in 1996. Phase II



Dose Reconstruction Group gets started at SRS Archives, 1993. WSRC-SRTC's Brian Looney (second from left in background) reviews methods with visiting researchers. The Center for Disease Control launched the SRS Dose Reconstruction Project in 1992 when it awarded a $1.7 million contract for the first phase of work to Radiological Assessments Corporation, of Neeses, South Carolina. The South Carolina firm was commissioned to examine plant records to determine the effects of the release of radioactive materials and chemicals since the site began operations. Courtesy of SRS Archives, negative 93-1780-10.

involved the reconstruction of the historical releases of radioactive materials and chemicals with the purpose of calculating the total amounts and types that were released. The final draft of the Phase II work is currently under review.

SAVANNAH RIVER ECOLOGY LABORATORY

The Savannah River Ecology Laboratory (SREL), a research unit of the University of Georgia, has grown to include a staff of around 165 individuals, including 20 faculty members. Its annual budget has grown from the initial grant of $10,000 to over $10 million. It is currently headquartered in A Area adjacent to SRTC within a large laboratory building completed in 1979 that is surrounded by waterfowl pens, greenhouses, and other laboratory structures. To help the SREL better conduct its educational outreach programs, it was announced in 1993 that a new Ecology Laboratory Conference Center would be constructed. This facility, which opened around 1997, is located near the extreme northern edge of SRS, in proximity to New Ellenton.[95]

The SREL works in partnership with DOE to clean up the local environment at SRS and to provide environmental public outreach programming. It has been instrumental in identifying the various waste sites previously used at SRS, and has helped SRTC in formulating treatment plans for the site's waste units. After contaminated sites have been identified, SREL begins a study of these locations, classifying them as one of three types of contaminated areas: a source zone of contamination, a primary contaminant plume, or a dilute plume or fringe area. Once the cleanup commences, it is always done with caution, since overreaction can be worse than the contamination itself.[96] SREL was instrumental

in cleaning up and revegetating Lost Lake, a Carolina bay that had been heavily impacted by adjacent industrial contamination from M Area's seepage basin.[97] Their efforts at Lost Lake are considered one of the landmark environmental projects at the Site. SREL is credited with developing procedures for microbial ecology, which employs microorganisms in subsurface cleanup.[98] In this endeavor, the SREL worked closely with scientists in the Savannah River Laboratory, now known as the Savannah River Technology Center. Among its many current programs are four major areas of interest: ecological stewardship, ecotoxicology, radioecology, and the operation of an Advanced Analytical Center.[99]

SREL's Environmental Outreach and Education Program is an important part of the laboratory's partnership with DOE. The major thrusts of the program are to communicate the importance of environmental awareness in decision-making that bears upon ecological problems and to introduce the site and instruct the American public about natural history and ecology. It has accomplished these goals through a variety of paths that include exhibits, public outreach brochures, laboratory tours, lectures, and eco-tours. The 1999 Environmental Report notes that SREL reached about 70,000 individuals in this manner, presenting a myriad of topics from plants and wetlands to careers in ecology. Also, in 1999, 33 graduate students and 12 undergraduate students participated in a SREL program that encouraged professional development. Their work contributed to the advancement of the Site's environmental stewardship mission.[100]



The red-cockaded woodpecker population at SRS has grown from 4 in 1985 to 120 today due to the efforts of the Savannah River Forest Station. Source: Savannah River Forest Station

SAVANNAH RIVER FOREST STATION—USDA FOREST SERVICE

The Savannah River Forest Station has assumed a more central role on the site in the 1990s with an expansion of responsibilities that involve secondary road and boundary maintenance, endangered species recovery and management, engineering support for environmental restoration, soil erosion and watershed management, wildland forest control, wetland restoration, land-use planning, and community outreach.[101] The role of the SRS forester in 1955 is far different than the role played by the foresters on site today. SRS is composed of approximately 198,000 acres, of which 12 percent is built out for industrial purposes, 9 percent is contained within ecological set-aside areas, and 7 percent is left undisturbed along Lower Three Runs and the Savannah River Swamps to limit the movement of trace radioactive contaminants.[102] The remaining 72 percent of the site, characterized as mixed forest with 31 percent hardwood and 69 percent pine, is managed by the Forest Service. This area supports 54 mammal, 103 reptile and amphibian, 81 fish, and 259 bird species.

The Forest Station's forest product program has accrued over $50 million in revenue since its inception in 1956 from the sale of forest products (mostly sawlogs for lumber), pulpwood for paper, and pinestraw for mulch. In 1999, the estimated value of SRS standing timber was approaching $500 million. Annually, 25 million board feet are harvested, which is roughly equivalent to about 20 percent of the wood supply in the CSRA. The amount harvested is dictated by DOE's sustainable-resource-management objectives that encourage not only the sale of forest products but the protection of habitats for endangered species and the maintenance of a wide variety of forest conditions.

In addition to forest products and silviculture, the Forest Station maintains a wildlife and botany program.[103] This includes the red-cockaded woodpecker recovery program, which began in earnest in the early 1990s. Red-cockaded woodpeckers, commonly found in mature pine forests, have been in decline in recent decades, and were put on the endangered species list in 1970. As a result of efforts by the Forest Service, these woodpeckers have grown from 4 on site in 1985 to 120 today.[104] Other species under monitoring and protection are the bald eagle, woodstork, American alligator, short-nose sturgeon, and the smooth purple coneflower.

Fire management is practiced as an ecological process; prescribed burning is carried out on 15,000 to 18,000 acres on a yearly basis. In addition to assistance with site planning, road maintenance, and research related to management problems, the forest station is committed to public outreach and education. The Forest Service is an active partner with the Ruth Patrick Science Center at the University of South Carolina–Aiken, managing classroom facilities and outdoor study areas. It also operates the Savannah River



Savannah River Forest Station staff stage fire-safety demonstration for DOE-SR Annual Kids Day Event, 1998. Courtesy of SRS Archives, negative 98-1260-212.

Environmental Sciences Field Station that began in 1996. This is the only field station in the nation dedicated to providing field education opportunities in environmental sciences for undergraduates from minority institutions. The Field Station is composed of 21 historically black colleges and universities, as well as 5 institutions from four states.

CRACKERNECK WILDLIFE AREA AND ECOLOGICAL PRESERVE

Other areas have been subject to even greater protection. The Crackerneck Wildlife Management Area and Ecological Preserve consists of 10,000 acres under the protection of the South Carolina Department of Natural Resources as a biological and wildlife refuge. This action will preserve the unique plant and wildlife habitat that is located on the Site's western boundary along the Savannah River, which has been recognized as a special habi-

tat for certain species including a variety of threatened and endangered animals. This preserve is located on the northwest side of SRS, west of Highway 125 and north of Upper Three Runs Creek. In 1972, this land was turned over to the Forest Service, which returned the area to the care of DOE around the time that Westinghouse became the prime contractor. The preserve was turned over to the care of South Carolina Department of Natural Resources in June 1999.[105]



First Citizen's Advisory Board. **First Row**: (From left to right) P. K. Smith, Walt Joseph (Facilitator), Bill Donaldson, Tom Heenan (DOE), Camilla Warren (EPA), Pat Tousignant, Tom Costikyan, Kathryn May, Mildred McClain, Alice Holingsworth, Vernon Zimmerman, Jo Ann Nestor, Ann Clark (SCHDEC). **Second Row**: Kevin Reed, Charlie Anderson (DOE), Lane Parker, Beaurine Wilkins, Ann Loadholt, Bob Slay, Kamalakar Raut, Andrew Rea, Bill Lawless, Myra Reece (SCDHEC), Ernie Chaput (DOE). Courtesy of the Citizen's Advisory Board.

CITIZEN'S ADVISORY BOARD

The voice of the public has input into operations and environmental issues engendered by the Site in the form of the Citizens Advisory Board (CAB), an independent organization chartered by DOE. This group, created in 1994, provides SRS "with ongoing counsel to help guide decisions consistent with stakeholder values and opinions."[106] Comprised of 25 people from all walks of life, the board is drawn from around 250 applicants from both South Carolina and Georgia, reflecting the local diversity of the central Savannah River area. Board members serve terms of two to three years, and are empowered to provide advice and recommendations concerning environmental conditions and waste management to the Department of Energy, the U.S. Environmental Protection Agency, and the South Carolina Department of Health and Environmental Control. The Citizens Advisory Board that serves SRS is similar to those that serve other DOE nuclear facilities, such as Fernald, Hanford, Oak Ridge, Idaho National Engineering Laboratory, the Nevada Test Site community, Pantex, Sandia, and Rocky Flats.[107] Savannah River's board, which is nationally recognized as one of the most productive site-specific advisory boards in the DOE complex, authored 35 recommendations to the Federal agencies in 1999 that addressed issues in the Solid Waste program, the Environmental Restoration Program, Material and Facility Stabilization, and the High-Level Waste Program.

STEWARDSHIP OF THE SRS TECHNICAL LEGACY

The foregoing sections have been dedicated to the concept of stewardship and its development as a mission at SRS. Embedded in each discussion of the site's areas of responsibility was a wealth of technical and scientific data accumulated by the many men and women who form the Savannah River Technology Center, and its predecessor, the Savannah River Laboratory. The technical and scientific legacy that stems from their endeavors is large and as varied as the Site itself.

In 1992, the Savannah River Laboratory was renamed the Savannah River Technology Center (SRTC).[108] With the new name came a broader scope of work and a new mandate that SRTC begin to engage in technology transfer, sharing its knowledge and expertise. Previously, the Laboratory's function was to support the plant's main missions, whether that was defense production or the transplutonium programs. While researchers and scientists were encouraged to attend conferences and present professional papers, the nature of the work during the first four decades made most research unreportable. Gathered in secrecy for 40 years, this knowledge was to be made available to public and private enterprise throughout the region and the nation.[109]



Aerial view of Technical Area in 1989. SRTC is the multi-wing building in the center of view. Courtesy of SRS Archives, negative 89-2070.

The SRTC offered 40 years of concentrated research and experimentation that ranged over the wide canopy of American science. In the course of providing assistance to areas like manufacturing, reactors, or separations, a considerable body of knowledge had been accumulated, and it was this accumulation that the SRTC proposed to share. One of the first examples of what came to be called "technology sharing" was the use of microbes to clean up organic solvent contamination with a minimum of surface and subsurface disturbance.[110] By 1995, this technology included methods for pumping methane into the ground to assist local microbes in the cleanup of toxic chlorinated solvents.[111]

By 1994, the SRTC's mission of "technology transfer" had spawned an Industrial Assistance Program whose sole-purpose was to provide technical assistance to private industry. At that time, it was noted that before 1990, only one technology transfer of this kind had ever been made, while in the years that followed, 58 licenses had been effected. Foremost among these were devices used to avoid exposure to radiation, as well as a wide array of robotics and remote sensors. SRTC also provided information on digital x-ray technology and specialized computer systems, among other technical offerings. One of the first local firms to benefit from the new technology transfer was the Graniteville Company, which acquired considerable expertise in remote sensor work.[112]

By 1995, the Hydrogen Technology Laboratory (HyTech) had been set up to disseminate SRTC's years of experience in hydrogen and tritium work.[113] The Technology Business Development Department, which encouraged participation in advanced technology programs throughout the DOE complex, was established at this time as a stimulus to private enterprise.

SRTC defines itself today as an applied research and development laboratory that provides the technical leadership for the site to meet the challenges in its three areas of responsibility: Stockpile Stewardship, Nuclear Materials Stewardship, and Environmental Stewardship. Its 770 employees work within five divisions: the Waste Treatment Technology Department, the Environmental Sciences and Technology Department, the Strategic Materials Technology Department, the Engineered Equipment & Systems Department, and the Measurements Technology Department.

Each of these departments works in the service of the site. The many processes developed for the DWPF were honed and brought to the production line by the Waste Treatment Technology Department. SRTC's personnel are sharing their know-how of vitrification and associated processes with Hanford staff, who are also in the process of stabilizing their high-level waste. The contributions of the Environmental Sciences and Technology Department in problem-solving for environmental issues and the development of new technologies have been noted above. In addition to new development, they keep abreast of new technologies with SRS applicability, adopt them, and demonstrate their usefulness.

The Strategic Materials Technology Department is the focus of support, in terms of materials, chemistry, and process development, for the site's ongoing missions. It is considered the SRS authority in all materials issues. This Department is also a springboard for technology development in pursuit of new site missions. They have pioneered the Melt Dilute technology for the disposal of aluminum research-reactor spent fuels, and the Laboratory's work with tritium has yielded knowledge and expertise in hydrogen that will fuel work in associated industries:

> SRTC is working with several partners to design, develop, demonstrate and ultimately commercialize a zero-emission light duty electric vehicle—suitable for transport and delivery in factories, airports and warehouses—that runs on renewable hydrogen energy. This vehicle uses a hydrogen storage system that is based on the hydride technology SRTC developed for use in the site's tritium mission.[114]

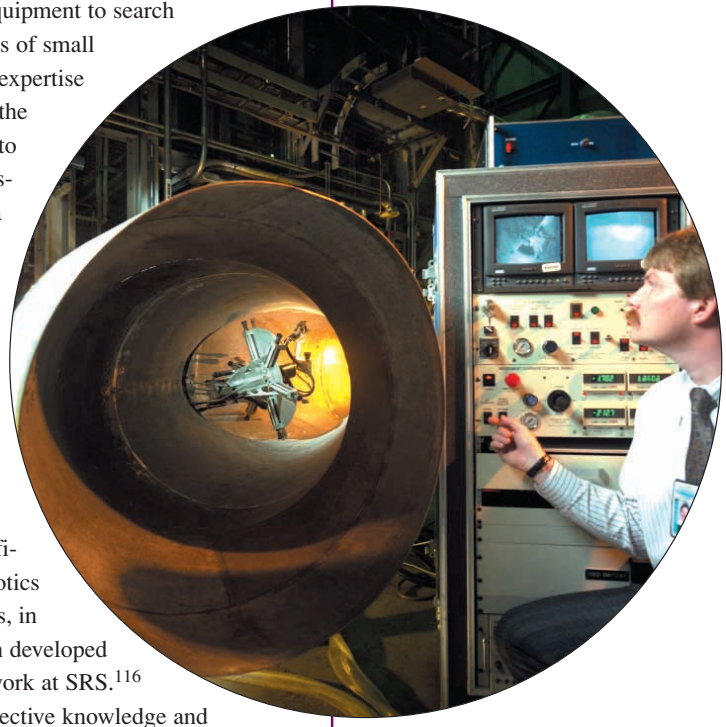


Engineering Equipment and Systems Department, group photograph in front of 723-A, 1992. Courtesy of SRS Archives, negative 92-1181-1.

The Engineered Equipment & Systems Department does a wide variety of jobs within their main mission of providing engineering and technical support to SRS within all three of the site's stewardship areas. Instrumentation, data acquisition, remote handling, robotics, engineering modeling, thermal-fluids analysis, and radioactive material packaging and transportation are some of their fields of expertise. The removeable pour-spout insert created to increase productivity with the DWPF operations by allowing greater pour rates is a recent innovation that will yield an estimated savings of more than $200 million by the end of DWPF operations. The Plutonium Bagless Transfer System, which involves the packaging of plutonium without plastic, is another coup for this Department that will increase savings within site operation.

The detection and measurement of radioactive, nonradioactive, and thermal emissions from SRS is the provenance of the Measurements Technology Department. This group's responsibilities extend beyond the region; they are also responsible for developing technologies for safeguarding special nuclear materials nationally and internationally. The department has played a significant role in developing technologies for use in non-proliferation, national security, and law enforcement agency applications. An example is a pilot program sponsored by DOE which involves a partnership that began with SRTC and local law enforcement agencies and has since spread.

> Under a pilot program sponsored by DOE, SRTC explored opportunities to assist law enforcement agencies in the two-state area adjoining SRS by developing new technologies for evidence-gathering, by deploying SRTC personnel and equipment to search for and recover evidence, by conducting analysis of small fragments of evidence, and by applying unique expertise to crime-fighting challenges. Working through the National Institute of Justice, SRTC is now able to provide similar types of unique technology assistance to help law enforcement agencies across a 15-state region. SRTC is also working with the FBI as its nuclear forensics support laboratory, supplying unique technical expertise for the investigation and prosecution of nuclear terroristic acts occurring or directed at the United States.[115]



Demonstration of robotic pipe crawler in action within pipe, 1992. Courtesy of SRS Archives, negative 92-2013-2.

This example of technology transfer well illustrates this new drive within the Laboratory. SRS technology transfer encompasses areas as diverse as hydrogen technologies, vitrification procedures, environmental restoration procedures, robotics and remote-engineered systems, and advanced sensor systems, in addition to the various technological programs that have been developed in recent years to support the remaining nuclear processing work at SRS.[116] It is a fitting tribute to all who labored at the site that the collective knowledge and intellectual capital that has accumulated over a half-century at SRS can find new life in service to its community.

ARSENAL FOR THE FUTURE

History, by definition, assumes a separation between the past and present. In reality, history is ongoing, the past separated from the present by moments. We are not used to thinking of the past in this manner, or of thinking of the very recent past as historic. Most histories are compiled for people, places, and events that are not only in the more distant past, but that have also reached conclusion. The story is thus complete, the results known, although they may be open to interpretation.



50th Anniversary commemoration of granite memorial at Ellenton town site on November 28, 2000. Former inhabitants of Dunbarton, Ellenton, and the general site area are saluted by the Department of Energy's Savannah River manager Greg Rudy. The stone is engraved with the following: "Fifty years ago today, November 28, 1950, President Harry S. Truman announced that the Savannah River Plant would be built. This marker is dedicated to the families who originally lived on this property and to the patriotic men and women who have made possible the safe operations and successful missions of the Savannah River Site." Courtesy of SRS Archives, negative no. 2000-1445-17.

The history of the Savannah River Site is not such a history. Written to celebrate the site's 50th anniversary, our story has no end. Indeed, this may be only the first installment in a series of histories, written at 50-year increments, tracking the course of a technology, an installation, a program, its missions, its people, and its region. As we look back on the first 50 years, we recognize that the site and the world surrounding it have changed dramatically. The Cold War, the threat of nuclear battle between the U.S. and the Soviet Union, has itself become historic, coming to an end. The promise of the atom was diminished as a result of shifts in America's perception of nuclear technology and the environment. The nuclear frontier, which once tantalized the American public, has been less vigorously explored as a consequence. Neither the site nor its mission is the same as a result, nor will they return to the way they were. It is important that a record is compiled that charts past actions, explains the site's technologies and their development, and provides younger generations with a sense of the spirit of the Savannah River Site community over the first 50 years of operations. Knowledge of the site's past and how it has faced numerous challenges—technological, economic, and social—between 1950 and 2000 provides an important arsenal of lessons learned and inspiration for the productive years ahead.

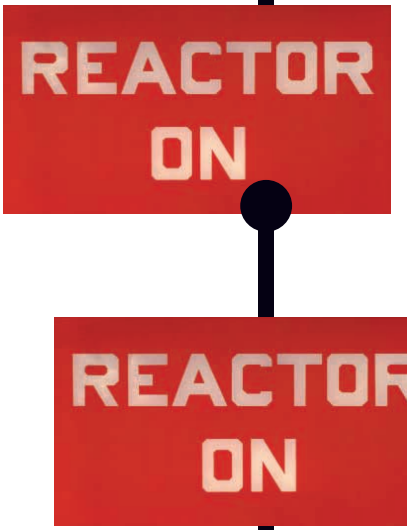
The Savannah River Site, although comprised of land, buildings, equipment and the people who manage and operate these things, has created an identity which is purely its own and which is greater than the sum of all these parts. Its legacy of technological research and innovation in engineering is among the finest in the country. Its contribution to the nation's defense and its role in the end of the Cold War have yet to be fully explored, a task best left to the next set of historians. While our country's need for nuclear weapons-grade fuel has decreased, Savannah River has a continuing defense mission with

the production of plutonium and tritium. Its diversified technological past, its high-caliber research laboratory, and its well-trained work force has opened many avenues for future missions within a location and community that embraces Savannah River Site and its continued well-being. The development of the MOX mission, continuing national defense production of plutonium and tritium, technology transfer, and the potential of establishing a nuclear research park within the Aiken area, and innovative documentation and treatment of environmental issues are all fitting endeavors and uses for the Savannah River Site which build on its legacy and carry it into the future. We can't forecast with certainty what the Savannah River Site will accomplish in the next 50 years, but, in light of the accomplishments of the first five decades, we expect no less in the future.

Savannah River Site at Fifty

Appendices





World War II to the New Century Timeline

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1945

Harry Truman becomes president (1945–1953).

U.S. drops atomic bombs on Hiroshima and Nagasaki, Japan. Japan surrenders August 14, 1945.

1946

Winston Churchill proclaims: "From Stettin in the Baltic to Trieste in the Adriatic, an iron curtain has descended across the continent."

Publication of the Lilienthal–Acheson Report which suggested that international control of atomic energy was obtainable if rivalry among nations was erased.

The Atomic Energy Act (McMahon Act) is passed, establishing the Atomic Energy Commission.

U.S. nuclear test at Bikini Atoll, Marshall Island.

First nuclear reactor-produced radioisotopes shipped for use from ORNL to Brainard Cancer Hospital, St. Louis, MO.

1947

Truman Doctrine—"I believe it must be the policy of the United States to support free peoples who are resisting subjugation by armed minorities or by outside pressures."

Truman nominates David E. Lilienthal as first chairman of AEC. Lilienthal narrowly wins confirmation and serves as chairman until February 1950.

1948

U.S. in possession of 50 nuclear bombs.

Soviet Union begins Berlin Blockade.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1949

Communists gain control of China.

Soviets explode their first atom bomb on August 29. The event surprised American scientists and shook the American public's sense of security.

1950

Truman announces his intention to accelerate the atomic energy program on January 19.

AEC Reactor Division recommends to AEC General Manager that proposed reactors be heavy-water moderated to produce increased quantities of thermonuclear materials on March 20.

Curtis Nelson is selected as AEC manager of the new project and Robert C. Blair, Deputy Manager, on June 29. Robert Mason is Field Project Manager for Du Pont.

AEC formally asks Du Pont to construct and operate new facility on June 12.

Truman requests funds from Congress for construction of two heavy-water reactors. for production of thermonuclear weapons on July 7.

At Du Pont's request, Truman formally asks Du Pont to assume the project of constructing and operating the new nuclear facility on July 25.

Special Committee of the National Security Council on Atomic Energy calls for the construction of three additional reactors in August.

Public Law No. 843 is passed, giving the AEC authority to acquire land for a plant to manufacture radioactive products on September 27.

Crawford Greenewalt, President of Du Pont, accepts project "on the basis of cost plus a fixed fee of one dollar" on October 17.

AEC designates the new facility as the Savannah River Plant on November 22.

Advent of McCarthyism—Senator McCarthy begins crusade to identify communist elements in America.

National Security Council document (NSC 68) approved by Truman, calling for the build up of conventional and nuclear forces to stop the spread of Soviet influence.

Truman decides to proceed with development of the hydrogen bomb, January 31.

Arrest of Dr. Klaus Fuchs for disclosure of secret atomic information to Russians on February 3.

North Korea invades South Korea in June.

Expansion/establishment of three AEC sites: Savannah River Plant, Los Alamos Scientific Laboratory, and Lawrence Livermore Laboratory.

SAVANNAH RIVER SITE TIMELINE

Construction of Dana Plant, a heavy-water production plant on WWII P-9 Plant at Wabash River Ordnance Works. Started by Girdler, construction of the Dana Plant was embraced under the larger Du Pont contract.

Public Announcement of the site location, near Aiken, South Carolina on November 28.

"The new plant...while having a primary military purpose at this time, will add to the Nation's capacity for producing fuels which some day will be needed to utilize atomic energy for useful power."

USAEC First Public Announcement, November 28.

General plant layout is completed on December 22.

Purex process chosen by Du Pont for its chemical separation of plutonium, a process based on solvent extraction.

First Right of Entry to proposed plant site property acquired on December 21:
Ellenton evacuated 3/1/52
Dunbarton evacuated 6/15/52
All land acquired 6/30/52
Close to 5,000 graves were removed

NATIONAL/STATE EVENTS TIMELINE

1951

Decision made to have two separations areas (F and H) and a possible third area (X Area) January 10.

Project boundary line changes to exclude Snelling and Jackson, South Carolina.

U.S. Army Corps of Engineers begins soil explorations at plant site in January.

Construction on SRP begins on February 1.

Du Pont Engineering Service Division "Weather Group" was established on plant site in March. First plant weather forecast given on September 13.

New York Shipbuilding selected for reactor fabrication on April 11.

Construction personnel occupy newly completed TC buildings, two large cartwheel shaped buildings that became symbolic of SRP.

First usable electricity from nuclear energy produced at Idaho National Engineering Laboratory.

SAVANNAH RIVER SITE TIMELINE

Environmental baseline study of the Savannah River, conducted by The Academy of Natural Sciences, led by Dr. Ruth Patrick begins in May. Defense Production Administration declares Augusta, Georgia, and area surrounding the SRP, a critical housing shortage area.

Cloverleaf intersection opened at junction of Highway 19 and the Four Lane Highway.

AEC announces ecological studies in the plant area to be done with the Biology Departments of the University of South Carolina and the University of Georgia. First grant of $10,000 for ecological research begins University of Georgia presence on site.

Pilot plant CMX completed in September. It is the first completed facility and the beginning of the Savannah River Laboratory.

AEC authorizes establishment of Reforestation and Forest Management Program to be administered by the U.S. Forest Service. Interagency Agreement for permanent program signed March 20, 1952.

NATIONAL/STATE EVENTS TIMELINE

1952

President Truman announces five to six billion dollar program to expand atomic energy projects. SRP is included in that expansion on January 21.

Construction forces set world safety record by working 4,862,763 person hours without a disabling injury on January 30.

AEC SROO approves contract with South Carolina Generating Company (Owned by the South Carolina Electric & Gas Company) to furnish electric power to plant.

Plant newspaper *SRP News and Views* first issued on February 29.

House Appropriations Committee turns down request of $4,000,000 to start construction of proposed Hartwell Dam on Savannah River, holding it unessential to the Savannah River Plant.

Construction forces set second world safety record by working 6,275,072 hours without a disabling injury on April 20.

Mike I: First U.S. thermonuclear detonation, November.

Dwight D. Eisenhower elected president in 1952 (1953–1961).

SAVANNAH RIVER SITE TIMELINE

Construction forces set third world safety record by working 10,018,160 person hours without a disabling or lost time injury on July 3.

D Area (400 Area), Heavy-Water Plant, begins operation in August. Heavy water used as reactor moderator and also for nondefense scientific applications.

Peak construction force of 38,582 reached.

New York Shipbuilding makes first barge shipment of reactor to the plant.

M Area (Fuel Target Manufacturing and Raw Materials Area) in production by 1952.

Graphite test pile in Building 305-M goes critical in September. First reactor to go critical at SRP.

AEC modified SRP production program by eliminating funds for thorium slug fabrication and separation of uranium-233. Recommended that SRP focus on plutonium production in all reactors while excess reactivity should be applied to tritium production.

All roads entering the plant closed to the general public on December 14.

Operations Recreation Association established.

University of Georgia hires Dr. Robert Norris, ecologist, to conduct full-time research on site.

NATIONAL/STATE EVENTS TIMELINE

1953

Process Development Pile (PDP), heavy-water moderated prototype for the SRP production reactors, goes into operation.

First reactor fuel was Mark I. Composed of solid slugs, natural uranium charges for plutonium production. Tritium only produced with lithium-alloy control rods. Reactors initially operated at low power, 375mw.

AEC authorizes startup and operation of 105-L Reactor on enriched fuel and 105R, P, K, & C to be loaded for maximum plutonium production with excess reactivity used for tritium production on December 2.

Joseph Stalin dies on May 5.

Julius and Ethel Rosenberg executed for WWII espionage on June 19.

Korean War ends.

U.S. nuclear arsenal grows from 300 to 1,000 bombs. President Eisenhower's "Atoms for Peace" speech in December.

South Carolina's first television station, WCSC (Charleston) goes on air, June 19.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

AEC allocated additional uranium-235 for SRP reactors for a total of three enriched loadings on December 10.

R Reactor reaches criticality on December 28, using Mark I natural uranium fuel.

U.S. Forest Service under contract with AEC engages in largest mechanized planting program in U.S. using 28 planting machines to plant 400,000 seedlings per day.

1954

AEC advises Du Pont that SRP facilities should be "planned on the basis of four reactors operating on enriched fuel and one on natural uranium" on January 21.

P Reactor reaches criticality on February 20.

Lieutenant General (retired) Leslie Groves, head of Manhattan District during WWII, visits SRP on March 5.

L Reactor reaches criticality on August 11.

K Reactor reaches criticality on August 14.

Plant rail system consisting of 82.2 miles of permanent railroad completed on August 14.

Operations begin in F Area in November.

First delivery of plutonium to AEC.

Waste Tanks in F Area (Tanks 1-7) put into service storing high-level and low-level waste. 76-acre area between F and H Areas designated as solid waste burial ground.

Castle Bravo: most powerful U.S. thermonuclear test.

Secretary of State John Foster Dulles announces U.S. policy of "massive retaliation."

Atomic Energy Act of 1954 passed to promote the peaceful uses of atomic energy.

U.S. Senator Joseph McCarthy begins televised hearings into alleged Communist activities in U.S. Army.

S.C. State Development Board is created with an aggressive agenda to entice new industries to state.

1955

C Reactor reaches criticality on March 28.

First high-level waste tank filled in June.

H Area began operating using the Purex process in July.

Tritium facilities become operational in October.

Arco, Idaho, becomes first U.S. town to be powered by nuclear energy in a one-hour demonstration.

Warsaw Pact—military alliance between Soviet Union and Eastern block countries.

SAVANNAH RIVER SITE TIMELINE

First delivery of tritium gas in November.

AEC and DoD announce plans for antiaircraft defense for SRP.

1955–1960s—Beginning of power ascension program in reactors (1955, 600-700mw; December, 1956, 1000mw, December, 1957, 1500mw, December, 1958, 2200mw); Continued in more gradual increments until 1967, led to the development of new marks.

1955–1956—First production of isotopes for peaceful use. Cobalt-60 used as heat source and food irradiation in 1955. Plutonium-238 would be used as a heat source for NASA and the DoD.

Uranium-233 used for breeder reactor program as part of the "Atoms for Peace" Campaign (1956–71).

Waste tanks 2-F, 9-H, 11-H, and 10-H put into service storing waste from Purex process. At this point H Area had only four tanks numbered 9–12.

NATIONAL/STATE EVENTS TIMELINE

1956

Supplementary Safety System installed in reactors so that a reactor can be shut down by operators even if the control and safety rods fail to drop into reactor.

Development of the coextrusion process for tubular targets.

Experimental program at SRP's P Reactor confirms the existence of the free neutrino, a particle without charge and with extremely small mass. Discovery of neutrinos, based on work done at P Reactor, by Drs. Cowan and Reines of Los Alamos Scientific Laboratory. Reines would later win the Nobel Prize for this achievement.

232-H Tritium facility goes into operation. Its capacity doubled in a year.

Development of Hollow Slugs (Mark VII) as power ascension program led to problems with the solid Mark I fuel slugs.

Patent issued for Nuclear Test Gage to SRL's Gerhardt Dessauer.

Waste tanks 3-F, 8-F, 12-H, and 13-H filled. Four additional tanks (13–16) placed into service in H Area.

Khrushev's "secret speech" denouncing Stalin, in February.

Soviets crush Hungarian Uprising, in November.

Suez Crisis, October–December.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1957

F Area canyon operations suspended for a major upgrade of equipment to achieve greater capacity. New jumbo mixer-settlers were put in place and the addition of a new plutonium finishing facility, the JB Line, was built on roof of canyon.

Start up of SRP's only production of weapons components, metal reservoirs filled with tritium, to be inserted into nuclear warheads.

1957–58—Dana Plant and two of the three heavy-water plants, Buildings 411-D and 413-D, at SRP shut down after an adequate reserve of heavy water had been produced. Half of remaining SRP facility converted to the reconcentration of heavy water that had become diluted in reactors.

300 Area terminates Mark I production in November.

Waste tank 14-H placed into service.

Building 411-D put on standby and half of the DW Plant converted to rework tritiated moderator.

Radiation released from graphite core of reactor at Windscale Nuclear reactor in England. Iodine and polonium were released into the air.

First large-scale nuclear power plant begins operating in Shippingport, PA.

Soviets launch "Sputnik" and NASA is established.

1958

Completion of Par Pond for cooling water to R and P Reactors.

First proposal for partial containment of SRP Reactors, by AEC Advisory Committee on Reactor Safeguards. This led to the first confinement measures, with building sealing and exhaust air filtration.

1958–59—First production of plutonium-238 at SRP as heat source for electricity; used by space program for electrical source.

Building 413-D (D_20 extraction) and E Plant placed on standby.

Explorer I, the first U.S. satellite, successfully orbits the earth.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1959

Resumption of Purex operations in F canyon.

Beginning of Transplutonium Programs at SRP. Various campaigns to make artificially formed elements heavier than plutonium. These programs increased in the 1960s, under Glenn Seaborg, Chairman of the AEC, 1961–71.

Construction begins on Heavy Water Components Test Reactor, April 20.

H canyon began using HM process for enriched uranium in May.

Publication of the discovery of tritium as a product of fission by SRL's Edward L. Albenesius.

Steam autoclaving initiated in 300 Area.

Waste tanks 5-F and 18-F receive high- and low-level wastes, respectively. Tanks 17-F and 20-F were constructed in F Area.

Fidel Castro seizes power in Cuba, January.

Dresden 1 Nuclear Power Station in Illinois begins operating.

First U.S. power plant built without government funding.

1960

Reprocessing uranium used as fuel in reactors at other sites begins at SRP's Receiving Basin for Offsite Fuels.

Evaporation of waste started in F Area. Tanks 15-H and 20-F put into service.

Whole-body counter, a room built with 12-inch pre-World War II armor plate, constructed.

Hot press bonding used in slug production begins at SRP, formerly done by an offsite vendor.

U.S. Forest Service plants 75 millionth pine seedling at site in June.

Soviet Premier Nikita Khrushchev addresses United Nations in New York, pledging support for "wars of national liberation."

John F. Kennedy, campaigning as an aggressive anti-Communist cold warrior, is elected president, November 1960 (1961–1963).

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1961

Exploratory drilling begins on bedrock project to ascertain potential for safe storage of SRP waste below ground.

AEC establishes permanent ecology laboratory on the site, known as the Laboratory of Radiation Ecology. Annual operating budget grows to $60,000 with a staff of 15.

F and H canyons begin working alternately.

Building 235-F begins processing neptunium, and the recycle process is established.

Building 234-H begins handling of offsite tritium containers.

Waste tanks 4-F, 17-F, 19-F, and 21-H received waste and tanks 21-H to 24-H placed in service in H Area.

Soviet cosmonaut, Yuri Gagarin, is first in space on landmark mission to orbit earth in Vostok I. From blastoff to landing, the trip lasted one hour and 48 minutes.

CIA-backed invasion of Cuba at the Bay of Pigs fails in April.

Berlin Wall erected in August.

Kennedy advises Americans to build fallout shelters to reduce U.S. vulnerability to nuclear attack.

Soviet Union explodes largest nuclear device in history, equal to 57 million tons of TNT, despite assurances to U.S. that all testing had ended.

Glenn Seaborg, Chairman of Atomic Energy Commission, begins push for transplutonium programs, 1961–71.

Development begins on isotope heat sources to power space satellites.

Alan Shepard, first American in space.

S.C. institutes innovative technical education program.

1962

1962–65—First confinement system (filters) installed to capture possible radioactive materials in exhaust air.

Heavy Water Components Test Reactor (HWCTR) begins operations. Designed to test components for heavy-water-cooled power reactors, as part of a general AEC program to test heavy-water-cooled power reactors for commercial use. Shutdown in 1964.

Waste tank 11-H receives HM high-level waste.

Cuban Missile Crisis: U.S. blockade of Cuba, October.

1963

First production of curium-244 as heat source for space program. First request for transplutonium isotopes.

John Glenn first American to orbit the earth.

SAVANNAH RIVER SITE TIMELINE

Waste tank 12-H receives HM high-level waste. Building 235-F switched from neptunium fabrication to curium-244 fabrication.

NATIONAL/STATE EVENTS TIMELINE

Limited Test Ban Treaty (LTBT) signers agreed not to test nuclear weapons in the atmosphere, in outer space, or under water.

Civil rights march on Washington, September.

President Kennedy assassinated, November 22, Lyndon Baines Johnson assumes presidency (1963–1969).

1964

R Reactor is shut down.

Computers installed in SRP reactors: GE412 online process computers used for monitoring. First known application of a computer to a nuclear reactor.

1964–67

Curium I program, 1964.
High Neutron Flux Program, 1955–66.
High Flux record, 6.1×10^{15} n/(cm^2)(sec), December, 1965.
Curium II program, 1965–67.

Thorex Campaign begins this year and continues through 1969.

1964–67— High specific activity cobalt-60 campaign. The highest specific activity Cobalt-60 ever produced is made at SRP. Record achieved February 9, 1966. This isotope was used in medicine, research, and industry. SRP reactors produced cobalt-60 of unusually high specific activity for experimental and other special needs.

Waste tank 6F receives Purex high-level waste. RBOF sends waste to tank 23-H.

Receiving Basin for Offsite Fuel (RBOF) completed and first offsite fuels received.

President Johnson announced reduction of nuclear material production in January.

Civil Rights Act signed into law, July.

Gulf of Tonkin Resolution, August, paves way for greater American involvement in Vietnam.

1965

C Reactor achieves the highest sustained neutron flux ever attained, Significant event in reactor technology.

RBOF ships first offsite fuel to canyon for processing.

F and H canyons stop alternating operations.

Height of Vietnam War, 1965–71.

SAVANNAH RIVER SITE TIMELINE	NATIONAL/STATE EVENTS TIMELINE
1966	
First-generation computers were installed in the four operating reactors by 1966 to improve reactor instrumentation.	
1967	
Record SRP reactor power level, 2915 mw, in C Reactor.	First major antiwar protest: March on the Pentagon.
The University of Georgia renames ecology lab the Savannah River Ecology Laboratory.	
H Area to F Area waste transfer line completed.	
1968	
L Reactor is shut down.	Martin Luther King, civil rights activist, is assassinated on April 4.
A major computational code called JOSHUA developed at SRL to quickly design reactor cores for completely new isotope production systems.	Robert Kennedy, presidential candidate, is assassinated on June 6.
First use of the Universal Sleeve Housing (USH) in reactor charges.	Richard M. Nixon elected president, November (1969–1974).
Shutdown of C Reactor for tank wall repair.	
U.S. Forest Service plants 100 millionth pine seedling on site in November.	
1969	
Tritium facility began recycling reservoirs.	Apollo XI moon landing, July 20, 1969.
1969-70- Californium I program is introduced, producing 2.1 g of Californium-252, the greatest amount ever made. Application of this isotope included cancer treatment, and terrestrial and underwater exploration for natural resources.	

SAVANNAH RIVER SITE TIMELINE

Use of AEC's SNAP-27 nuclear generator on lunar surface by Apollo 12 astronauts. The plutonium-238 used in the generator was produced at SRP.

NATIONAL/STATE EVENTS TIMELINE

1970

SRP receives AEC's "Best Ever" Award in industrial safety for having accumulated the largest number of injury-free man hours ever achieved by an AEC contractor.

1970–74—Closed Loop computer control of the reactors implemented for control and safety.

Construction begins on Multi-Purpose Processing Facility (MPPF) designed to separate 252-Cf and other isotopes.

First Earth Day celebrated on April 22 launching environmental movement.

National Environmental Policy Act (NEPA) of 1969 signed and the U.S. Environmental Protection Agency (EPA) established.

Non-Proliferation Treaty (NPT) signers agreed not to aid nonnuclear powers in developing nuclear weapons.

1971

Standby equipment in 400 Area (Buildings 411-D, 413-D, and E plant) dismantled and sold for scrap.

Waste tanks 29-H and 32-H begin receiving waste. All solid waste burial records computerized into COBRA system.

Huge antiwar march in Washington, DC.

1972

Establishment of SRP as a National Environmental Research Park.

Development of Mark 22, the ultimate tritium producer, with its combination of inner and outer fuel and target tubular elements.

Solid waste burial ground enlarged to 195 acres. Tank 31-H begins receiving waste concentrate.

MPPF Building completed and put on standby.

Republican agents burglarize Democratic headquarters at Watergate.

Antiballistic Missile Treaty—U.S. and Soviet Union agree to limit antiballistic missile sites to two each.

Strategic Arms Limitation Treaty (SALT I)—U.S. & Soviet Union agree to limit number of missile launchers.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1973

Meteorologists added to SRL and meteorological monitoring begins. Weather Information and Display (WIND) system developed at SRP to predict realtime consequences of both airborne and liquid releases of radionuclides or toxic chemicals from production.

SRL participated in the National Uranium Resource Evaluation Program (NURE) to evaluate U.S. uranium resources and to identify areas favorable for uranium exploration.

SRP adopts use of the thermoluminescent dosimeter (TLD) to monitor radiation exposure.

U.S. Forest Service develops and implements SRS ecosystem management plan.

SREL begins thermal ecology program to investigate the ecological effects of hot water from SRP reactors on the fauna and flora of streams, ponds, and swamps. Hosts scientific symposium on the field of thermal ecology.

Waste Tank 34-F begins receiving waste concentrate.

400 Area begins purchase of hydrogen sulfide from offsite vendor.

U.S. troops leave Vietnam; the Paris Accord which ended American involvement in Vietnam signed January 27.

Arab oil embargo causes severe shortage and energy prices skyrocket.

Spiro Agnew, Nixon's vice-president, resigns.

Gerald Ford, congressman from Michigan, becomes the new vice president.

1974

H Area processes low-enriched offsite fuel.

First inter-area waste transfer occurred in April. Tank 33-F in service.

Economy in worst recession in 40 years.

Watergate Crisis; Nixon resigns, August 9, 1974.

Ford becomes the 38th president after Richard Nixon, facing impeachment charges, is forced to resign. Ford remains in office until 1977.

Threshold Test Ban Treaty (TTBT)—U.S. and Soviet Union agree to limit underground tests to 150-kiloton devices.

AEC established the Formerly Utilized Sites Remedial Action Program (FUSRAP) to identify former AEC sites that were privately owned, but needed environmental clean up.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

Energy Reorganization Act of 1974 abolished the AEC and creating the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC).

1975

Fire and explosion in A-Line causes F canyon shutdown from February to August.

NURE Program initiated in C Area.

U.S.F.S. Savannah River Project renamed Savannah River Forest Station by DOE.

South Vietnam falls to Communist forces of North Vietnam on April 30.

Resource Conservation and Recovery Act (RCRA) passed.

1976

Buttresses were added to reactor towers to strengthen them in the event of seismic activity.

Jimmy Carter elected president, in November (1977–1981).

1977

Plutonium Fuel Form Facility operational to manufacture plutonium-238 for space programs

Organization of Palmetto Alliance an antinuclear and consumer advocacy group active in South Carolina.

South Carolina Department of Health and Environmental Control (SCDHEC) becomes first state agency to have jurisdiction over a federal facility. SCDHEC asks SC attorney general to fine site $10,000 a day for failure to meet state and federal clean air standards.

SREL moves into its new facility in DOE headquarters area.

U.S. Department of Energy (DOE) replaces the Energy Research and Development Administration (ERDA), becoming the twelfth cabinet level department in the Federal government.

James R. Schlesinger serves as first Secretary of Energy (1977–1979).

President Carter bans the recycling of used or spent nuclear fuels from commercial reactors.

Voyager 2 spacecraft launched to explore outer planets of our solar system.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1978

Savannah River Archaeological Research Program established full time onsite, University of South Carolina and South Carolina Institute of Archaeology and Anthropology staff program.

Residents of Love Canal, NY, evacuated due to dangerous toxic chemicals buried in the area.

U.S. cancels development of neutron bomb.

Uranium Mill Tailings Radiation Control Act passed. Directed DOE to stabilize and control uranium mill tailings at inactive milling sites.

1979

Process Development Pile closed down in Building 777-M. Made obsolete by advent of powerful computers.

Three-day anti-nuclear protest staged at site.

Charles Duncan Jr. serves as Secretary of Energy (1979–81).

Radioactive emission at Three Mile Island nuclear powerplant, near Harrisburg, Pennsylvania, on March 28 caused by a partial core meltdown of TMI-2.

South Carolina creates Nuclear Advisory Council and curtails the shipment of low-level waste into state in reaction to Three Mile Island.

U.S. and Soviet Union sign Strategic Arms Limitation Treaty (SALT) II limiting each side's arsenals and restricting weapon development and modernization.

U.S. hostages taken in Iran in November.

Soviet Union invades Afghanistan in December. U.S. boycotts Moscow Summer Olympics as consequence and stops ratification process of SALT II.

1980

Five-year Restoration Program for process facilities is launched.

Beginning of L Reactor Restart Program. First time a mothballed reactor had been restarted.

Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) passed in response to discovery in late 1970s of abandoned leaking hazardous waste dumps.

Ronald Reagan elected president in 1980 (1981–1989).

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

SRL begins major program to develop and use metal hydrides in its tritium production facilities.

1981

305-M graphite test pile shut down.

SRL development of thermal cycling absorption process (TCAP), an SRS-patented technology used to separate hydrogen isotopes allowing enrichment of gas in reservoirs.

M-Area Settling Basin cleanup begins under the Resource Conservation and Recovery Act.

Study conducted by Computer Systems Division (CSD) of SRL on automation needs for laboratory researchers. Group recommends establishing a local area network (LAN) based on Ethernet.

Columbia, America's first reusable spacecraft, was launched in 1981.

James B. Edwards serves as Secretary of Energy (1981–1982).

1982

Last of the Heavy Water Production Units, Building 412-D, shut down.

Development of Robotics Technology Group at SRL.

Diagnosis of Multiple Alarms Computer: This system was developed at SRP to assist reactor operators at SRP in their response to developing incident or accident situations.

Beginning of automation of canyon processes, with installation of Distributed Control System (DCS) in F Area warm canyon.

Tracking Atmospheric Radioactive Contaminants (TRAC) vehicle built.

Genesis of site computer network, called SRSnet.

Underground counting facility built in technical area for highly sensitive counting and measurement.

Six anti-nuclear protesters known as the "Savannah River Six" arrested for trespassing on government property.

Donald P. Hodel serves as Secretary of Energy (1982–1985).

Shippingport nuclear power plant retired.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1983

Impoundment of L Lake.

Groundbreaking ceremonies held for the Defense Waste Processing Facility (DWPF).

Nuclear Waste Policy Act of 1982 signed authorizing the development of a spent fuel and high-level nuclear waste repository.

President Reagan announces the Strategic Defense Initiative (SDI), a satellite-based defense system that would destroy incoming missiles and warheads in space.

DOE begins construction of the Defense Waste Processing Facility at SRP.

1984

Wackenhut Services, Inc. assumes responsibility for plant security.

Legal Environmental Assistance Foundation vs. Hodel ends with court ruling that DOE's Y12 Plant in Tennessee was subject to the Resource Conservation and Recovery Act. This decision implies that DOE would need to comply with RCRA nationwide.

1985

C Reactor is shut down for repairs, and finally shut down permanently by order of the DOE in 1986.

Formation of Computer Projects Department.

HB-Line begins producing plutonium-238 for NASA's deep space exploration program.

Beginning of DOE's Subsurface Microbiology Program.

A full-scale groundwater remediation system built in M Area.

Soviet Union announces a nuclear testing moratorium which lasted from August 1985 through 1987.

Mikhail Gorbachev becomes leader of Soviet Union.

John Herrington serves as Secretary of Energy (1985–1989).

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SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1986

Reactor simulator system developed to train reactor operators in operations and for correct responses to emergency conditions.

Construction complete on the Naval Fuel Materials Fuel Facility.

Construction begins on Replacement Tritium Facility.

Ethernet LANs installed in each building area. LANs connected using site CATV system and broadband Ethernet bridges. SRSnet became one of the largest "campus" networks in country.

Space shuttle Challenger exploded 74 seconds after liftoff at Cape Canaveral, Florida, killing all seven astronauts in January.

Arms control summit in Geneva. Gorbachev makes proposal for disarmament that results in the Intermediate Range Nuclear Forces Treaty.

Chernobyl Nuclear Reactor meltdown and fire in the Soviet Union in April.

Hanford's N Reactor, which was similar to the Chernobyl reactor, is shut down in response to Chernobyl incident.

1987

Administrative limits were placed on reactor power levels, due to concerns over uncertainties about emergency cooling systems (ECS). New power levels were an average 1200 mw.

Du Pont announces it will not renew contract to operate SRP.

Reagan and Gorbachev meet in Reykjavik, Iceland, to discuss reducing armaments by half over a five-year period and then eliminating all offensive nuclear weapons by 1997.

Intermediate-Range Nuclear Forces (INF) Treaty signed by superpowers that called for elimination of a whole class of intermediate range missiles.

Nuclear Waste Policy Amendments Acts designated Yucca Mountain, Nevada, as candidate site for the nation's first geological repository for high level radioactive waste and spent nuclear fuel.

Era of Glasnost in Soviet Union, 1987–89.

1988

All remaining reactors are shut down (K, L, P). News releases on reactor incidents cause public debate on reactor safety.

DOE announces that Westinghouse Savannah River Co. will replace Du Pont, in September.

Effluent Treatment Facility begins treating low-level radioactive wastewater from F- and H-Area separations facilities.

George Bush elected president, November (1989–1993).

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1989

Westinghouse Savannah River Company becomes contractor at SRP, April.

Savannah River Plant becomes Savannah River Site, reflecting mission change.

Naval Fuel Materials Facility placed on standby.

Reactor Restart Program begins. Work concentrates on K Reactor.

Integrated Demonstration Project begins in M Area, achieves national and international recognition for contributions to fundamental and applied research on innovative technology for characterizing and cleaning soils and groundwater.

SRS is officially included on the National Priority List and, as such, is regulated by the EPA.

Tiananmen Square Massacre on June 4.

Fall of the Berlin Wall, November.

Collapse of Communist governments in Eastern Europe.

Establishment of Office of Environmental Restoration and Waste Management within DOE. Rocky Hills Flats, Colorado, and Fernald Feed Materials Production Center in Ohio cease production and begin operating as sites.

James Watkins serves as Secretary of Energy (1989–1993).

1990

SRS response to technology transfer making government based technologies available to public.

Construction of K Reactor Cooling Tower, 1990–1992.

Saltstone Facility (a part of the Defense Waste Processing Facility Operation) becomes operational.

Conference on Security and Cooperation in Europe formally ends Cold War. Months later Warsaw Pact is formally dismantled.

Saddam Hussein invades Kuwait; the Gulf War results.

1991

SRS employees reach post-construction peak of 27,000.

Creation of Citizens for Nuclear Technology Awareness (CNTA).

Restoration of Lost Lake, a Carolina Bay, in M Area vicinity.

Site, led by Information Resource Management Department (IRM), publishes blueprint for transformation of SRSnet to a PC LAN system.

U.S. and Soviet Union sign agreement to cut back long-range nuclear weapons by more than 30% over a seven-year period.

Soviet Union dissolved in wake of failure of hard-line Communist uprising, in August. Boris Yeltsin becomes president of independent Russia.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

Mixed Waste Management Facility is the first SRS facility closed and certified under the provisions of the Resource Conservation and Recovery Act.

Tritium leaked into Savannah River creates adverse publicity for K Reactor Restart Program, December.

1992

Savannah River Laboratory renamed Savannah River Technology Center.

K Area cooling tower completed.

K Reactor goes critical for test run, June 8.

SRL's nonproliferation technologies move forward.

Launching of SRS Dose Reconstruction Project, in October.

SRSnet connected to Internet.

Workstation Integration System for Desktop Office Machines (WISDOM) implemented. Standardized site PC computer use.

President Bush announced that the U.S. would no longer produce plutonium or enriched uranium for nuclear warheads. Hanford changes its mission from production to environmental cleanup of its facilities.

Push within DOE for technology transfer programs to place innovative technologies developed by government scientists into the hands of firms in the private sector.

Bill Clinton elected president, November (1993–2000).

1993

Hazel O'Leary announces that K Reactor would not be restarted, November.

K Reactor placed in cold standby as Nation's tritium source.

Construction begins on Consolidated Incineration Facility.

Tritium introduced into the Replacement Tritium Facility and radioactive operations begin.

Workforce Transition and Community Assistance begins at SRS.

U.S. Forest Service develops the SRS Natural Resource Management Plan (NRMP).

Hazel R. O'Leary serves as Secretary of Energy 1993–1997.

American involvement in Somalia.

"Breaking the Silence"—Selective but large-scale declassification effort begins of historical data within DOE records.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1994

Replacement Tritium Facility, 233-H, begins operations, including unloading gases from reservoirs returned from the Department of Defense, separating and purifying the useful hydrogen isotopes (tritium and deuterium), mixing the gases to exact specifications, and loading the reservoirs.

Savannah River Site Citizens Advisory Board is formed to provide public input into SRS decision-making in the areas of environmental restoration, waste management, technology, and development, and related activities at SRS.

U.S. troops used in overthrow military dictatorship in Haiti.

1995

DOE calls for bids for new SRS contractor operator.

Completion of Replacement Telephone System (RTS) which replaced all site telephone switches and installed fiber optic backbone tying site areas together.

Alfred P. Murrah Federal Building in Oklahoma City bombed by American terrorists on April 19, 1995.

1996

Westinghouse Savannah River Co. re-awarded contract for SRS. Also brought on board for the 1996 Contract renewal were Bechtel, Babcock & Wilcox Co. (later, BWX Technologies), and British Nuclear Fuels, Ltd.

Defense Waste Processing Facility begins operations.

Unexpected benzene buildup causes delay in the disposal of liquid salt waste.

F canyon restarts and begins stabilizing nuclear materials.

Savannah River Information Network Environment (SHRINE), a system of web servers, introduced for internal site use.

20,000 American troops were deployed to Bosnia as part of a NATO peacekeeping force.

SAVANNAH RIVER SITE TIMELINE

NATIONAL/STATE EVENTS TIMELINE

1997

F Area Tank 20 closed. First of its kind in the DOE complex to be closed.

Opening of SREL's Ecology Laboratory Conference Center.

Groundbreaking for expansion of Ruth Patrick Science Education Center, University of South Carolina-Aiken.

Savannah River Forest Station renamed Savannah River Natural Resource Management and Research Institute (SRI).

First official classes offered at Environmental Sciences Field Station. This program was initiated in 1996 in cooperation with South Carolina State University. This is the only field station in the nation that provides field education opportunities in environmental sciences for undergraduates from minority institutions.

Federico Peña named Secretary of Energy (1997–1998).

1998

Development of MOX fuel mission.

Bill Richardson named Secretary of Energy (1998–2001).

1999

South Carolina Department of Natural Resources assumed primary management of the Crackerneck Wildlife Management Areas and Ecological Reserve.

U.S. joined NATO in air strikes against Yugoslavia in an effort to halt the Yugoslavian government's policy of ethnic cleansing in its province of Kosovo.

2000

Groundbreaking for Tritium Extraction Facility, July.

Fiftieth Anniversary of Site's announcement is celebrated. Anniversary committee headed by former manager John Granaghan, with support of CNTA, creates year-long celebration of Savannah River and its history.

Albert Einstein named "Man of the Century" by *Time* magazine.

Biographies

Manager Biographies
Department of Energy and Predecessor Agencies

Curtis A. Nelson

Curtis Nelson, a Nebraska native and engineer, was the first manager of the Atomic Energy Commission's newly established Savannah River Operations Office. He was responsible for overseeing the Savannah River Project's design and construction, and for establishing an identity for the new plant, both within the AEC complex and within the local communities.

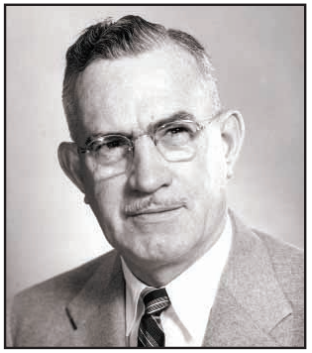
Posted months before the project was announced, Mr. Nelson brought a wealth of construction experience to his position at SRP. He had gained that experience as a member of the Corps of Engineers, the Civilian Conservation Corps, and the Federal Works Agency, supervising the large-scale construction of buildings, dams, and railroads and engineering aspects of lake restoration and river diversions during the 1930s. Mr. Nelson had more than ten years active duty with the U.S. Army, and held a reserve commission as colonel in the U.S. Army Corps of Engineers. As Captain Nelson, he was assigned as constructing quartermaster to Joliet, Illinois, where he became responsible for the construction of the Ordnance Plant in 1941.

His experience with atomic energy began in 1943 when he was assigned to the Manhattan Engineering District, Army Corps of Engineers at Oak Ridge. In 1947, he became the U.S. liaison to Canada's heavy-water production facility at Chalk River, Ontario. This assignment helped prepare him for his future work at SRP. Mr. Nelson was assigned to SRP in June of 1950, where he oversaw design and construction of what was then the largest construction project ever undertaken by the Atomic Energy Commission. He served as SRP's manager through January of 1955, after which, he became the first director of the Atomic Energy Commission's Inspection Division in Washington, which was newly created under the Atomic Energy Act of 1954. He retired from federal service in 1969.



Curtis A. Nelson (1950–1955)

Sources: A.E.C. Savannah River Operations Office, Biography donated by Nelson Family; *SRP News and Views*, Volume 3, No. 25, January 28, 1955; *SRP News and Views,* Volume 2, No. 26, February 4, 1955; Savannah River Operations Office, Press Release No. 668, "C.A. Nelson, First AEC Manager at Savannah River Plant, Will Retire from Federal Service," October 28, 1969. Courtesy of SRS Archives, negative CurtisNelson.jpg.



Robert C. Blair (1955–1965)

Robert C. Blair

Robert Blair succeeded Curtis Nelson in February of 1955, after having worked as deputy manager under Curtis Nelson since the beginning of the Savannah River Project. His tenure, which lasted through 1965, witnessed the startup of operations, the training of a mostly agricultural workforce into industrial workers, and the absorption of the plant and its workers into the fabric of the Central Savannah River Area. During the Nelson and Blair years, the plant was a catalyst for the growth of academic programs in science and engineering in the region's schools and universities, and for the development of professional organizations within engineering disciplines.

Robert Blair was a native of Urbana, Illinois, and studied civil engineering at the University of Illinois, after which he served with the U.S. Army Corps of Engineers in Tennessee, and later with the St. Louis District. At the outbreak of World War II, he was head engineer of the Syracuse New York District. He entered military service in 1942, advancing to lieutenant colonel in 1943, when he was serving in the Manhattan Engineer District. Blair was one of the first engineers chosen by Col. James C. Marshall, MED District Engineer, to join the newly formed Corps district in 1942. An organization chart for April 1943 shows him third in command as executive engineer. He continued in this post through the summer of 1943, participating in the site-selection process for Oak Ridge. When the leadership of the Manhattan District changed in July of 1943, Blair and others of the "old guard," under Col. Marshall, left the MED and went overseas. At the close of the war, Blair was in the Southwest Pacific Theater as commander of the 5222 Engineer Brigade (Construction), Headquarters and Headquarters Company in the Philippines and Japan. For his war service, he was awarded the Bronze Star and the Legion of Merit. During the postwar years, Blair initially returned to the Corps of Engineers, but left there to pursue work in the private sector in a position with an American engineering firm based in Argentina. On his return to the U.S. in 1949, he accepted a position with the Military Application Division of the AEC in Washington. From that job, he was transferred with Nelson to the new operations office in Augusta.

During the decade that he managed the plant, Mr. Blair received many accolades within his profession. He received an honorary doctorate in engineering from Clemson University in 1957 for "outstanding public service in applying the basic principles of engineering to the national interests in an atomic age." He was named South Carolina Engineer of the Year in 1961, and he served as president of two professional organizations: the South Carolina Section of the American Society of Civil Engineers and the South Carolina Society of Professional Engineers. He was also recognized for his record of community service with the Rotary Club, Aiken Chamber of Commerce, American Legion, Aiken Salvation Army, Aiken County United Fund, and the Georgia-Carolina Boy Scout Council. He was honored with Aiken's "Man of the Year" award in 1964. Mr. Blair retired from federal service in 1965 in Aiken, setting a precedent that future Savannah River Operations Office managers would follow.

Sources: *SRP News and Views*, Volume 3, No. 25, January 28, 1955, *SRP News and Views*, Volume 2, No. 26, February 4, 1955, *SRP News and Views*, Volume 13, No. 13, December 10, 1965; *Aiken Standard and Review*, December, 1, 1965. Courtesy of SRS Archives, negative RobertCBlair.jpg.

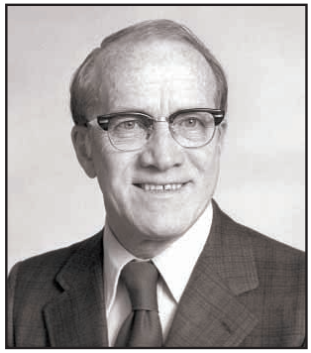
Nathaniel Stetson

Nathaniel Stetson, a New Bedford, Massachusetts, native, headed the Savannah River Operations Office of the Department of Energy and its predecessor agencies for fourteen years, keeping pace with the Cold War defense production mission set by the federal government. Under Mr. Stetson's guidance, SRP developed programs to further peaceful applications for atomic energy. Specifically, he administered a program to verify the quantities of nuclear materials consumed and produced through operation of some of the nation's privately owned power reactors. He also administered the AEC's interests in the development and operation of the first privately owned plant for reprocessing spent reactor fuels from the nuclear power industry. In the early 1960s, he established cooperative programs involving the heavy-water power production system with Canada, Great Britain, France, Norway, and Sweden. He served as the Vice Chairman of the Fuel Cycle Committee of the Nuclear Energy Agency, headquartered in Paris. Regional partnership in education in the fields of science and technology remained a focus under Mr. Stetson. His tenure also witnessed changes in American society that stemmed from the Vietnam War, the civil rights movement, and environmentalism. He set a path for the plant's future within this changing national environment.

In 1941, Mr. Stetson was employed in the research and development department of Celanese Corporation of America in Maryland. While there, he studied problems associated with pigmented yarn and developed an olive drab pigment for use in yarns and fabric that was used by the U.S. Army in their coat linings. He began a one-year stint with the U.S. Chemical Warfare Service in Denver in charge of plant maintenance, after which he joined the Tennessee Eastman Corporation at Oak Ridge. Mr. Stetson was in the forefront of the nation's atomic energy program. At Oak Ridge, he helped direct the startup and operation of the electromagnetic process for the separation of uranium-235 in 1944. He was associated with Carbide and Carbon Chemical Company at Oak Ridge between 1947 and 1952, directing research in the Electromagnetic Research Division. He was instrumental in the design and development associated with particle accelerators and physics research associated with the behavior of electromagnetic fields. In addition, he helped organize and administer a radioisotopes production program on the 86-inch cyclotron.

Mr. Stetson joined the Savannah River staff of the Atomic Energy Commission in 1952 as a production engineer. From that position, he progressed into management. He was named Assistant Director for Operations in 1955 and later Deputy Director of the Technical and Production Division. He also was part of a detail assigned to establish the Civilian Reactor Division of the AEC and was later named Director of that group. He held this position until he was transferred to AEC headquarters in 1962. Between 1962 and 1966, Nathaniel Stetson served as Deputy Director of the Division of Production until he was named Manager, Savannah River Operations office on January 1, 1966, succeeding Robert Blair as manager.

Mr. Stetson was educated at the New Bedford Textile Institute; he earned his bachelor's degree at North Carolina State University in chemical engineering. He continued with post-graduate studies at Illinois Institute of Technology and was awarded an honorary Doctor of Science degree from Southeastern Massachusetts University in 1968. When he retired in 1980, he maintained membership in such professional organizations as the American Chemical Society, the American Nuclear Society, and the American Association



Nathaniel Stetson (1965–1980)

for the Advancement of Science. He is listed in *Who's Who in America and Who's Who In Government*.

Community service was a significant part of Mr. Stetson s career. He was instrmental in the formation of the Citizens for Nuclear Technology Awareness and served on its board. Notably, he served on the Aiken County Commission on Higher Education from 1968 and acted as vice chairman of the commission in 1980. The Aiken Rotary Club, Aiken Businessman's Club, Aiken County Red Cross Chapter, the Salvation Army, the United Way of Aiken County, the Georgia-Carolina Council of Boy Scouts, and the Augusta Radiation Therapy Center, all benefited from his service in a variety of capacities.

Sources: *Savannah River Plant News,* Volume XXVII, No. 24, February 7, 1980; *Savannah River Plant News*, Volume XXVII, No. 26, March 6, 1980; *Aiken Standard and Review*, December, 1, 1965; *The Augusta Chronicle*, March 13, 2001; and A.E.C. Savannah River Operations Office Biography, not dated. Courtesy of SRS Archives, negative Nathanial Stetson.jpg.



Robert L. Morgan (1980–1988)

Robert L. Morgan

Robert Morgan, a West Point graduate and Massachusetts Institute of Technology alumnus with advanced degrees in civil and nuclear engineering, served as deputy manager at SRP under Mr. Stetson between 1973 and 1976. He also served as assistant manager for Health, Safety and Environment in 1978 before becoming SROO manager in 1980. Mr. Morgan managed SRP during the tumultuous 1980s. L Reactor restart, the upgrading of the main process facilities, and expansion of the administrative complex in the 700 Area all occurred under his tenure.

Mr. Morgan joined the Atomic Energy Commission in 1965, working within the commission's reactor development programs. He was senior site representative at the Agency's Canoga Park Office in California; he had also served as director of Savannah River's Heavy Water Cooled Reactor Division. Between 1977 and 1978, he was detailed to Washington, serving as acting director of Field Operations Management for the Assistant Secretary for Energy Technology, and the following year, he was acting director of the Office of Nuclear Waste Management.

Mr. Morgan's eight-year tenure was spent between SRS and DOE headquarters, as he maintained duties in both the field and at headquarters. In 1981, he served as acting Assistant Secretary for defense programs in Washington, and completed a three-month stint as acting Deputy Undersecretary (July 1981 through September1981). Mr. Morgan's responsibilities in Washington continued between 1983 and 1984 when he directed the development of the Nuclear Waste Policy Act and then served as DOE's Deputy Assistant Secretary for Defense Programs. Mr. Morgan provided a complex-wide leadership role in increasing production that is considered to have accelerated the end of the Cold War. He returned to his SROO post in 1984, residing in Aiken with his family. Mr. Morgan retired four years later, after 39 years of federal service.

Sources: *Savannah River Plant News,* Volume XXVII, No. 26, March 6, 1980; *Savannah River News*, Volume XXXV, No. 4, March 3, 1988. Courtesy of SRS Archives, negative RobertMorgan.jpg.

Paul W. (Bill) Kaspar



Paul W. Kaspar (1988–1991)

Mr. Kaspar, formerly acting Deputy Assistant Secretary for Operations in DOE's defense programs at headquarters, managed the plant for a short but significant time for SRS. His tenure coincided with many pivotal events: the end of the Cold War, the transition of the plant into a site; and contract change when Westinghouse assumed responsibility for the plant.

Having worked in DOE's San Francisco Operations Office as an assistant manager for energy research in technology, Mr. Kaspar later served as assistant manager for safety and environment at Oak Ridge during the early 1980s. He subsequently served as deputy manager at that location from 1984 to 1987. He was acting Deputy Assistant Secretary for operations between 1987 and 1988 in Washington. Mr. Kaspar is retired.

Sources: *Savannah River Plant News*, Volume XXVII, No. 26, March 6, 1980; *Savannah River News*, Volume XXXV, No. 4, March 3, 1988. Courtesy of SRS Archives, negative PWBillKasper.jpg.

Peter M. Hekman



Peter M. Hekman (1991–1993)

Vice Admiral Hekman, a graduate of the U.S. Naval Academy with a degree in naval science, and a MS in management degree from the Naval Postgraduate School, was appointed manager of the Savannah River Field Office in 1991. Nick Aquilina, manager of the Nevada Field Office, served temporarily in this capacity until Vice Admiral Hekman's appointment. Although the groundbreaking for the Defense Waste Production Facility occurred in the 1980s, the facility began operations in 1992 under Vice Admiral Hekman's management.

Vice Admiral Hekman, a California native, enjoyed a 39-year Navy career, including command of the *USS Benjamin Stoddert* and the *USS Mississippi*. Following his promotion to Rear Admiral in 1982, Admiral Hekman' s flag rank assignments include: Deputy Director of Operations, National Military Command Center, Office of the Joint Chiefs of Staff; Commander, Cruiser-Destroyer Group One; Commander, Task Force SEVENTY-FIVE; Deputy Director, Office of Research, Development, Test, and Evaluation, in the Office of the Chief of Naval Operations; and Deputy Director of Surface Combatants, Naval Sea Systems Command. In 1988 he assumed command of the Naval Sea Systems Command. He received the Defense Superior Service Medal, Legion of Merit (with three gold stars), the Bronze Star model, the Navy Commendation Medal, the Navy Achievement Medal, the Armed Forces Expeditionary Medal, and numerous service and campaign ribbons.

Source: U.S. Department of Energy, Savannah River Operations Office, Biography, August, 1991. Courtesy of SRS Archives, negative PeterHeckman.jpg.



Mario P. Fiori (1993–1997)

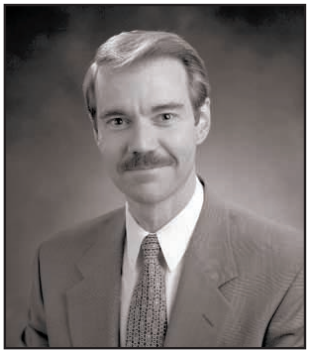
Mario P. Fiori

Mario P. Fiori, a resident of Martinez, GA, managed SRS during a period of reassessment of past missions and the environmental legacy they created, and the exploration of new missions for the future. Under his management, the site was the recipient of scores of awards for safety, environmental innovation, and technology transfer on the local, state, and federal level. During this process of redefinition came the need to honor the past; the current Cold War historical programs on site also emanate from Mr. Fiori's vision.

Dr. Fiori earned his undergraduate degree at the U.S. Naval Academy. His graduate work was completed at the Massachusetts Institute of Technology, where he earned an MS in mechanical engineering, a nuclear engineering degree, and a Ph.D. in nuclear engineering. During 26 years of service in the United States Navy, Dr. Fiori served as Commander, Submarine Squadron Four; Assistant to the President's Science Advisor; Commander, *USS Spadefish* (a nuclear attack submarine); and senior executive of the Naval Underwater Systems Center, a major Naval Research and Development facility.

As the Department of Energy's representative to the Defense Nuclear Facilities Safety Board (DNFSB) from October 1991 to January 1993, Dr. Fiori was responsible for facilitating the DNFSB' s efforts in fulfilling its congressionally mandated safety oversight role. The DNFSB was established by statute to provide independent external oversight of the Department of Energy's defense-related operations and facilities.

Source: U.S. Department of Energy, Savannah River Operations Office, Biography, May, 1997. Courtesy of SRS Archives, negative Mario Fiori.jpg.



Greg Rudy (1998–present)

Greg Rudy

Greg Rudy is the current Savannah River Operations Office manager. He began his duties in October 1997 as Acting Manager, having ten months' previous experience at the Site as Deputy Manager. Mr. Rudy is responsible for bringing the Site into the 21st century with new missions, safely handling the environmental legacy of the Site's Cold War defense mission, and continuing the Site's tradition of innovation, research, and development in the nation's interest. The site has received numerous awards under his management for safety, scientific achievement, and pollution prevention, and had received the Weapons Complex Award of Excellence. His experience within the Department's national defense and nuclear energy-related programs shows a wide familiarity with naval reactors, civilian nuclear energy, commercial nuclear fuel services, the nuclear weapons program, and the disposition of surplus weapons plutonium and highly enriched plutonium.

Born in Hammond, Indiana, Mr. Rudy earned his graduate degree from Purdue University's Krannert School of Management. He first participated in the Department of Energy's nuclear energy programs in 1977 when he served on the headquarters staff of Admiral Hyman Rickover, the Director of the Naval Nuclear Propulsion Program. Later

Mr. Rudy would serve on numerous departmental task forces and special assignments, representing DOE in interagency, domestic, and international forums. Prior to 1987, he served in Washington as the Special Assistant to the Department's Assistant Secretary for Nuclear Energy. Between 1987 and 1990, he acted as the Deputy Director for Marketing and Sales in the Department of Energy's Uranium Enrichment Services.

Mr. Rudy served as the Executive Director for Policy, Planning and National Environmental Policy Act Coordination in the Department's Office of Defense Programs between November 1990 and January 1994. From that assignment, he led DOE's Office of Fissile Materials Disposition as Acting Director and Deputy Director prior to his appointment as Acting Manager to SRS in October 1997.

Source: U.S. Department of Energy, Savannah River Operations Office, Biography, October, 1999. Courtesy of SRS Archives, negative Greg Rudy.jpg.

Prime Contractor

Don A. Miller



Don A. Miller (1952–1957)

Born in Plantsville, Connecticut, in 1906, Don A. Miller graduated from Tufts College with a degree in chemistry. He joined Du Pont as a chemist at Eastern Laboratory in Gibbstown, New Jersey, on graduation. In 1936, Mr. Miller became part of the production staff at the Du Pont Explosives Department. After several assignments, he was sent to the GOCO plant in Charlestown, Indiana, where he became general superintendent in 1944.

Don Miller was then assigned to the government's atomic energy project as a technical specialist in 1945. Shortly thereafter, he became plant manager of the Hanford Engineering Works at Richland, Washington. He managed the heavy-water production facility known as the Dana Plant in Newport, Indiana, prior to coming to Savannah River Plant as manager in March 1952. He was handpicked for the job. Mr. Miller managed SRP until October 1957, placing the enormous plant into operation, training a new workforce, and helping to root the plant into its new community. In accordance with Du Pont company philosophy in which managers serve about five years and then are reassigned, he was detailed to Du Pont's Niagara Falls facility in 1957. In the early 1990s, when asked about his contribution to the site's history, Don Miller noted that the training of the site's new personnel was his strongest contribution.

Source: *SRP News and Views,* Volume I, No. 2, March 14, 1952. Courtesy of SRS Archives.

Julian D. Ellett



Julian D. Ellett (1957–1966)

A Virginia native, Julian D. Ellett received his education in chemical engineering at Virginia Tech, and then worked for Du Pont's Spruance Plant in Richmond as shift supervisor beginning in 1936. During World War II, Ellett served at Chickasaw Ordnance

Works in Memphis, Tennessee, Kankakee Ordnance Works in Joliet, Illinois, and the Oklahoma Ordnance Works. He was later assigned to Du Pont's program for the Manhattan District in 1943 and then the Hanford facility in Washington where he became assistant superintendent of the Separations Department. Between 1946–50, Ellett moved back into commercial operations as a production supervisor at the Arlington, New Jersey, Plastics Works and as a construction consultant, area supervisor and superintendent at the Washington Polychemicals Works in Parkersburg, West Virginia.

He reentered the Atomic Energy Division in 1950 when Du Pont undertook the design, construction and operation of the Savannah River Plant. In 1952, he moved to SRP with the position of general superintendent of Production. Five years later, he was promoted to manager of SRP, a position he held until December 1966. Mr. Ellett's nine–year tenure as manager witnessed the development of plant processes and the push toward diversification, the construction of the Heavy Water Components Test Reactor, and record reactor power levels. After completing his tenure at SRP, Mr. Ellett took a post as director of manufacture in the Explosives Atomic Energy Division in Wilmington, Delaware.

While living in Aiken, Mr. Ellett was active in the First Baptist Church and the Augusta Rotary Club. He was also chairman of the Yamassee Boy Scout District, president of the Aiken County United Fund Community Services, and chairman of the Aiken County Hospital Board of Trustees.

Source: *Savannah River Plant News*, Volume XIV, No. 24, December 23, 1966. Courtesy of SRS Archives, negative 28086-4.

J. Armand Monier, Jr.



J. Armand Monier, Jr. (1966–1972)

J. Armand Monier, Jr. received all of his degrees, including a Ph.D. in organic chemistry from the Massachusetts Institute of Technology. In 1933, he became a chemist with Du Pont at the Experimental Station in Wilmington, Delaware. He was then transferred to the Belle, West Virginia, Works in 1936 and later the Morgantown, West Virginia, Ordnance Works in 1943. After World War II, he returned to Belle and subsequently moved to a position at Sabine River, Texas, in 1947 as production superintendent.

In 1951 he entered into atomic energy work as technical superintendent at the Dana heavy-water plant in Indiana. He became assistant plant manager there in 1952 and transferred to Savannah River Plant in 1955 as general superintendent of Production. Dr. Monier was promoted to plant manager at SRP in January 1967, and remained at that post until December l972.

Dr. Monier and his family were Augusta residents. Like his predecessors, he was also active in the community, serving as a member of the board of directors and chairman of the Community Planning Committee of the Augusta-North Augusta United Fund, and serving several terms as president and vice president of that organization. Dr. Monier was active in the Junior Achievement of Augusta.

Source: *Savannah River Plant News,* Volume XIV, No. 24, December 23, 1966. Courtesy of SRS Archives, negative 28086-4.

Kenneth W. French

Kenneth W. French, a native of Sabetha, Kentucky, began working with Du Pont upon his graduation from the University of Nebraska in 1936. During World War II, he served in supervisory positions at Oak Ridge and Hanford with Du Pont. Mr. French came to the Savannah River Plant in the 1950s, was involved in its initial staffing, and participated in R Reactor achieving criticality. He was superintendent of the reactor and heavy-water departments, and then served as general superintendent of production beginning in June 1966. Mr. French became assistant plant manager at the Savannah River Plant in January 1967, and plant manager in January 1973, after twenty years at SRP. He retired in December 1976, after forty years of service with Du Pont.

French was a deacon, president of the Men of the Church, and superintendent of the senior department of the Sunday School at First Presbyterian Church in Aiken. He also served as chairman of the Yamassee Boy Scout District, president of the Aiken Rotary Club, vice chairman of the Aiken County Technical Education Commission, director of the Palmetto Federal Savings and Loan Association, and a member of the Business Men's Club and the Salvation Army Advisory Board.

Sources: *Savannah River Plant News*, Volume XXIV, No. 22, December 16, 1976; *The Augusta Chronicle*, January 10, 2000. Courtesy of SRS Archives, negative 28086-4.



Kenneth W. French (1973–1976)

William J. Mottel

William J. Mottel grew up in Michigan and received a chemical engineering degree from Michigan State University. He served in the Army's nuclear weapons program, and attained the rank of major in the Army Reserve. He began his employment with Du Pont at the Savannah River Laboratory in 1953 and transferred to the Savannah River Plant in 1964 as an area supervisor in Separations Technology. He became assistant plant manager in September 1975 and the fifth plant manager upon Kenneth W. French's retirement in December 1976.

While Mr. Mottel served as manager, SRP observed its twenty-fifth year of operation without a nuclear-related injury. The plant held a record as one of the four safest industrial plants in the world during his tenure. Mottel left SRP in November 1979, to become production manager for polyester and acrylic intermediates in the Petrochemicals Department in Wilmington, Delaware. He would later co-author a book, *Industrial Safety is Good Business: The Du Pont Story*. While working at SRP, Mottel served as chairman of the Aiken County Public Service Authority and was also a member of the North Augusta City Council.

Sources: *Savannah River Plant News,* Volume XXIV, No. 22, December 16, 1976; *Savannah River Plant News,* Volume XXVII, No.18, November 6, 1979. Courtesy of SRS Archives, negative 27462-1.



William J. Mottel (1977–1979)

John T. Granaghan



John T. Granaghan (1979–1988)

A native of Jacksonville, Florida, John T. Granaghan graduated from Auburn University in 1950, with a BS in chemical engineering. After graduation, Du Pont hired him at the Sabine River Works in Orange, Texas. He left in 1952, to serve with the U.S. Army Corps of Engineers in Korea. He returned to the Sabine River Works in 1954, but transferred a year later to Wilmington, Delaware. He then became assistant power superintendent and division maintenance superintendent at the Washington Works in Parkersburg, West Virginia.

Mr. Granaghan found himself again, at the Sabine River Works in 1965, where he held a variety of positions, including division superintendent for methanol production, maintenance superintendent for the nylon area, and assistant employee relations superintendent. He moved to Du Pont's Pontchartrain Plant at LaPlace, Louisiana, in 1970, and became general plant superintendent. Later, Mr. Granaghan became assistant plant manager at the Victoria, Texas, plant, and then manager of the Cape Fear Petrochemicals Plant in Wilmington, North Carolina, in 1977. He was assigned to the Savannah River Plant as plant manager in 1979.

In his tenure at SRP, the facility witnessed over 50 million man-hours without a lost-time accident, a record that approached world-record levels for safety performance. In addition, employees' average radiation exposure levels dropped to record lows. The number of employees increased from 5,769 to more than 8,000 and the facilities themselves also expanded. Billions of dollars of construction began, including the Defense Waste Processing Facility. He was manager when Du Pont decided to not renew its contract with DOE and was also the plant's leader through the difficult 1980s when the plant was in the throes of change. Mr. Granaghan maintained his position as plant manager until his retirement from Du Pont in 1988.

Mr. Granaghan and his family are Aiken residents. He belongs to a number of local civic groups. So many, in fact, he refers to himself as Mr. Momo, or Man of Many Organizations. Some of these groups include the Aiken Rotary Club, the Greater Aiken Chamber of Commerce, the Heart Association, the Aiken Chapter of the Red Cross, the Palmetto Forum (an organization for senior executives at major corporations), the Aiken Business Men's Club, and the Board of Visitors at Clemson University. In 1999, he accepted the chair of the 50th Anniversary committee, a group assembled to guide events in celebration of the site's fifty-year history.

Sources: *Savannah River Plant News*, Volume XXVII, No.18, November 6, 1979; *Savannah River News*, Volume XXXV, No. 21, October 27, 1988. Courtesy of SRS Archives.

John T. Lowe



John T. Lowe (1988–1989)

John T. Lowe is a graduate of Georgia Tech and received his Ph.D. in physical chemistry from the University of Illinois. He began at Du Pont in 1965 as a researcher. From 1971 to 1974, Dr. Lowe worked as research supervisor at the Experimental Station in

Wilmington, Delaware, and at the Sabine River Laboratory in Orange, Texas. Beginning in 1974, Dr. Lowe held a number of positions including technical superintendent at the Victoria, Texas, plant, director of the Sabine River Laboratory, and Adiponitrile Plant Superintendent in Victoria. He returned to the Savannah River Plant in 1983 as program manager. He became the director of the Savannah River Laboratory in May 1984 and maintained that position until October 1988, when Dr. Lowe took over John Granaghan's position as Savannah River Plant manager in October.

Lowe was a member of the Aiken Rotary Club, the Aiken County Commission for Technical Education at the Aiken Technical College, and the Aiken Chamber of Commerce. He was a past chairman of the visiting committee for the Chemical Engineering Department at the University of Texas and was also active in several local colleges and universities.

Source: *Savannah River News*, Volume XXXV, No. 21, October 27, 1988.

James S. Moore

James S. Moore attended school at the Carnegie Institute of Technology where he received an MS in nuclear engineering in 1963. From 1975 to 1979, Moore was president of Westinghouse Nuclear Europe based in Belgium. He directed marketing, engineering, construction, and operations support of Westinghouse Nuclear Systems throughout Western Europe and Scandinavia. After returning to the U.S., Moore was appointed general manager and vice president of the Westinghouse Water Reactor Division, a post he held until 1986. He then became vice president and general manager of the Westinghouse Government Operations Business Unit where he directed GOCO operations of the Westinghouse Materials Company of Ohio, the Westinghouse Idaho Nuclear Company, the West Valley Nuclear Services Company in New York, the Waste Isolation Division in New Mexico, and the Machinery Technology Division in Pittsburgh.

In 1989, Moore was appointed President of the Westinghouse Savannah River Company, which is the highest executive position at the Savannah River Site. During his career, Moore pioneered and advanced nuclear safety in the U.S. and throughout the world, and led Westinghouse's interaction with the Atomic Energy Commission and the U.S. Nuclear Regulatory Commission.

Mr. Moore served in a number of community activities, including positions on the board of directors for C&S Bank of South Carolina, the Augusta Symphony, and the Aiken United Way. He was also a member of the Aiken County Commission for Higher Education, the President's Advisory Councils of the Medical College of Georgia, and advisory groups of Clemson University.

Source: Westinghouse Savannah River Company Profile. Courtesy of SRS Archives, negative JimMoore.jpg.



James S. Moore (1989–1991)

Ambrose L. Schwallie



Ambrose L. Schwallie (1991–1999)

Ambrose L. Schwallie received two degrees in mechanical engineering from Ohio State University. He joined Westinghouse in 1972 upon his graduation. In 1979 he was named manager of Core Design for the Clinch River Breeder Reactor project. While there he directed the regulatory licensing of the core, safety documentation, and interaction with the U.S. Nuclear Regulatory Commission for the project.

During his career with Westinghouse, he also served as engineering manager for the corporation's Advanced Energy Systems Division, proposal manager for Savannah River Site's management and operating contract proposal, and executive vice president of Westinghouse Savannah River Company (WSRC). He was named president of WSRC in 1991 and maintained that position until August 1999.

Mr. Schwallie was on the board of directors for Palmetto Federal and S.C. Business Center for Excellence in Education. He was also a member of the Metro Augusta Chamber of Commerce, the Palmetto Business Forum, the President's Advisory Council at Clemson University, and the Aiken Rotary Club.

Source: Westinghouse Savannah River Company Profile, April 9, 1996. Courtesy of SRS Archives, negative AmbroseSchwallie.jpg.

Joseph J. Buggy



Joseph J. Buggy (1999–present)

Joseph J. Buggy graduated from Villanova University with a degree in mechanical engineering in 1963. He served as a lieutenant in the U.S. Nuclear Submarine Program from 1963 to 1967, and then joined the Westinghouse Company as an engineer in the former Advanced Reactor Division. During his ten years there, he held several positions including manager of the Liquid Metal Fast Breeder Reactor Plant and Thermal Systems, manager of General Electric programs, and technical assistant to the project manager.

Mr. Buggy then transferred to the Westinghouse Advanced Energy Systems Division in 1977, where he developed a diversified energy-systems background as manager of Solar Energy, Fuel Cells, and Energy Programs and Operations. In 1988, he became vice president and deputy manager of West Valley Nuclear Services Company, a Westinghouse subsidiary, which is the management and operations contractor for the U.S. Department of Energy in western New York. Just three years later, he was named president and general manager of the company, and was responsible for all aspects of management and operations related to the environmental restoration of a former nuclear fuel reprocessing facility. Mr. Buggy was then appointed executive vice president of the Westinghouse Savannah River Company in 1991, and later became president in September 1999.

Mr. Buggy has been active in the United Way of Aiken County, is a member of the Aiken County Commission for Technical and Comprehensive Education, and has advised the City of Aiken on strategic planning. He also serves on the executive council of the Energy Facility Contractors Group.

Sources: Westinghouse Savannah River Company Profile, August 9,1999. *Savannah River News*, September, 1999. Courtesy of SRS Archives, negative JoeBuggy.jpg.

Laboratory Directors

Milton H. Wahl



Milton H. Wahl (1953–1960)

Born in Emden, Illinois, in 1908, Milton H. Wahl received a BA from Central Wesleyan College in 1928, an MA in chemistry from the University of Missouri in 1930, and a Ph.D. in physical chemistry from the University of Illinois in 1933. In his early career, Dr. Wahl worked with Nobel Prize winner Harold C. Urey on isotope separation. He joined Du Pont at the Eastern Laboratory in the Explosives Department in 1935, where he worked on radically new explosives and hazards associated with chemical reactions. In 1942, he transferred to Wilmington, Delaware, as technical assistant to the Assistant Chemical Director. He quickly moved to the Technical Division, where he worked on the design of equipment for the Hanford, Washington, project. Later he joined the Process Group as process manager.

Dr. Wahl returned to the Eastern Laboratory in July 1945, where he served as section head in charge of a development group. In 1950, he was assigned to the Atomic Energy Division and was appointed liaison office manager at Argonne National Laboratories. Dr. Wahl arrived at the Savannah River Laboratory in August 1952 to assume his role as laboratory director, a position he held until 1960.

Source: *Savannah River Plant News*, Volume I, No. 6, May 1, 1953. Courtesy of SRS Archives.

William P. Overbeck



William P. Overbeck (1961–1967)

A native of Glenwood Springs, Colorado, William P. Overbeck received a BS in electrical engineering from the Massachusetts Institute of Technology and was a graduate student at the University of Chicago, where he was one of a small group of scientists conducting the first controlled nuclear chain reaction experiments in 1942. Mr. Overbeck shares the original patent for nuclear reactors. He joined the Du Pont Company at the Hanford, Washington, atomic energy facility in 1944. He became director of the Savannah River Plant laboratory in 1961 and retired in October I967.

Mr. Overbeck was involved in higher education in South Carolina, serving on the Governor's Advisory Commission on Higher Education and the Aiken County Commission on Higher Education where he worked to expand the University of South Carolina-Aiken curriculum in physics and astronomy. An amateur astronomer, he tracked space satellites to obtain data in his spare time.

Source: *Savannah River Plant News*, Volume XV, No.18, October 6,1967. Photograph source: *Savannah River Plant News*, October 6, 1967.



Frank E. Kruesi, Jr. (1968–1969)

Frank E. Kruesi, Jr.

Frank E. Kruesi, Jr. was born in Seattle, Washington, and graduated from Union College, Schenectady, New York. Employed by the General Electric Company at the Hanford, Washington Plant, he joined Du Pont in 1952 as a physicist in the firm's Atomic Energy Division. At Savannah River, Mr. Kruesi served in the Reactor Technology Section and the Reactor Department as one of the top supervisors. He then assumed the assignment of assistant director of advanced operational planning before being posted as director of Savannah River Laboratory in 1968. He held that position until 1969, when he was promoted to director of manufacturing of the Atomic Energy Division of Du Pont's Explosive Department in Wilmington, Delaware.

Source: *Savannah River Plant News*, Volume XVI, No. 25, January 10, 1969. Photograph source: *Savannah River Plant News*, October 6, 1967.



Clark H. Ice (1970–1979)

Clark H. Ice

Clark H. Ice was a native of Fletcher, Oklahoma, and received his MA and Ph.D. from the University of Oklahoma. He came to the Savannah River Plant in 1952 as a Du Pont employee. From 1964 to 1967, he was the director of Separations Chemistry and Engineering Section of the Savannah River Laboratory. Dr. Ice became assistant laboratory director at Savannah River Laboratory in 1967, and after two years became the laboratory's director. Dr. Ice retired from SRL in 1979, after 26 years at Savannah River that stretched over some of the most productive years at the plant.

Source: *Savannah River Plant News*, Volume XVI, No. 25, January 10, 1969. Photograph source: *Savannah River Plant News*, October 6, 1967.



Albert H. Peters (1979–1981)

Albert H. Peters

Albert H. Peters grew up in Summerville, South Carolina, and is a 1950 graduate of Clemson University, where he received a degree in chemical engineering. Mr. Peters is the only native South Carolinian to serve as laboratory director. He served two years in the Air Force Air Research and Development Command, where he attained the rank of captain.

Mr. Peters began his employment at the Savannah River Laboratory in 1953. He was transferred to the plant's Reactor Technology Department in 1969, as a chief supervisor. He worked as an area superintendent in both Reactor and Separations Departments, and in 1973, he became the plant's environmental coordinator. The following year he was named general superintendent of Production, and two years later, he moved to the position of general superintendent of Employee Relations. He was appointed assistant plant manager in January 1977, and then moved to Du Pont's Victoria, Texas, facility to serve the same role. Mr. Peters was called back to Savannah River Plant in 1979 to serve as laboratory manager, a post he held until 1981. In 1979, functions of the laboratory were divided into three groups under an organization change; Mr. Peters, as laboratory manager, was head one of

the groups. On retirement in 1989, he was manager of Plant Facilities and Services. Sources: *Savannah River Plant News*, Volume XXIV, No. 22, December 16, 1976; *Savannah River Plant News*, Volume XXVII, No. 22, December 19, 1978; *Savannah River Plant News*, Volume XXVII, No. 21, December 12, 1978. Photograph courtesy of SRS Archives, negative 28086-3.

Joseph P. Glas



Joseph P. Glas (1979–1981)

Joseph P. Glas, a native of Des Moines, Iowa, received MS and Ph.D. degrees in chemical engineering from the University of Illinois. Dr. Glas joined Du Pont in 1964 as a research engineer at the Circleville, Ohio, film plant. He was later promoted to research supervisor at Circleville, and was then transferred to the Florence, South Carolina, plant as a development supervisor. In 1969, Dr. Glas moved to Du Pont's Tecumseh, Kansas, plant as a technical superintendent. He was manager of Kapton polyimide and metalized Mylar polyester in Wilmington, Delaware, in 1974 and 1975. He advanced to research manager in Du Pont's Commercial Resins Division of the Plastic Products and Resins Department in Wilmington, a position he held from 1976 to 1978. He was transferred to the Savannah River Plant's Atomic Energy Division, and served as the director of research for process development and plant support from 1979 to 1981 when, under an organizational change, the functions of the laboratory were split into three groups.

Sources: *Savannah River Plant News*, Volume XXVII, No. 22, December 19, 1978; *Savannah River Plant News*, Volume XXVII, No. 21, December 12, 1978.

Samuel Mirshak



Samuel Mirshak (1979–1984)

Samuel Mirshak, a native of Oak Park, Illinois, received a master's degree in chemical engineering from Northwestern University in 1953. Du Pont then employed him in research at the Savannah River Plant. He moved to the Advanced Operational Planning Group in 1965, and in 1968, he became the research manager of the Reactor Engineering Division. From 1969 to 1975, he was the director of the Nuclear Engineering and Materials Section of the Savannah River Plant Laboratory. Mr. Mirshak was the general superintendent of production at the Savannah River Plant's Manufacturing Division beginning in 1977. In 1979, when the laboratory was divided into three groups, Mr. Mirshak also became responsible for special programs as director of research. He was appointed associate technical director of Petrochemicals' Atomic Energy Division in 1984.

Mirshak and his family were North Augusta residents. Mr. Mirshak served on the parish council at Our Lady of Peace Catholic Church and as a member of the board of education of the Roman Catholic Diocese of Charleston. He was also chairman of the American Nuclear Society's Savannah River Section, and was a member of the Rotary Club, the North Augusta Chamber of Commerce, and the Augusta Symphony League.

Sources: *Savannah River Plant News*, Volume XXVII, No. 22, December 19, 1978; *Savannah River Plant News*, Volume XXVII, No. 21, December 12, 1978.



J. Roger Hilley (1982–1984)

J. Roger Hilley

A native of Dalton, Georgia, J. Roger Hilley received a BS in physics from Berry College and a MS in physics from Emory University. He joined Du Pont in 1957 at the Savannah River Plant. While there, he worked as research manager and section director in the laboratory and general superintendent of Works Technical and Employee Relations. He served as technical advisor to the Department of Energy from 1980 to 1981. In 1982, he became director of the SRL, a position held until retirement in 1984. He then assumed a new position as associate director for Storage and Transportation Systems in the U.S. Office of Civilian Radioactive Waste Management for the Department of Energy in Washington, DC.

Hilley served as director and vice president for public affairs in the Greater North Augusta Chamber of Commerce and as a director of the North Augusta Development Corporation. He was also a member of the North Augusta Rotary Club and the Aiken County United Way, and was active in Boy Scouts, the American Nuclear Society, and the CSRA Science Fair.

Source: *Savannah River News*, Volume XXI, No. 8, September 20, 1984. Courtesy of SRS Archives, negative 20728-19.

John T. Lowe (1984-1988)

John T. Lowe became the director of the Savannah River Laboratory in 1984 and maintained that position until 1988, when he took over John Granaghan' s position as Savannah River Plant manager in October. See also John T. Lowe under Plant Manager biographies under Prime Contractor.

Dan L. McIntosh (1988-1989)

Dan L. McIntosh received his education, including a Ph.D. in chemical engineering at Washington University in St. Louis, Missouri. He then worked for McDonnell Aircraft and Mallinckrodt Chemical, both in St. Louis. McIntosh joined Du Pont in 1960 as a research engineer at the Experimental Station in Wilmington, Delaware. During his career, he has served in a variety of production and research assignments, both in the United States and abroad. Between 1973 and 1978, he was in Europe, initially to negotiate a joint venture between Du Pont and Rhone Poulenc, and then as a manager at Petrochemicals-Europe, where he oversaw the design, construction, and startup of a new Adiponitrile plant. McIntosh has also worked at the Sabine River Works in Orange, Texas, in Wilmington, Delaware, and at the Savannah River Plant.

In 1982, he was program manager for separations and the tritium production team at SRP, and in 1984, he was named the program manager for waste management and the Naval Fuel facility. He served as the Savannah River Laboratory's program manager for

Defense Waste Processing, Naval Fuel, and hydrogen technology, beginning in 1987. A year later, he became the director of the SRL.

Source: *Savannah River News*, Volume XXXV, No. 21, October 27, 1988.

Richard T. Begley (1989-1992)

Richard T. Begley received a BS in metallurgical engineering in 1953 from Lehigh University. From there he started his career with Westinghouse Electric Corporation in the company's Aviation Gas Turbine Division in Philadelphia. With Westinghouse, Begley worked in materials research and became a pioneer in the development of several high-strength alloys. In 1979, he managed Steam Generator Systems Engineering for Westinghouse Water Reactors in Pittsburgh. He then served as manager of Westinghouse's Solid State Research and Development Division at the corporate Science and Technology Center from 1981 to 1983. Begley became general manager of Westinghouse's Service Technology Division in 1986. He was vice president and director of the Savannah River Technology Center from 1989 to 1992.

Source: Westinghouse Savannah River Company Profile.

Crispin Thiesen (1992-1994)

Mr. Thiesen became vice president and acting director of the Savannah River Technology Center in 1992. Educated at Yale, where he achieved a BE in Metallurgy, and at La Salle Institute, where he received a BS in Accounting, Mr. Thiesen continued his coursework at Stanford University, where he completed the Executive Management Program in 1986. He began his nuclear career in the U.S. Navy. After graduation, he was commissioned as an officer, and was selected by Admiral Hyman Rickover for the nuclear power submarine program. During his seven years in the Navy, he served on the commissioning crew of the *USS Greeling*. He entered the Naval Reserve as a Lieutenant Commander, USNR after his final posting as weapons officer on a Polaris missile submarine.

His career with the Westinghouse Electric Corporation began in 1970, when he became a member of the Nuclear Fuels Division. During the 1970s and early 1980s, he assumed a number of positions that required his transfer overseas to Europe, and later, extensive travel through Europe and Asia to manage international nuclear technology licensing arrangements for Westinghouse. His international work culminated in his appointment as president, Westinghouse Nuclear International-Europe. He remained in that post until 1984, when he was transferred back to the U.S. to first manage Westinghouse's new Subsidiary Services Integration Division, and later, their Radiological Services Division. Mr. Thiesen became part of Savannah River Site when Westinghouse became the prime contractor. In addition to his duties at the laboratory, where he was responsible for managing research and development, he was also responsible vice presi-

dent and manager of the New Production Reactor Program. Prior to retirement, he was vice president and manager of administration and infrastructure. Mr. Thiesen, an Aiken resident, served on the Executive Committee of the United Way.

Source: Westinghouse Savannah River Company Profile.



Susan Wood (1994–present)

Susan Wood

Susan Wood, director of Savannah River Technology Center (SRTC), holds degrees from Victoria University of Manchester and the University of Pittsburgh, where she earned her Ph.D. in materials engineering. Dr. Wood joined Westinghouse in 1976 as general manager of the Materials Technology Division. She also worked in other positions at the Westinghouse Science and Technology Center in Pittsburgh. Dr. Wood holds patents in materials engineering, and has performed extensive work in advanced analytical techniques with a wide range of materials.

Dr. Wood came to the Savannah River Site in 1994, following two years as manager of the Manufacturing Technology Department in Baltimore, Maryland. She serves as vice president as well as director of SRTC, where she is responsible for managing research and development programs and activities in support of the U.S. Department of Energy and SRS operations. Dr. Wood has served as a member of the Defense Science Board, and continues to serve on the board of directors and in other advisory capacities for universities throughout the country. She serves on the Board of Directors of the Women in Engineering Program Advocates Network (WEPAN), and was a member of the Board of Directors for the 1997 United Way of Aiken County. Dr. Wood serves on the Nuclear Materials Technology Division Review Committee for Los Alamos National Laboratory and the South Carolina Technical Advisory Council.

Source: Westinghouse Savannah River Company, Savannah River Technology Center Profile. Photo: Courtesy of SRS Archives.

AWARDS

NATIONAL, FEDERAL, STATE, AND INDUSTRIAL SAFETY AWARDS

Atomic Energy Commission Award of Honor—1954, 1955, 1958, 1960, 1961, and 1971
Construction Division—1956, 1967

Atomic Energy Commission Award of Merit—1952, 1957
Construction Division—1959

Atomic Energy Commission Best Ever Award—1970 (Largest number of injury-free man-hours ever achieved in the national atomic energy program.)

Chemical Manufacturers Association's Certificate of Achievement—1979, 1982, and 1985

Chemical Manufacturers Association's Certificate of Honor— 1982, 1983, 1984, 1985, 1986, and 1987

National Safety Council – Award of Honor —1955, 1958–1963, 1966–1969, 1971–1972, 1974–1976, 1978–1982, 1995–1996
Central Services Works Engineering, 1995
SRS High Level Waste Division, 1995
Operations Division, 1997

National Safety Council—Award of Merit—1956, 1957

National Safety Council Award of Recognition—BSRI and WSRC Employees—1997

Presidential Safety Award—1962

South Carolina Industrial Safety Record—1987 (43 million injury-free exposure hours)

South Carolina Occupational Safety Award—1968

U.S. Department of Energy's Award of Excellence—1981, 1982, and 1985

U.S. Department of Energy's Award of Achievement—1986

U.S. Department of Energy Award of Excellence —Savannah River Technology Center—1981-1986

U.S. Department of Energy Complex Leader
Development and Implementation of the Defense Nuclear Facilities Safety Board's Initiative for Integrated Safety Management, 1998

NATIONAL, FEDERAL, REGIONAL TECHNICAL ACHIEVEMENT AWARDS (1989–2000)

SAVANNAH RIVER SITE

American Academy of Environmental Engineers Award for Superior Achievement
Excellence in Environmental Engineering for Work on a Complex-Wide Environmental Management Integration Team That Provided DOE-HQ with an Effective Cradle to Grave Clean Up Management, 1998

National Environmental Policy Act Presidential Award
Integrating NEPA Compliance with the RCRA/CERCLA Process and Producing the NEPA/CERCLA Integration Guidance Document, 1998

Southern States Energy Board
Providing the Vision and Drive behind SSEB's Permitting Leadership in the U.S. which Resulted in the Adaptation of Policy Positions on Expedited Multi-site Deployment of Environmental Technologies, 1997

U.S. Department of Energy, Chief Information Officers Information Management Award
Technical Excellence in Image Expansion System, 1997

U.S. Department of Energy Award for Mentor Firm of the Year
Coaching Vanguard EMI through Five Significant Dismantling and Demolition Projects, 1998

U.S. Department of Energy Pollution Prevention Award
Education and Training, 1995
Solid Waste Recycling, 1995, 1997
Chemical Commodity Management Center, 1997
Excell Recycling, 1997
Utilizing Contract Incentives to Motivate Waste Reduction, 1998
Integrated Planning and Design – Process Improvements to Eliminate Mixed Waste Generation From Off Spec Heavy Water Purification, 1998
Leadership: Excellence in P2 program Management leadership at DOE-SR Operations Office, 1998

U.S. Department of Energy Recycling Award, 1993

U.S. Department of Energy Special Performance Award, 1993

U.S. Department of Energy Weapons Complex Award of Excellence
Reservoir Function Test Facility Startup, 1997
Unloading RAMP Reservoirs, 1997

White House Closing the Circle Award for Environmental Innovation
Reduction of Office Paper, 1994
Toxic Chemical Reduction and Chemical Management, 1996

SAVANNAH RIVER TECHNOLOGY CENTER (SRTC)

Federal Laboratory Consortium Award of Excellence
- Contaminated Waste Storage Container, 1995
- Robotic Wall Crawler, 1995
- Hydrogen Bus Project, 1996
- Technology Transfer: Cleanup of Contaminated Groundwater/Soil, 1996
- Technology Transfer: In Place Breakdown and Removal of Chlorinated Solvents in Subsurface Water and Sediment by Natural Gas Injection and Air Stripping, 1996

Federal Laboratory Consortium Certificate of Merit
- Cone-Sipper Technology Transfer Team, 1997
- Global Positioning System Recorder Technology Transfer Partnering Team, 1997
- Baro-Ball, 1998
- Digital Radiography Imaging, 1998

Federal Laboratory Consortium Southeastern Regional Award of Excellence
- Contaminated Materials Beneficial Reuse Team and Applied Science and Engineering Technology Team, 1995

Research and Development 100 Awards
- Fiber Optic Temperature Sensors, 1995
- In-situ Bioremediation of Chlorinated Solvents with Natural Gas, 1995
- PHOSter Bioremediation Process, 1996

U.S. Department of Energy Glenn T. Seaborg Award for Advances in Nuclear Energy Technology, 1996, 1997

INDIVIDUAL SRTC AWARDS

Dr. David G. Karraker, Glenn T. Seaborg Actinide Separations Award, 1996

Donald A. Orth Award for Technical Excellence

- McIntyre R. Louthan, Jr., Material Science and Applied Engineering, 1994
- Henry W. Randolph, Applied Physics and Electronics, 1995
- Major C. Thompson, Actinide Chemical Processing, 1996
- Carl B. Fliermans, Limnology and Microbial Ecology, 1997
- Myung W. Lee, Nuclear Chemistry and Hydrogen Technology, 1998
- Albert L. Boni, Nuclear Nonproliferation and High Sensitivity and Measurements of Radionuclides, 1999
- William R. Kanne, Jr., Welding and Metallurgical Engineering, 2000

George Westinghouse Signature Award of Excellence—Corporate Level

- Paul S. Hebert
- Scott B. Beck
- Carl Fliermans
- Frank C. Saffington
- Jim Klein
- Ken Lombard
- Joe Wermer
- Anita Poore
- George Nichols
- M. J. Whitaker
- W. J. Ramsey
- C. A. Langton
- R. E. Edwards, Jr.
- C. D. Hopkins
- Carol Jantzen
- P. E. O'Rourke
- T. C. Hazen
- L. C. Baylor
- Brian Looney
- R. R. Livingston
- K. G. Brown
- John Scogin
- Myung Lee
- Carol Eddy-Dilek
- Leung Heung
- Dennis Bickford
- Marilyn Franck

PATENTS

Patents listed between April 1950 and August 2000 Funded by Savannah River Operations

"True progress, as someone has said, moves quietly and persistently, without notice. The spectacular new product or the startling new advance captures the imagination, generates momentum, and leaves its bright mark for all to see and admire. But fireworks displays, while exciting to watch and satisfying to recall, provide little in the way of sustained illumination. Substantial and enduring progress arises, quite unromantically, out of day-to-day efforts that seldom make the headlines. In any given period, the gains may seem inconsequential, but patiently applied and unremittingly pressed, the smallest increments grow to important dimensions."

- Crawford Greenewalt

Source: "The Slow and Steady Way of Progress," *Chemical Engineering Progress*, Vol. 58, No. 1, January, 1962.

Due to the nature of the work at Savannah River, this is an incomplete listing of patents relating to the site and its missions. Despite this proviso, this list provides as complete a list as possible from sources provided by the Office of Patent Counsel and from research among early logs that recorded research leading to SRS related patents. This list was compiled to recognize the wide body of research conducted under Savannah River Operations funding in its fifty-year history. It also identifies the many individuals responsible for this work. The authors regret if there are any omissions. All patents listed were given by the US Patent Office with the exception of CA625998 that was issued from the Canadian Intellectual Property Office.

Patents listed between April 1950 and August 2000 Funded by Savannah River Operations

Patent No.	Inventor	Title/Subject	Date
2,503,078	Frederic B. Stilmar, William S. Struve, and Ralph N. Lulek	Cyclic Compounds & Method of Making	4/4/1950
2,541,190	Anthony F. Benning	Fluorination of Lubricating Oil	2/13/1951
2,549,609	Kenneth C. Johnson	Separation of Fluorinated Hydrocarbons By Distillation with Hydrogen Fluoride	4/17/1951
2,549,988	Melvin A. Perkins	Manufacturing of Organic Fluorine Compounds	4/24/1951
2,567,759	Anthony F. Benning	Fluorination of High Molecular Compounds	9/11/1951
2,569,644	Frederic B. Stilmar	Organic Fluorine Compositions and Method of Making	10/2/1951
2,570435	Frederick B. Downing Et al.	Catalytic Vapor Phase Fluorination Apparatus	10/9/1951
2,719,924	J. Robert Oppenheimer, Stanley Phillips Frankel, and Eldred Carllyle Nelson	Magnetic Shims	10/4/1955
2,733,125	Louis Spiegler	Recovery of Uranium From Waste Metal Products	1/31/1956
2,733,126	Louis Spiegler	Uranium Liberation	1/31/1956
2,733,127	Louis Spiegler	Precipitation of Fluoride-Free Uranium Tetroxide	1/31/1956
2,741,541	Sanford B. Smith	Production of Uranium Sulphate	4/10/1956
2,759,789	Louis Spiegler	Uranium Products and Methods of Using	8/21/1956
2,770,521	Louis Spiegler	Separation of Uranium from Mixtures	11/13/1956
2,787,526	Jerome S. Spevack	Method of Isotope Concentration	4/2/1957
2,771,338	Louis Spiegler	Manufacture of Uranium Peroxide	11/20/1956
2,794,670	R. L. Menegus et al.	Releaseable Holder for Rod	6/4/1957
2,836,548	Allen G. Gray and Ernest W. Schweikher	Surface Treatment of Metallic Uranium	5/27/1958
2,847,321	Lowell D. Eubank	Metal Surface Treatment	8/12/1958

Patent No.	Inventor	Title/Subject	Date
2,848,796	Lowell D. Eubank and Ernest R. Boller	Alloy Coatings and Method of Applying	8/26/1958
2,848,797	Lowell D. Eubank	Metal-Coated Articles and Method of Making	8/26/1958
2,849,348	Allen G. Gray	Electrodeposition of Nickel on Uranium	8/26/1958
2,854,737	Allen G. Gray	Copper Coated Uranium Article	10/7/1958
2,854,738	Allen G. Gray	Nickel Coated Uranium Article	10/7/1958
2,859,431	Jean M. Morris	Visual Alarm System	11/4/1958
2,872,348	Lowell D. Eubank	Fused Salt Method for Coating Uranium with a Metal	2/3/1959
2,873,209	Harold A. Gage	Leveling Metal Coatings	2/10/1959
2,884,364	Elmer W. Rebol and Ralph F. Wehrmann	Method of Electroplating on Uranium	4/28/1959
2,901,313	Alfred Gavin Maddock and Fred Smith	Separation of Plutonium from Water Insoluble Fluorides Derived from Nitrate Solutions of Plutonium, Uranium and Fission Products	8/25/1959
2,906,852	Arthur A. Cornell, John V. Dunbar, and James H. Ruffner	Welding Method	9/29/1959
2,908,548	William S. Calcott	Manufacture of UF 4	10/13/1959
2,928,168	Allen G. Gray	Iron Coated Uranium and Its Production	3/15/1960
2,954,421	Raymond L. McCarthy et al.	Low-loss Cable and Method of Fabrication	9/27/1960
2,936,274	Gerhard Dessauer	Determination of Specific Neutronic Reactivity	5/10/1960
CA625998 Canadian Intellectual Property Office	C. V. Ellison, T.C. Runion, and W. B. Lanham, Jr.	Process for Segregation of Plutonium, Uranium, and Fission Products Values	8/22/1961
3,002,614	James Byron Jones	Vibratory Squeeze-Forming of Metals in the Solid State and Apparatus	10/3/1961
3,095,973	Carl De Buigne	Extrusion Cladding Apparatus	7/2/196

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Patent No.	Inventor	Title/Subject	Date
3,140,108	Albert R. Kaufmann, Joseph Lester Klein, and Paul Loewenstein	Process and Product of Metallurgically Joining Zirconium to Ferrous Metal	7/7/1964
3,152,984	Warren E. Winsche and Milton W. Davis, Jr	Method of Dehydrating and Insolubilizing of an Aqueous Nuclear Reactor Waste Solution	10/13/1964
3,174,818	Francis G. Rust	Reducing Corrosion of Stainless Steel in Hot Nitric Acid Solutions by Adding Carbon Black or Elemental Sulphur to the Solution	3/23/1965
3,195,984	Arthur E. Sands	Column Dissolver	7/20/1965
3,208,817	William J. Jenkins	Method of Dissolving Plutonium With Sulfamic Acid	9/28/1965
3,208,819	Richard M. Wallace	Method for Decontaminating Nuclear Fuels Containing Ruthenium Complexes	9/28/1965
3,224,615	James E. Henry	Crane Device with an Extensible Gripper Mechanism	12/21/1965
3,243,254	Thomas H. Siddal III	Method for Extracting Lanthanides and Actinides	3/29/1966
3,275,421	David G. Karraker and William C. Perkins	Recovery of Actinides from Halite Debris	9/27/1966
3,291,126	Raymond R. Messick	Air Cooling Unit for Protective Clothing and the Like	12/13/1966
3,291,997	Edward L. Albenesius, Clyde C. Haskell, and Richard H. Hawkings	Method and Apparatus for Tracing Fluid Flow Through Porous Media	12/13/1966
3,293,434	Arthur H. Dexter and Alwyn C. Lapsley	Photoneutron Monitor for Detecting Reactor Fuel Element Failures	12/20/1966
3,294,209	Robert D. Kachman and William R. Kee	Friction Mechanism with Sapphire Friction Surface	12/27/1966
3,296,123	William E. Prout, Edwin R. Russell, and Harold Groh, Jr.	Removal of Cesium From Aqueous Solutions by Ion Exchange	1/3/1967
3,309,280	Leonard J. Balog	Pressure-Tube Nuclear Reactor Including Fuel Assembly with Thermal Baffle	3/14/1967

Patent No.	Inventor	Title/Subject	Date
3,309,323	Edwin R. Russell, William E. Prout, Harold J. Groh, and George W. Watt	Thorium Oxide or Thorium-Uranium Oxide with Magnesium Oxide	3/14/1967
3,326,042	John D. Ross, Leslie E. Goodwin, and Thomas R. Herold	Ultrasonic Liquid Level Indicator	6/20/1967
3,332,614	Donald S. Webster and Warren E. Winsche	Centrifugal Extractor	7/25/1967
3,337,372	Robert E. Reed-Hill	Process for Improving Properties of Zirconium Metal	8/22/1967
3,359,788	Donald W. Colvin	Ultrasonic Measurement of Solution Concentration	12/26/1967
3,397,869	Donald S. Webster	Hydrofoil Agitator Blade	8/20/1968
3,398,064	Robert C. Propst	Scanning Coulometry Method and Apparatus	8/20/1968
3,398,278	William F. Splichal, Jr.	Neutron Detector for Measuring Dose Rate	8/20/1968
3,411,884	Victor R. Thayer	Process for Concentrating Heavy Water	11/19/1968
3,419432	James C. Hesson	Seal	12/31/1968
3,420,640	John A. Porter	Process for Depleting 17O and 18O in 238 PUO2	1/7/1969
3,427,475	Bruce L. Wilkinson and Paul W. Le Vier	High Speed Commutating System for Low Level Analog Signals	2/11/1969
3,439,187	Michael G. Strauss	Antilogarithmic Function Generator	4/15/1969
3,454,490	Richard M. Wallace	Concentration of Ions Using Ion Selective Membranes	7/8/1969
3,459,925	Malcolm H. Goosey, Arthur H. Dexter, John N. Wilson, Richard W. Leep, Wayne K. Hodder, Edward R. Brady, and Lewis C. Page	High Speed Temperature Monitor	8/5/1969
3,461,292	William F. Splichal, Jr,	Low Level Radiation Monitor	8/12/1969
3,469,254	Malcolm H. Goosey and Edward R. Brady	Analog-to-Digital Converter	9/23/1969

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Patent No.	Inventor	Title/Subject	Date
3,470,902	James R. Hackman	Liquid Flow Control Device	10/7/1969
3,482,003	Roger W. Lavan	Method of Extrusion of Ribbed Composite Members	12/2/1969
3,527,948	Frederick N. Rhines, James A. Donovan, and William R. McDonell	Cobalt-Rhenium Energy Source	9/8/1970
3,549,323	Dale F. Babcock	Dual Temperature Isotope Exchange Process	12/22/1970
3,549,324	Dale F. Babcock	Dual Temperature Isotope Exchange Process	12/22/1970
3,549,325	Dale F. Babcock	Dual Temperature Isotope Exchange Process	12/22/1970
3,562,480	Alvin Korba	Thermoluminescent Dosimeter Badge	2/9/1971
3,573,462	Charles A. Wilkins and Franklin D.R. King	Sealed Container with Pressure Relief for Hazardous Material	4/6/1971
3,575,806	John Boulton	Hydriding Resistant Zirconium Alloy Components	4/20/1971
3,576,994	Mark Brown and Paul B. Parks	Neutron Radiography of Deuterated Tissue	5/4/1971
3,627,691	Alexander R. Boulogne and Jean P. Faraci	Method of Preparing a Californium-252 Neutron	12/14/1971
3,638,020	Dick Duffey, Peter F. Wiggins, and Frank E. Senftle	Mineral-Detection Apparatus	1/25/1972
3,649,829	Henry W. Randolph	Laminar Flow Cell	3/14/1972
3,649,834	Henry W. Randolph	Laminar Gas Flow Radiation Detector	3/14/1972
3,666,953	William F. Splichal, Jr.	Up-Down Counter for Background Compensation	5/30/1972
3,677,825	Le Conte Cathey	Thermoelectric Generator	7/18/1972
3,699,337	John E. Hoy	Personnel Neutron Dosimeter	10/17/1972
3,699,338	Norman P. Baumann and Charles E. Ahlfeld	Oscillating Monitor for Fissile Material	10/17/1972
3,702,932	Allan B. Tanner, Frank E.Senftle, and Robert M. Moxham	Melting Cryogen Cooling for Radiation Logging Probe	11/14/1972

Patent No.	Inventor	Title/Subject	Date
3,711,598	Dale F. Babcock and John S. Neill	Increased Recovery in Dual Temperature Isotope Exchange Process	1/16/1973
3,723,732	John G. Larson and John M. Orange	On-Stream Analysis	03/27/1973
3,738,873	Le Conte Cathey	Self Generating Thermoelectric Converter	6/12/1973
3,747,001	George E. Fasching and George H. Patton	Pulse Processing System	7/17/1973
3,773376	John M. Orange	Radioactive Source Handling Apparatus	11/20/1973
3,774,033	Hubert D. Scott and Michael P. Smith	Dual Spaced Epithermal Neutron Detector Porosity Logging	11/20/1973
3,778,295	Paul K. Smith, Richard T. Huntoon, and Wilbur C. Mosley, Jr.	Chemical Plating Method of Preparing Radiation Source Material	12/11/1973
3,787,321	Burton L. Dahlen, Wilbur C. Mosley, Jr., Paul K. Smith, and Edward L. Albenesius	Californium-Palladium Metal Neutron Source Material	1/22/1974
3,792,156	Dale F. Babcock	Dual Pressure-Dual Temperature Isotope Exchange Process	2/12/1974
3,873,651	Wilbur C. Mosley, Jr. and Paul K. Smith	Freeze Drying Method for Preparing Radiation Source Material	3/25/1975
4,078,907	Carl Solomon Schlea	Separation and Purification of Xenon	3/14/1978
4,095,471	David W. Hayes	Tidal Sampler	6/20/1978
4,096,042	Robert B. Looney and William E. L. Smith	Electroplating Method and Apparatus	6/20/1978
4,111,833	A. Gary Evans	Activated Carbon Material	9/5/1978
4,150,632	Francis T. Matthews	Char Separator	4/24/1979
4,167,157	Edward A. Zielinski	Fluid-bed Air-Supply System	9/11/1979
4,167,918	Keramettin Atabay	Fluid-Bed Air-Supply System	9/18/1979

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Patent No.	Inventor	Title/Subject	Date
4,173,950	Richard E. Waryasz	Coal Fired Fluid Bed Module for a Single Elevation Style Fluid Bed Power Plant	11/13/1979
4,201,738	David R. Johnson	Preparation of U_3O_8	5/6/1980
4,259,910	Jeffrey H. Warren and Harry E. Hootman	Electric Controlled Air Incinerator for Radioactive Wastes	4/7/1981
4,292,406	Lars G. Ljungdahl, Jurgen K.W. Wiegal	Anaerobic Thermophilic Culture System	9/29/1981
4,292,407	Lars G. Ljungdahl et al.	Anaerobic Thermophilic Culture	9/29/1981
4,325,327	Prabhudas P. Kantesaria and Francis T. Matthews	Hybrid Fluidized Bed Combustor	4/20/1982
4,326,117	William R. Kanne, Jr., John W. Kelker, and Robert J. Alexander	Weld Braze Technique	4/20/1982
4,329,324	Brian C. Jones	Method of Burning Sulphur-Containing Fuels in a Fluidized Bed Boiler	5/11/1982
4,335,662	Brian C. Jones	Solid Fuel Feed System for a Fluidized Bed	6/22/1982
4,335,785	James L. Hodges and Anthony E. Cerkanowicz	Apparatus and Method for Controlling Heat Transfer Between a Fluidized Bed and Tubes Immersed Therein	6/22/1982
4,367,196	Charles W. J. Wende, Dale F. Babcock, and Robert L. Menegus	Neutronic Reactor	1/04/1983
4,385,117	Lars F. Ljungdahl and Laura H. Carriera	High Ethanol Producing Derivatives of Thermoanaerobacter Ethanolicus	5/24/1983
4,387,559	Anthony Leto	Fuel Burner and Combustor Assembly for a Gas Turbine Engine	6/14/1983
4,423,159	Martha A. Ebra and Richard M. Wallace	Phenolic Cation Exchange Resin Material for Recovery of Cesium and Strontium	12/27/1983
4,430,257	James M. Pope and Edward J. Lahoda	Alcohol-Free Alkoxide Process for Containing Nuclear Waste	2/7/1984
4,432,893	Lien-Mow Lee and Lester L. Kilpatrick	Precipitation-Adsorption Process for the Decontamination of Nuclear Waste Supernates	2/21/1984

Patent No.	Inventor	Title/Subject	Date
4,447,353	Dallas T. Pence and Chun-Chao Chou	Method for Treating a Nuclear Process Off-Gas Stream	5/8/1984
4,453,494	Richard E. Waryasz	Fluidized Bed Boiler Having a Segmented Grate	6/12/1984
4,464,294	Dietrich Thiele	Process for the Stabilization of Radioactive Wastes	8/7/1984
4,465,201	Gordon G. Chafant	Conical O-Ring Seal	8/14/1984
4,467,152	Wade T. Gordy	Circuit Breaker Lock Out Assembly	8/21/1984
4,470,699	Don D. Gay	Micro-Column Plasma Emission Liquid Chromatagraph	9/11/1984
4,476,790	Richard W. Borio and Stephen L. Goodstine	Method of Feeding Particulate Material to a Fluidized Bed	10/16/1984
4,499,034	John E. McAllister, Jr.	Vortex-Augmented Cooling Tower-Windmill Combination	2/12/1985
4,509,855	Don D. Gay	Dual Liquid and Gas Chromotograph System	4/9/1985
4,522,794	Robert C. Hochel and Kathy A. Saturday	Fluorination Process Using Catalyst	6/11/1985
4,530,250	Don D. Gay and William G. McMillan	Method for Sampling Sub-Micron Particles	7/23/1985
4,534,709	Marshall G. Nielsen	Water Displacement Mercury Pump	8/13/1985
4,595,529	James C. Neace	Solvent Wash Solution	6/17/1986
4,615,468	Don D. Gay	Gas Ampoule-Syringe	10/7/1986
4,654,173	Darrel D. Walker and Martha A. Ebra	Nuclear Waste Solutions	3/31/1987
4,677,863	Don D. Gay and William G. McMillan	Sub-Micron Particle Sampler Apparatus	7/7/1987
4,832,122	John C. Corey, Brian B. Looney, and Dawn S. Kaback	In-Situ Remediation System and Method for Contaminated Groundwater	5/23/1989
4,847,321	Heinrich Hess, Richard Kopp, Manfred Bock, and Werner Clarenz	Process for the Production of Thermosetting One-Component Polyurethane-Polyurea Systems	6/11/1989

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Patent No.	Inventor	Title/Subject	Date
4,840,765	Joseph P. Doherty and C. Marek	Precipitate Hydrolysis Process for the Removal of Organic Compounds From Nuclear Waste Slurries	6/20/1989
4854173	Gerry Mott, Mustan Attar, and Rick D. Rishel	Measurement of Intergranular Attack in Stainless Steel Using Ultrasonic Energy	8/8/1989
4,877,736	Carl B. Fliermans	Aerobic Micoorganism for the Degradation of Chlorinated Aliphatic Hydrocarbons	10/31/1989
4,888,979	Timothy J. Steeper	Leak Detection Aid	12/26/1989
4,945,953	James W. Kronberg	Surface Mount Component Jig	8/7/1990
4,952,892	James W. Kronberg	Wave Guide Impedance Matching Method and Apparatus	8/28/1990
4,955,250	John J. Fisher	Multiple Forearm Robotic Elbow Configuration	9/11/1990
4,975,027	Justin E. Halverson and Wilfred W. Bowman	Extreme Pressure Fluid Sample Transfer Pump	12/4/1990
4,979,397	James W. Kronberg	In-Line Rotating Torque Sensor with On-Board Amplifier	12/25/1990
5,008,140	John C. Schmertz	Biaxially Corrugated Flexible Sheet Material	1/16/1991
5,011,604	Edward W. Wilde, John R. Benemann, Joseph C. Weissman, and David M. Tillet	Use of Microalgae to Remove Pollutants from Power Plant Discharges	4/30/1991
5,018,451	Mark Hapstack	Extendable Pipe Crawler	5/28/1991
5,030,011	James W. Kronberg	Mixing Blade System for High-Resistance Media	7/9/1991
5,039,114	Guy B. Lowery	Collar Nut and Thrust Ring	8/13/1991
5,039,224	Patrick E. O'Rourke, Ronald R. Livingston, and William S. Prather	Self-Referencing Remote Optical Probe	8/13/1991
5,039,978	James W. Kronberg	Analog Graphic Display Method and Apparatus	8/13/1991
5,046,371	James W. Kronberg	"In-Line" Rotating Capacitative Torque Sensor	9/10/1991
5,054,023	James W. Kronberg	"Smart" Watchdog Safety Switch	10/1/1991

Patent No.	Inventor	Title/Subject	Date
5,102,439	Carol M. Jantzen	Method For Melting Glass by Measurement of Non-Bridging Oxygen	4/7/1992
5,119,014	James W. Kronberg	Sequential Power-Up Circuit	6/2/1992
5,121,694	William T. Zollinger	Pipe Crawler with Extendable Legs	6/16/1992
5,131,746	Patrick E. O'Rourke, David R. Van Hare, and William S. Prather	On-Line Process Control Monitoring System	7/21/1992
5,135,169	Daniel L. Mensink	Self-cleaning Feed Distributing Delivery Device for Glass Melters	8/4/1992
5,135,728	David G. Karraker	Method for Dissolving Delta-Phase Plutonium	8/4/1992
5,137,314	Larry W. Gunter	Catwalk Grate Lifting Tool	8/11/1992
5,143,149	James W. Kronberg	Wastewater Heat Recovery Apparatus	9/1/1992
5,147,471	James W. Kronberg	Solder for Oxide Layer-Building Metals and Alloys	9/15/1992
5,148,573	Mark A. Killian W. Thor Zollinger	Apparatus for Attaching a Cleaning Tool to a Robotic Manipulator	9/22/1992
5,152,748	Philippe Chastagner	Medical Catheters Thermally Manipulated by Fiber Optic Bundles	10/6/1992
5,153,141	David T. Hobbs	Method of Determining PH by the Alkaline Absorption of Carbon Dioxide	10/6/1992
5,153,931	Bruce R. Buchanan and William S. Prather	Fiber Optic Hydrogen Sensor	10/6/1992
5,154,340	Harold B. Peacock	Method and Device for Frictional Welding	10/13/1992
5,154,899	Edward F. Sturcken	Metal Recovery from Porous Materials	10/13/1992
5,156,659	George T. Wright	Cooler and Particulate Separator for an Off-Gas Stack	10/20/1992
5,157,426	James W. Kronberg	False Color Viewing Device	10/20/1992
5,157,465	James W. Kronberg	Universal Fiber-Optic C.I.E. Colorimeter	10/20/1992
5,159,318	James W. Kronberg	Universal Single Point Liquid Level Sensor	10/27/1992
5,168,367	Patrick E. O'Rourke, Jerry E. McCarty, and Ricky A. Haggard	Variable Path Length Spectrophotometric Probe	12/1/1992

Patents listed between April 1950 and August 2000 Funded by Savannah River Operations

Patent No.	Inventor	Title/Subject	Date
5,172,091	Jeffrey W. Arnold and Mark M. Hart	Asynchronous Parallel Status Comparator	12/15/1992
5,172,192	William S. Prather	In-Situ Spectrophotometric Probe	12/15/1992
5,186,255	John C. Corey	Flow Monitoring and Control System for Injection Wells	2/16/1993
5,189,359	James W. Kronberg	Solid State Safety Jumper Cables	2/23/1993
5,190,333	Richard L. Minichan and Mark A Killian	Gripper Deploying and Inverting Linkage	3/2/1993
5,190,628	Jane P. Bibler	Method and Apparatus for Removing Ions from Soil	3/2/1993
5,198,185	John P. Church	Nuclear Reactor Flow Control Method and Apparatus	3/30/1993
5,198,870	James W. Kronberg	Atomic Line Emission Analyzer for Hydrogen Isotopes	3/30/1993
5,204,530	Phillippe Chastagner	Noise Reduction in Negative-Ion Quadrupole Mass Spectrometry	4/20/1993
5,204,671	James W. Kronberg	Random One-of- N Selector	4/20/1993
5,217,009	James W. Kronberg	Compact Biomedical Pulsed Signal Generator for Bone Tissue Stimulation	6/8/1993
5,217,112	Amy C. Almon	Voltametric Analysis Apparatus and Method	6/8/1993
5,220,976	Larry W. Gunter	Safety Harness	6/22/1993
5,228,624	Daniel L. Mensink	Swirling Structure for Mixing Two Concentric Fluid Flows at Nozzle Outlet	7/20/1993
5,231,288	Daniel M.C. Odell	Audible Radiation Monitor	7/27/1993
5,232,599	Clifford M. Cole	Disposable Sludge Dewatering Container and Method	8/3/1993
5,243,621	Keith R. MacNeill	Method of Feeding Glass Batch to a Glass-Melting Furnace	9/7/1993
5,245,619	James W. Kronberg	Generation of Low-Divergence Laser Beams	9/14/1993
5,248,649	Wilbur C. Mosley, Jr.	Palladium/Kieselguhr Composition and Method	9/28/1993
5,249,457	Richard L. Minichan	Robotic End Effector	10/5/1993
5,251,278	James K. Samborsky	Fiber Optic Monitoring Device	10/5/1993
5,251,490	James W. Kronberg	Ultrasonic Fluid Flow Measurement Method and Apparatus	10/12/1993

Patent No.	Inventor	Title/Subject	Date
5,259,382	James W. Kronberg	Optical Transcutaneous Bilirubin Detector	11/9/1993
5,263,795	John C. Corey, Dawn S. Kaback, and Brian B. Looney	In-Situ Remediation System for Groundwater and Soils	11/23/1993
5,265,132	William T. Zollinger	Vacuum Tool Manipulator	11/23/1993
5,265,478	Mark D. McKay, Chad E. Sweeney, and B. Samuel Spangler, Jr.	Fluid Flow Monitoring Device	11/30/1993
5,268,736	William S. Prather	Light Absorption Cell Combining Variable Pump and Length Pump	12/7/1993
5,271,032	Terrance D. Phillips	Lid Heater for Glass Melter	12/14/1993
5,273,661	John B. Pickett, Hollis L. Martin, Christine A. Langton, and Willie W. Harley	Method for Processing Aqueous Wastes	12/28/1993
5,275,214	Kevin M. Rehberger	Apparatus for Unloading Pressurized Fluid	1/4/1994
5,285,689	Mark Hapstack. Ted R. Talarek, W. Thor Zollinger, Frank M. Heckendorn, II, and Larry Park	Piping Inspection Instrument Carriage with Precise and Repeatable Position Control and Location Determination	2/15/1994
5,289,716	Ray F. Schumacher	Monitoring and Analyzing Waste Glass Composition	3/1/1994
5,289,838	D. MacKenzie C. Odell	Ultrasonic Cleaning of Interior Surfaces	3/1/1994
5,294,313	Dennis F. Bickford	Sensors for Monitoring Waste Glass Quality and Method of Using the Same	3/15/1994
5,296,438	Leung K. Heung	Dimensionally Stable Metallic Hydride Composition	3/22/1994
5,296,715	James W. Kronberg	Optically Isolated Signal Coupler With Linear Response	3/22/1994
5,298,196	Leung K. Heung	Method and Apparatus for Extracting Tritium and Preparing Radioactive Waste for Disposal	3/29/1994
5,298,428	Patrick E. O'Rourke and Dennis R. Van Hare	Self-Referencing Spectrophotometric Measurement	3/29/1994
5,304,808	Daniel M.C. Odell	Method and Apparatus for Data Sampling	4/19/1994

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Patent No.	Inventor	Title/Subject	Date
5,308,979	Eliel Villa-Aleman	Analysis of Hydrogen Isotope Mixtures	5/3/1994
5,309,844	W. Thor Zollinger	Flexible Pipe Crawling Device having Articulated Two Axis Coupling	5/10/1994
5,311,016	Eliel Villa-Aleman	Apparatus for Preparing a Sample for Mass Spectrometry	5/10/1994
5,312,597	Leung K. Heung	Apparatus for Separating and Recovering Hydrogen Isotopes	5/17/1994
5,314,735	James W. Kronberg	Surface Coating for Prevention of Crust Formation	5/24/1994
5,315,884	James W. Kronberg	Capacitive Proximity Sensor	5/31/1994
5,316,649	James W. Kronberg	High Frequency Reference Electrode	5/31/1994
5,317,253	James W. Kronberg	Concealed Wire Tracing Apparatus	5/31/1994
5,319,955	Philippe Chastagner	Tritium Monitor	6/14/1994
5,324,661	Terry C. Hazen	Chemotactic Selection of Pollutant Degrading Soil Bacteria	6/28/1994
5,324,948	Aed M. Dudar, David G. Wagner, and Gregory D. Teese	Autonomous Mobile Robot for Radiological Surveys	6/28/1994
5,326,451	Amy A. Ekechukwu	Liquid Electrode	7/5/1994
5,326,540	Phillippe Chastagner	Containment System for Supercritical Water Oxidation Reactor	7/5/1994
5,326,703	Terry C. Hazen and Geralyne Lopez-De-Victoria	Method of Degrading Pollutants in Soil	7/5/1994
5,334,847	James W. Kronberg	Composition for Radiation Shielding	8/2/1994
5,335,067	William S. Prather and Patrick E. O'Rourke	Spectrophotometric Probe	8/2/1994
5,336,889	Kenneth J. Hofstetter	Composition and Apparatus for Detecting Gamma Radiation	8/9/1994
5,339,694	Brain B. Looney and Sanford Ballard	Monitoring Probe for Groundwater Flow	8/23/1994
5,343,607	James M. Southerland, Jr. and Curtis N. Barringer, Jr.	Gasket and Snap Ring Installation Tool	9/6/1994
5,345,034	John C. Corey	Containment of Subsurface Contaminants	9/6/1994

Patent No.	Inventor	Title/Subject	Date
5,348,396	Patrick E. O'Rourke, Ronald R. Livingston, and William S. Prather	Method and Apparatus for Optical Temperature Measurement	9/20/1994
5,354,438	Amy C. Almon	Separation of Metal Ions from Aqueous Solutions	10/11/1994
5,354,991	Daniel M. C. Odell	Apparatus and Method for Detecting Full-Capture Radiation Events	10/11/1994
5,370,006	William T. Zollinger and Richard C. Treanor	Piping Inspection Carriage Having Axially Displaceable Sensor	12/6/1994
5,373,163	Raymond A. Sigg	Apparatus and Method for Detecting Gamma Radiation	12/13/1994
5,374,403	Robert C. W. Chang	Apparatus for Incinerating Hazardous Waste	12/20/1994
5,375,457	Donald J. Trapp	Apparatus and Method for Detecting Leaks in Piping	12/27/1994
5,375,530	William T. Zollinger and Richard C. Treanor	Pipe Crawler with Stabilizing Midsection	12/27/1994
5,376,803	Matthew C. Mc Fee, Tim J. Kirkham, and Tippi H. Johnson	Device for Calibrating a Radiation Detector System	12/27/1994
5,380,162	Thomas P. Evans II, Jwalit J. Purohit, and John M. Fazio	Split Driveshaft Pump for Hazardous Fluids	1/10/1995
5,384,048	Terry C. Hazen Carl B. Fliermans	Bioremediation of Contaminated Groundwater	1/24/1995
5,388,446	James W. Kronberg	Method and Apparatus for Container Leakage Testing	2/14/1995
5,389,784	Robert R. Weller	Ion Cyclotron Resonance Cell	2/14/1995
5,398,560	W. Thor Zollinger, D. Keith Appel, and Larry R. Park	Apparatus for Inspecting Piping	3/21/1995
5,402,508	Patrick E. O'Rourke and Ronald R. Livingston	Fiber Optic Probe Having Fibers with End-faces Formed for Improved Coupling Efficiency and Method Using Same	3/28/1995
5,404,218	Stanley E. Nave, Ronald R. Livingston, and William S. Prather	Fiber Optic Probe for Light Scattering Measurements	4/4/1995

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Patent No.	Inventor	Title/Subject	Date
5,405231	James W. Kronberg	Conveyor with Rotary Airlock Apparatus	4/11/1995
5,405,588	James W. Kronberg	Process for Removing Cadmium from Scrap Metal	4/11/1995
5,408,356	Mark M. Hart	Fiber Optic Signal Amplifier Using Thermoelectric Power Generation	4/18/1995
5,411,928	L.K. Heung	Composition for Absorbing Hydrogen	5/2/1995
5,412,465	Lewis C. Baylor, Bruce R. Buchanan, and Patrick E. O'Rourke	Method for Vitrification of Constituents of a Process Stream Just as They Go Through an Inlet of a Reaction Vessel	5/2/1995
5,413,973	Carol M. Jantzen	Method for Thermal Processing Alumina-Enriched Spinel Single Crystals	5/9/1995
5,414,199	Scott D. Fleischman	Apparatus and Method for Two -Stage Oxidation of Wastes	5/9/1995
5,413,596	James W. Kronberg	Digital Electronic Bone Growth Stimulator	5/9/1995
5,424,042	J. Bradley Mason, R. Paul Denault, Mark A. Hall, and Maurice P. Carson	Apparatus and Method for Processing Wastes	6/13/1995
5,424,211	Lewis C. Baylor and Susan M. Stephens	Composition for Detecting Uranyl	6/13/1995
5,424,731	James W. Kronberg	Remote Two-Wire Data Entry Method and Device	6/13/1995
5,431,148	James W. Kronberg	Immersible Solar Heater for Fluids	7/11/1995
5,432,595	Martin J. Pechersky	Method for Measuring Residual Stresses in Materials by Plastically Deforming the Material and Interference Pattern Comparison	7/11/1995
5,433,236	W. Thor Zollinger, D. Keith Appel, and Gregory W. Lewis	Apparatus for Moving a Pipe Inspection Probe Through Piping	7/18/1995
5,434,333	Carol M. Jantzen, John B. Pickett, and Hollis L. Martin	Method for Treating Materials for Solidification	7/18/1995
5,435,942	Chia-Lin W. Hsu	Processing for Treating Alkaline Wastes for Vitrification	7/25/ 1995
5,441,991	Jane P. Bibler and Richard M. Wallace	Cesium-Specific Phenolic Ion Exchange Resin	8/15/1995

Patent No.	Inventor	Title/Subject	Date
5,443,604	Michael S. Stowell	Polishing Compound for Plastic Surfaces	8/22/1995
5,443,616	J.W. Congdon	Metal Hydride Composition and Method of Making	8/22/1995
5,457,313	Lewis C. Baylor and Bruce R. Buchanan	Fiber Optic Detector and Method for Using Same for Detecting Chemical Species	10/10/1995
5,460,745	Myung W. Lee	Hydride Compositions	10/24/1995
5,461,185	Charles W. Forsberg, Edward C. Beahm, and George W. Parker	Radioactive Waste Material Disposal	10/24/1995
5,463,377	James W. Kronberg	Apparatus for Detecting the Presence of a Liquid	10/31/1995
5,473,953	D. Keith Appel	Device for Inspecting Vessel Surfaces	12/12/1995
5,480,549	Brian B. Looney, Kenneth H. Lombard, Terry C. Hazen, Susan M. Pfiffner, Tommy J. Phelps, and James W. Borthen	Method for Phosphate-Accelerated Bioremediation	1/2/1966
5,482,688	Samuel D. Fink, H. Perry Holcomb, David G. Karraker, Edwin N. Moore, and Michael A. Vest	Plutonium Dissolution Process	1/9/1996
5,489,536	Amy A. Ekechukwu	Detection of Chlorinated Aromatic Compounds	2/6/1996
5,490,561	Joao E. Cardoso-Neto and Daniel W. Williams	Purge Water Management System	2/13/1996
5,499,529	James W. Kronberg and James R. Cadieux	Detecting Small Holes in Packages	3/19/1996
5,499,597	James W. Kronberg	Optical Temperature Indicator Using Thermochromic Semiconductors	3/19/1996
5,502,439	Gary J. Berlin	Method for Compression of Binary Data	3/26/1996
5,505,829	Eliel Villa-Aleman	Molecular Separation Method and Apparatus	4/9/1996
5,520,052	Martin Pechersky	Method and Apparatus for Determining Material Structural Integrity	5/28/1996
5,529,635	D. MacKenzie C. Odell	Ultrasonic Cleaning of Interior Surfaces	6/25/1996

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Patent No.	Inventor	Title/Subject	Date
5,547,283	James W. Kronberg	Optical Temperature Sensor Using Thermochromic Semiconductors	8/20/1996
5,569,021	Charles D. Hopkins, Ronald R. Livingston, and William R. Toole, Jr.	Hydraulic Pump With In-Ground Filtration and Monitoring Capability	10/29/1996
5,583,051	Amy A. Ekechukwu	Use of a Fiber Optic Probe for Organic Species Determination	12/10/1996
5,595,945	George G. Wicks	Ceramic Composite Coating	1/21/1997
5,601,058	Gregory M. Dyches	Starting Apparatus for Internal Combustion Engines	2/11/1997
5,611,088	Amy C. Almon	Method and Device for Disinfecting a Toilet Bowl	3/18/1997
5,611,766	Richard C. Carle, Karl M. Sievert, Douglas H. Davis, John E. Poleyn, David M. Bennert, and Irving M. Williams	Transportable, Modular Vitrification System for the Treatment of Waste Material	3/18/1997
5,628,808	Carol M. Jantzen	Glass Melter Off-Gas System	5/13/1997
5,637,507	Lewis C. Baylor, Ronald R.Livingston, Patrick E. O'Rourke, Michael J. Whitaker, and George G. Wicks	Tetraethyl Orthosilicate-based Glass Composition and Method	6/10/1997
5,641,245	Bradley E. Pemberton, Christopher P. May, and Joseph Rossabi	Apparatus for Passive Removal of Subsurface Contaminants	6/2/1997
5,662,579	Dennis F. Bickford	Vitrification of Organics-Containing Materials	9/2/1997
5,686,365	Carol M. Jantzen	Method for Dissolution and Stabilization of Silica-Rich Filter Materials	11/11/1997
5,740,545	David N. Maxwell, Robert H. Hones, and Lane Rogers	Bagless Transfer Process and Apparatus for Radioactive Waste Confinement	4/14/1998
5,747,418	John D. Metzger and Mohammed S. El-Genk	Superconducting Thermoelectric Generator	5/5/1998
5,701,125	Gary J. Berlin	Method for Compression of Data Using Single-Pass LZSS and Run-Length Encoding	12/23/1997

Patent No.	Inventor	Title/Subject	Date
5,722,290	James W. Kronberg	Closed-Field Capacitive Liquid Level Sensor	3/3/1998
5,753,109	James W. Borthen, Tery C. Hazen, Kenneth H. Lombard, Brian B. Looney, Susan M. Pfiffner, and Tommy J. Phelps	Apparatus and Method for Phosphate-Accelerated Bioremediation	5/19/1998
5,770,800	Charles F. Jenkins and Boyd D. Howard	Flexible/Rotating Ultrasonic Pipe Inspection Apparatus	6/23/1998
5,772,328	James W. Kronberg	Optical Temperature Sensor Using Thermochromic Semiconductors	6/30/1998
5,783,152	S. E. Nave	Thin-Film Fiber Optic Hydrogen and Temperature Sensor System	7/21/1998
5,843,287	George G. Wicks, David E. Clark, and Rebecca L. Schulz	Method for Recovering Metals from Waste	12/1/1998
5,846,278	Carol Maryanne Jantzen, John Butler Pickett, Kevin George Brown, and Thomas Barry Edwards	Method of Determining Glass Durability	12/8/1998
5,852,790	David W. Hayes, Kenneth J. Hofstetter, Robert F. Eakle, Jr., and George E. Reeves	Global Positioning System Recorder and Method Government Rights	12/22/1998
5,889,217	Joseph Rossabi, Christopher P. May, Bradley E. Pemberton, Jim Shinn, and Keith Sprague	Process and Apparatus for Obtaining Samples of Liquid and Gas from Soil	3/30/1999
5,891,011	George G. Wicks	Vitrification of Waste	4/6/1999
5,903,306	Frank M. Heckendorn, Erin K. Anderson, Casandra W. Robinson, and Harriet B. Haynes	Constrained Space Camera Assembly	5/11/1999
5,920,017	Martin J. Pechersky	Thermal Input Control and Enhancement for Laser based Residual Stress Measurements Using Liquid Temperature Indicating Coatings	7/6/1999

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Patent No.	Inventor	Title/Subject	Date
5,922,950	Bradley E. Pemberton, Christopher P. May, Joseph Rossabi, Brian D. Riha, and Ralph L. Nichols	Depth-Discrete Sampling Port	7/13/1999
5,945,342	Sherrod L. Maxwell III and Sheldon T. Nichols	Method for Digesting Spent Ion Exchange Resins and Recovering Actinides Therefrom Using Micowave Radiation	8/31./1999
5,958,098	Leung K. Heung	Method and Composition in Which Metal Hydride Particles Are Embedded in a Silica Network	9/28/1999
5,960,368	Robert A. Pierce, James R. Smith, William G. Ramsey, Connie A. Cicero-Herman, and Dennis F. Bickford	Method for Acid Oxiation of Radioactive, Hazardous and Mixed Organic Waste Materials	9/28/1999
5,965,482	Leung K. Heung and Myung W. Lee	Composition for Absorbing Hydrogen from Gas Mixtures	10/12/1999
5,968,400	George G. Wicks, David E. Clark, and Rebecca L. Schulz	Tandem Microwave Waste Remediation and Decontamination System	10/19/1999
5,976,867	C.B. Fliermans	Use of Serospecific Biocarrier Compositions for Enhanced Biodegradation and Bioremediation of Groundwater	11/2/1999
5,977,547	Terrance D. Phillips and Howard D. Edwards	Filter for On-Line Monitor Unaffected by Radon Progeny and Method of Using Same	11/2/1999
5,998,490	Steven M. Serkiz	Nonaqueous Ozonation of Vulcanized Rubber	12/7/1999
6,015,041	Leung K. Heung	Apparatus and Methods for Storing and Releasing Hydrogen	1/18/2000
6,023,981	Terrance D. Phillips and Craig Johnson	Sampling Box	2/15/2000
6,052,972	Michael J. Rea and Roger A. Brown	Portable Containment Sleever Apparatus	4/25/2000
6,111,599	Thomas A. Nance, Micah L. Boylston, Casandra W. Robinson, William C. Sexton, and Frank M. Heckendorn	Apparatus for Observing a Hostile Environment	8/29/2000

Operating Budget

Fiscal Year	Grand Total	Operating Costs	Plant & Capitol Equipment Costs*
1950	0	0	0
1951	77,558,999	3,429,167	74,129,832
1952	439,211,797	17.333,850	421,877,947
1953	471,782,554	22,485,328	449,297,226
1954	271,651,937	40,917,265	230,734,672
1955	147,429,292	80,721,562	66,707,730
1956	112,954,056	89,830,864	23,123,192
1957	126,220,829	94,908,694	31,312,135
1958	118,864,609	89,702,843	29,161,766
1959	106,905,582	90,999,148	15,906,434
1960	104,793,044	95,724,867	9,068,177
1961	121,771,367	106,830,628	14,940,739
1962	130,906,860	113,711,363	17,195,497
1963	122,598,395	111,123,191	11,475,204
1964	107,078,779	92,682,283	14,396,496
1965	99,962,512	88,880,025	11,082,487
1966	112,692,646	97,670,744	15,021,902
1967	112,930,724	99,492,969	13,437,753
1968	98,760,137	83,684,469	15,075,668
1969	105,933,787	91,091,727	14,842,059

Operatng Budget Continued

Fiscal Year	Grand Total	Operating Costs	Plant & Capitol Equipment Costs*
1970	122,990,344	111,218,222	11,772,122
1971	136,999,569	123,309,789	13,689,788
1972	128,230,212	115,332,224	12,897,988
1973	147,214,178	131,110,473	16,103,699
1974	146,577,378	128,827,155	17,750,223
1975	168,029,479	138,883,223	29,146,256
1976 and T76	271,338,521	223,703,260	47,635,261
1977	269,304,975	213,119,494	56,185,481
1978	331,448,097	261,218,825	70,229,272
1979	378,637,778	299,991,637	78,646,141
1980	424,160,869	338,373,997	85,786,872
1981	523,973,046	411,869,714	112,103,332
1982	708,545,538	571,001,430	137,544,051
1983	797,845,989	592,792,979	205,053,010
1984	1,010,534,192	692,021,511	318,512,681
1985	1,271,439,762	806,207,452	465,232,310
1986	1.323,795,947	852,169,365	471,626,582
1987	1,269,677,768	889,986,491	379,691,277
1988	1,378,806,713	1,019,946,101	358,860,612
1989	1,629,595,121	1.312,754,229	316,840,892
1990	1,892,017,939	1,518,001,691	374,016,248
1991	2,032,443,798	1,566,668,578	465,775,220
1992	1,913,968,521	1,607,701,605	306,266,916
1993	1,928,449,390	1,578,716,844	349,732,546
1994	1,868,909,448	1,519,176,897	349,732,551

Fiscal Year	Grand Total	Operating Costs	Plant & Capitol Equipment Costs*
1995	1,736,645,000	1,483,338,000	253,307,000
1996	1,639,867,000	1,421,751,000	218,116,000
1997	1,507,435,000	1,350,480,000	156,955,000
1998	1,421,209,000	1,270,570,000	150,639,000
1999	1,496,552,000	1,339,113,000	157,439,000
2000	1,513,532,000	1,337,766,000	175,766,000

*Projects not considered as “line item projects” but more substantial than general plant projects.

Churches within Federal Acquisition Area

Bean Pond Baptist Church
Indian Grove Baptist Church
Colored Ellenton Church of Christ
Cypress Chapel Church
Fairmont Colored Baptist Church
Joyce Branch Baptist Church
Park Branch Baptist Church
Pleasant Hill Baptist Church
St. Luke's Baptist Church
Ned Branch Baptist Church
Love, Prosperity, and Good Will Society
Steel Creek Baptist Church
Bethlehem Baptist Church
Canaan Fair Methodist Church
Canaan Methodist Colored Church
Christian Baptist Benevolent Society
Dunbarton Baptist Church
Ebenezer Church
Ellenton Baptist Church
Ellenton Christian Church
Ellenton Methodist Episcopal Church, South
Fair Branch Baptist Church
Fairfield Baptist Church
Four Mile Baptist Church
Friendly and Benevolent Society
Friendship Baptist Church
Methodist Episcopal Colored Church
Park Baptist Church
Pleasant Mountain Baptist Church
Runs Baptist Church
Shining Light Benevolent Society
Spring Branch Baptist Church
St. John's Baptist Church
St. Luke's Baptist Church
St. Phillips Church
Steel Creek Baptist Church
Church of God
Thomas Grove Baptist Church
Union Branch Baptist Church
Williams Chapel Church
Zion Fair Baptist Church
Zion Grove Church
United House of Prayer

Source: U.S. Army Corps of Engineers. Office of the Chief of Engineers Real Estate Tract Register: (Department of the Army, South Atlantic Division, Prepared for the Savannah River Operations, U.S. Atomic Energy Commission, South Carolina, 19??).

Cemeteries

Cemetery	Graves Removed	New Cemetery	New Location
Asbury Chapel and Mixon Cemetery (African American)	47	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Ashley Cemetery (cultural affiliation not noted)	5	North Augusta Cemetery	No site location provided
Bailey Cemetery (European American)	19	Bates-Foreman Cemetery (17 graves) New Williston Cemetery (2 graves)	Bates-Foreman-1 mi. N of Jackson, next to old Foreman Cemetery, Aiken County, SC; New Williston – adjacent to existing Williston Cemetery at Williston, Barnwell County, SC
Bailey Cemetery (European American)	27	New Williston Cemetery	Adjacent to existing Williston Cemetery at Williston, Barnwell County, SC
Baker Cemetery (cultural affiliation not noted)	4	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Bates Cemetery (African American)	118	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Baughman Cemetery (cultural affiliation not noted)	16	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Bean Pond Cemetery (African American)	60	Bean Pond Church Cemetery	1 mi. SW of Jackson, Aiken County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Boyd Cemetery (European American)	6	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Boyd Cemetery (African American)	96	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Briar Hill Cemetery (African American)	9	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Bryant Cemetery (African American)	13	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Bush Cemetery (African American)	4	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Bush Cemetery (African American)	14	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Bush Cemetery (African American)	106	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Bush Cemetery (European American)	5	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Bush Cemetery (European American)	21	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Bush Cemetery (European American)	38	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Bush Field Cemetery (African American)	191	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Cale Cemetery (African and European American)	22	New Williston Cemetery, New White Pond Cemetery	New Williston - Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; New White Pond -1 mile NE of White Pond Railroad Crossing, Aiken County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Camelite Cemetery (European American)	50	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Canaan Fair Cemetery (African American)	277	New Canaan Fair Cemetery (275 graves) New Runs Baptist Church Cemetery (2 graves)	Canaan Fair – no location provided New Runs – approximately 10 mi. S of Aiken, SC
Chisholm Cemetery (African American)	28	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Church of God Cemetery (African American)	1	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Clarisa R. Bush (European American)	5	Barnwell County Cemetery	Barnwell County, SC
Cochran Cemetery (European American)	11	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Cypress Chapel Cemetery (European American)	72	Barnwell County Cemetery and other unnamed cemeteries in the area	Barnwell County, SC
Daisy Mae Cemetery (European American)	34	Barnwell County Cemetery	Barnwell County, SC
Darlington Cemetery (European American)	4	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Davis Cemetery (European American)	2	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Dicks Cemetery (European American)	2	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Dicks Cemetery (European American)	5	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Doe Cemetery (African American)	16	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Dunbar Cemetery (African American)	9	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Dunbar Cemetery (African American)	27	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Dunbar-Rountree Cemetery (European American)	13	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Ebenezer Church Cemetery (cultural affiliation not noted)	141	Ebenezer Church Cemetery	Approximately one mi. S of Williston, Barnwell County, SC
Ellenton Cemetery (European American)	99	Cassels Cemetery and other unnamed cemeteries in area	Adjacent to Bates-Foreman Cemetery, 1 mi. N of Jackson, Aiken County, SC
Fair Branch Cemetery (African American)	87	New White Pond Cemetery (86 graves) Unknown gravesite	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Ficklen Cemetery (African American)	98	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Floyd Cemetery (African American)	34	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Foreman Cemetery (European American)	8	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Four Mile Cemetery (African American)	70	Four Mile Church Cemetery	New Ellenton, Aiken County, SC
Friendship Cemetery (African American)	28	New Friendship Baptist Church Cemetery	Silver Bluff Road, approximately 10 mi S of Aiken, SC
Givens Cemetery (African American)	7	New Friendship Baptist Church Cemetery	Silver Bluff Road, approximately 10 mi. S of Aiken, SC

Cemetery	Graves Removed	New Cemetery	New Location
Green Cemetery (African American)	6	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Green Cemetery (European American)	1	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Green Cemetery (European American)	3	Green Pond Church Cemetery	Approximately 3 mi. NE of Jackson, Aiken County, SC
Green Cemetery (European American)	4	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Green Cemetery (European American)	5	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Green Cemetery (European American)	7	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Green Cemetery (European American)	12	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell, SC
Green Cemetery (European American)	43	Old Williston Cemetery (8 graves) New Williston Cemetery (35 graves)	New Williston and Old Williston Cemeteries are located adjacent to each other in Williston, SC
Grubfield Cemetery (African American)	27	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Hankinson Cemetery (African American)	10	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Hankinson Cemetery (European American)	3	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Hankinson Cemetery (European American)	10	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Hay Cemetery (African and European American)	55	New Williston Cemetery (15 European-American graves); New White Pond Cemetery (40 African-American graves)	New Williston - Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; New White Pond- 1 mi. NE of White Pond White Railroad Crossing, Aiken County, SC
Hazel Cemetery (African American)	4	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Hazel Cemetery (African American)	24	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Hickson Cemetery (African American)	33	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Hiers Cemetery (African American)	18	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Holland Cemetery (African American)	13	Barnwell Methodist Church Cemetery (12 graves) Westover Cemetery (1 grave)	Barnwell Methodist Church Cemetery – location not provided; Westover Cemetery- Augusta, GA;
Indian Grove Baptist Church (cultural affiliation not noted)	62	Indian Grove Baptist Church Cemetery, new site	Approximately 10 mi. S of Aiken, SC
Johnson Cemetery (African American)	1	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Joyce Branch Cemetery (European American)	291	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Kennedy Cemetery (European American)	2	Pleasant Hill Cemetery	Approximately 7 mi. S of Williston, Barnwell County, SC
Kennedy Cemetery (European American)	4	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Killingsworth Cemetery (European American)	13	Barnwell County Cemetery	Barnwell County, SC
Killingsworth Cemetery (European American)	78	Barnwell County Cemetery	Barnwell County, SC
Log Cane Cemetery (African American)	8	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Love, Benevolent Baptist Burial Society Cemetery (African American)	12	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Lucas Cemetery (European American)	2	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
McClain Cemetery (European American)	3	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken, SC
McElhenny Cemetery (European American)	3	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken, SC
Melton Cemetery (European American)	7	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Meyers-Sweat Cemetery (European American)	22	Barnwell County Cemetery, New Williston Cemetery	Barnwell County Cemetery, Barnwell County, SC; New Williston Cemetery- and other unnamed locations, Williston, Barnwell County, SC
Mills Cemetery (African American)	13	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Mooney Cemetery (African and European American)	34	New Williston Cemetery, New White Pond Cemetery	New Williston - Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; New White Pond -1 mi. NE of White Pond Railroad Crossing, Aiken County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Mose Williams Cemetery (African American)	10	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Muns Cemetery (European American)	42	Bates-Foreman Cemetery	1 mi. S of Jackson, Aiken County, SC
Ned Branch Church Cemetery (African American)	290	New cemetery name is not provided	No new site location provided
Old Dunbar Cemetery (African American)	534	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Owen Cemetery (European American)	23	New Williston (4 graves), Pine Grove Cemetery (19 graves)	New Williston - Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; Pine Grove Cemetery-Langley, Aiken County, SC
Owen-Stallings Cemetery (African and European American)	90	New Williston Cemetery (European American graves), New White Pond Cemetery (African American graves)	New Williston - Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; New White Pond -1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Owens Cemetery (European American)	25	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken, SC
Park Baptist Church Cemetery (cultural affiliation not noted)	110	Park Baptist Church Cemetery (new site)	Approximately 9 mi. S of Aiken, SC
Park Branch Church Cemetery (cultural affiliation not noted)	15	Park Baptist Church Cemetery (new site)	Approximately 9 mi. S of Aiken, SC
Parker Cemetery (African American)	5	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Patrick Cemetery (European American)	7	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Reynolds Cemetery (African American)	10	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Reynolds Cemetery (African American)	112	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Rhett Green Cemetery (European American)	30	Old Williston Cemetery (3 graves) Bates-Foreman Cemetery (27 graves)	Old Williston – adjacent to New Williston Cemetery, Barnwell County, SC; Bates-Foreman Cemetery – 1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Runs Baptist Church Cemetery (African American)	20	Runs Baptist Church Cemetery (new site)	Approximately 10 mi. S of Aiken, SC
Sanders-Beard Cemetery (European American)	24	Bates-Foreman Cemetery	1 mile N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
St. Luke Baptist Church Cemetery (cultural affiliation not noted)	289	St. Luke Baptist Church Cemetery (new site)	Approximately 5 mi. SW of Barnwell, SC
St. Phillips Cemetery (African American)	56	New Thomas Grove Church	SC Highway 41, approximately 5 mi. NE Cemetery of Barnwell, SC
Spring Branch Baptist Cemetery (African American)	29	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Steel Creek Cemetery (European American)	66	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Stephen Cemetery (European American)	2	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Stephens Cemetery (African American)	19	New White Pond Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County

Cemetery	Graves Removed	New Cemetery	New Location
Steve Bush Cemetery (European American)	16	New Williston Cemetery (5 graves) Bates-Foreman Cemetery (7 graves) Cassels Cemetery (4 graves)	New Williston-adjacent to existing Williston Cemetery in Williston, Barnwell County, SC; Bates-Foreman Cemetery – 1 mi. N of Jackson, adjacent to old Foreman Cemetery, Aiken, County, SC; Cassel Cemetery – adjacent to Bates - Foreman Cemetery, 1 mi. N of Jackson, Aiken County, SC
Sun Hill Cemetery (African American)	53	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Sweat Cemetery (European American)	2	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Thomas Grove Cemetery (African American)	136	New Thomas Grove Church Cemetery	SC Highway 41, 5 mi. NE of Barnwell, SC
Tobin Cemetery (European American)	4	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Treadway Cemetery (European American)	63	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Tyler Cemetery (European American)	18	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Unknown Cemetery (African American)	11	New Dunbar Cemetery	1 mi. S of Jackson, Aiken County, SC
Unknown Cemetery (African American)	11	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Unknown Cemetery (African American)	22	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Unknown Cemetery (African American)	22	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC

Cemetery	Graves Removed	New Cemetery	New Location
Unknown Cemetery (African American)	27	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Unknown Cemetery (African American)	55	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Unknown Cemetery (African American)	56	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Unknown Cemetery (European American)	1	No new cemetery name was provided	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Weathersbee Cemetery (European American)	10	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Weathersbee Cemetery (European American)	34	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Weathersbee-Chapman Cemetery (cultural affiliation not noted)	6	Bates-Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Williams Cemetery (European American)	12	Bates Foreman Cemetery	1 mi. N of Jackson, SC adjacent to old Foreman Cemetery, Aiken County, SC
Woods Cemetery (African American)	72	New White Pond Cemetery	1 mi. NE of White Pond Railroad Crossing, Aiken County, SC
Woods Cemetery (European American)	6	New Williston Cemetery	Adjacent to existing Williston Cemetery in Williston, Barnwell County, SC
Zion Fair Cemetery (cultural affiliation not noted)	232	Zion Fair Cemetery (new site)	No site location provided

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Endnotes

CHAPTER 1

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CHAPTER 2

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CHAPTER 5

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2. Much of the early history of the du Ponts is taken from E. I. du Pont de Nemours and Company, Inc., *Du Pont, The Autobiography of an American Enterpris*e (New York: Charles Scribner's Sons, 1952), 6–88; other background information is from *Encyclopædia Britannica*, Internet online ed., s.v. "du Pont Family," "du Pont, Pierre-Samuel," "The French Revolution and Napoleon, 1789–1815," "Turgot, Anne-Robert-Jacques, Baron De L'aulne," "Hundred Days," "Lavoisier, Antoine-Laurent," "Robespierre, Maximilien François-Marie-Isidore de," "Mexican War," "History of Black Powder," "Saltpetre," and "explosives."
3. Du Pont, *Autobiography of an American Enterprise*, 10 (note).
4. *Ibid*., 55.
5. "The Wizards of Wilmington," *Time*, 57(16), April 16, 1951, 98. In France, the Du Ponts had a family home at Chevannes, about 60 miles south of Paris. The general area was also known as Nemours, which Pierre-Samuel had added to his name when he arrived in the United States.
6. There was a precedent for such an executive committee at General Electric, which the Du Pont committee resembled with the exception that at Du Pont the committee met weekly rather than monthly and was composed entirely of fulltime salaried managers, whereas at General Electric financiers served as the top managers.
7. Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Massachusetts: Belknap Press, 1980), 443; Du Pont, *Autobiography of an American Enterprise*, 55.

8. David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy, Du Pont R&D, 1902–1980* (New York: Cambridge University Press, 1988), 18; Chandler, *The Visible Hand*, 442–444 and 451–452. At the beginning of the twentieth century Du Pont headed a powder cartel that included Laflin and Rand, Hazard, and a number of small family firms, and also a dynamite business controlled under the holding company Eastern Dynamite Company. Chandler, *The Visible Hand*, 439.
9. A good examination of this change in the role of science can be found in P. L. Galison and B. W. Hevly, eds., *Big Science: The Growth of Large Scale Research*, (Stanford, California: Stanford University Press, 1992).
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11. Hounshell and Smith, *Science and Corporate Strategy*, 13, 26.
12. In spite of differences, an item that all agreed on was the definition and function of what was called a "works laboratory," a forerunner of the Works Technical Department that performed important functions at Savannah River. The works laboratories would only deal with the routine chemical and material tests necessary to plant operations, and would not develop new products or processes.
13. Hounshell and Smith, *Science and Corporate Strategy*, 17, 27–29.
14. Du Pont, *Autobiography of an American Enterprise*, 61; Hounshell and Smith, *Science and Corporate Strategy*, 11, 14.
15. Receipts and earnings for 1904 through 1921 are presented at Hounshell and Smith, *Science and Corporate Strategy*, 12.
16. Hounshell and Smith, *Science and Corporate Strategy*, 74. The argument was, at least in part, over the promotion of a du Pont family member. "Pierre's insistence that no du Pont serve in middle or top management unless he was fully qualified helped to bring on a bitter family fight." Chandler, *The Visible Hand*, 452.
17. Du Pont, *Autobiography of an American Enterprise*, 84; *Encyclopædia Britannica,* Internet online ed., s.v. "DuPont [sic] Company."
18. Du Pont, *Autobiography of an American Enterprise*, 13, 56, 98, 286.
19. *Ibid.*, 85–86.
20. Specifically, Stine's four arguments were that such research would have advertising value because of the good publicity through the presentation and publishing of papers; more theoretical research would improve the morale among research staff and make recruiting high-caliber chemists easier; research findings could be exchanged with other institutions that had information Du Pont might need in its development and production efforts; and finally, production with commercial uses might be discovered. Hounshell and Smith, *Science and Corporate Strategy*, 223.
21. Hounshell and Smith, *Science and Corporate Strategy*, 137 and 223–227; David A. Hounshell, *Du Pont and the Management of Large-Scale Research and Development*, (Publisher: Location, publication year) 239.
22. Hounshell and Smith, *Science and Corporate Strategy*, 279.
23. *Ibid.*, 211, 228–231; Hounshell, *Du Pont and Management*, 239.
24. As can be expected, the difference in philosophy between Stine and Bolton, and the increased concentration on commercial production, had a negative impact on the researchers involved in the program Stine had initiated. By 1932, half the 16 researchers Stine had originally hired had left the pure science program. Hounshell and Smith, *Science and Corporate Strategy*, 243.
25. Hounshell, *Du Pont and Management,* 239–240; and Hounshell and Smith, *Science and Corporate Strategy*, 233.
26. Hounshell and Smith, *Science and Corporate Strategy,* 211.
27. Helmut Carol Engelbrecht and Frank Cleary Hanighen, *Merchants of Death; A Study of the International Armament Industry* (1934; reprint, New York: Garland Publishing, Inc., 1972), 5–11. The reprint edition contains a foreword by Harry Elmer Barnes, who discusses the context of the original publication and notes that although the the sis presented by Engelbrecht and Hanighen was of limited validity, the authors did describe an early version of what has come to be known as the military-industrial complex.
28. *Encyclopædia Britannica*, Internet online ed., s.v. "DuPont [sic] Company"; Du Pont, *Autobiography of an American Enterprise*, 110; Arthur M. Schlesinger, Jr., *The Almanac of American History* (New York: Barnes and Noble Books, 1993), 466; Hounshell and Smith, *Science and Corporate Strategy*, 321.
29. Hounshell and Smith, *Science and Corporate Strategy*, 332–333.
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31. Du Pont, *Autobiography of an American Enterprise*, 119; Hounshell and Smith, *Science and Corporate Strategy,* 337.
32. Rodney P. Carlisle and Joan M. Zenzen, *Supplying the Nuclear Arsenal: American Production Reactors, 1942–1992* (Baltimore: The Johns Hopkins University Press, 1996), 18; Richard G. Hewlett and Oscar E. Anderson Jr., *The New World: A History of the United States Atomic Energy Commission, Volume I, 1939–1946* (1962; reprint, Berkeley: University of California Press, 1990), 91, 105–106.
33. Hewlett and Anderson, *The New World*, 106–107; typescript concerning Du Pont's involvement in military use of plutonium (a section of a larger unidentified report *ca.*1948), Hagley Museum and Library, Wilmington, Delaware, Records of the Atomic Energy Division, Accession 1957, Series I, Box 1, Folder 3, 2–3.
34. Hewlett and Anderson, *The New World*, 186. Although the negative impact of taking on the project is usually presented and probably represents the most important aspect of Du Pont's point of view, there were some benefits, such as those recalled by Du Pont scientist D. F. Babcock 40 years later: "One of the major benefits that Du Pont

saw was that it would be able to retain many of the personnel that might otherwise be lost to the Army. Also, the people who joined the nuclear group would become better acquainted with the people from other Du Pont sites and would be broadened by this experience. To me, the greatest thrill was to rub elbows with the famous scientists from all over the world, many of whom either then had received the Nobel Prize or would receive this prize later." Address by Dale F. Babcock, "Du Pont and Nuclear Energy," at Savannah River Laboratory, E. I. Du Pont de Nemours and Company, June 22, 1982, 3 (on file, personal collection of J. M. Boswell, Aiken, South Carolina).

35. Hounshell, *Du Pont and Management*, 247; Hounshell and Smith, *Science and Corporate Strategy*, 339; Du Pont, *Autobiography of an American Enterprise*, 117.
36. Hounshell and Smith, *Science and Corporate Strategy*, 261; Hounshell, *Du Pont and Management*, 242–243.
37. Eugene Wigner, one of the more vocal scientists who did not like Du Pont's participation, had promoted a heavy-water design for the initial reactors, which Du Pont put off in favor of the apparently simpler graphite reactor design. Opinions like this coming from a commercial company, and taking precedence over the views of nuclear physicists, did much to raise Wigner's ire. Carlisle and Zenzen, *Supplying the Nuclear Arsenal*, 34.
38. Carlisle and Zenzen, *Supplying the Nuclear Arsenal*, 13; P. L. Galison, introduction to Galison and Hevly, eds., *Big Science,* 12; Hounshell, *Du Pont and Management*, 249.
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40. *Ibid*.,42; Hewlett and Anderson, *The New World*, 425.
41. Hounshell and Smith, *Science and Corporate Strategy*, 331.
42. Du Pont, *Autobiography of an American Enterprise*, 119.
43. Crawford H. Greenewalt Papers, 1928–1968, Hagley Museum and Library, Wilmington, Delaware, Accession 1814, "Unclassified Portions of C. H. Greenewalt's Notes," entry for February 15, 1943, in vol. 2 (December 16, 1942–December 31, 1943), 97: Hounshell and Smith, *Science and Corporate Strategy*, 341–342.
44. Hounshell and Smith, *Science and Corporate Strategy,* 343.
45. Hounshell, *Du Pont and Management,* 253–254; and Hounshell and Smith, *Science and Corporate Strategy*, 351–352, 360.
46. Hounshell, *Du Pont and Management*, 260.
47. Hounshell and Smith, *Science and Corporate Strategy*, 359–360.
48. *Ibid*., 317, 345.
49. C. H. Greenewalt to W. S. Carpenter, Jr., personal communication February 16, 1948, as quoted in Hounshell and Smith, *Science and Corporate Strategy*, 345.
50. The report containing the findings of the survey is *Survey of the Plutonium Project*, revised 1983, Document Number DPW-72-143-1, deleted version (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., March 25, 1949), available from Hagley, Records of the Atomic Energy Division, Acc. 1957, Series II, Box 6, Folder 9. Internal memoranda related to this work, also available from Hagley, Acc. 1957, Series I, Box 2, Folder 9, include: R. P. Genereaux to R. M. Evans, "Objective of Survey," December 29, 1948; L. Squires to J. N. Tilley, "APC Objectives," December 29, 1948; and R. M. Evans to file, January 3, 1949.
51. Hounshell and Smith, *Science and Corporate Strategy*, 345.
52. Hewlett and Anderson, *The New World*, 629. Although General Electric would seem to be the first choice because of involvement in postwar Hanford operations, there were problems during the first few years of General Electric operations there. Atomic Energy Commission Director of Production Walter J. Williams in 1948 was worried about General Electric's handling of new construction at Hanford, feeling that the company failed to take seriously its responsibilities, and that the combined construc tion and operation efforts at Hanford exceeded General Electric's capabilities at that time. Admiral Thorvald A. Solberg, a Navy member of the Military Liaison Committee, thought management at Hanford was weak. Carlton Shugg saw the attitude there as needing "shock treatment" to bring home the importance of new construction at the plant. Atomic Energy Commission general manager Carroll Wilson was dissatisfied with the company's performance at Hanford, but agreed that they were "heavily committed" to doing Atomic Energy Commission work at Hanford and elsewhere. Richard G. Hewlett and Francis Duncan, *Atomic Shield, A History of the United States Atomic Energy Commission, Volume II, 1947–1952* (1962; reprint, Berkeley: University of California Press, 1990), 85–86, 143, 145, 189–199, 215.
53. Hewlett and Duncan, *Atomic Shield*, 428.
54. Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 407, May 15, 1950, National Archives, Records of the Atomic Energy Commission, Office of the Secretary, RG 326, Box 2 of 5, Vol. 5, 273.
55. Hewlett and Duncan, *Atomic Shield*, 427–428. An Atomic Energy Commission discussion of the meeting with Crawford Greenewalt can be found in Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 407, May 15, National Archives, Records of the AEC,1950, RG 326, Box 2 of 5, Vol. 5, 271.
56. Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 418, June 5, 1950, National Archives, Records of the AEC, RG 326, Box 2 of 5, Vol. 5, 320–321.
57. Hewlett and Duncan, *Atomic Shield*, 430; Greenewalt Papers, H. F. Brown to C. H. Greenewalt, "Organization," July 11, 1950, Hagley, Acc. 1814, Series III, Box 30, Folder 5, 1.
58. F. M. Burns to R. C. Blair, attachment "History of Negotiation of Contract AT(07-2)-1," September 5, 1958, Hagley, Records of the Atomic Energy Division, Acc.1957, Series II, Box 5, Folder 1, 2–4.
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61. H. F. Brown to supervisors and managers of the Explosives Department, "Organization," August 2, 1950, Hagley Records of the Atomic Energy Division, Acc. 1957, Series II, Box 6, Folder 7, 2–4; and Burns to Blair, "History of Negotiation of Contract AT(07-2)-1," September 5, 1958, Hagley, Acc. 1957, Series II, Box 5, Folder 1, 5.62. R. M. Evans to Curtis A. Nelson, August 9, 1950, Hagley Museum, Records of the Atomic Energy Division,Acc. 1957, Series II, Box 6, Folder 7, 1; and S. A. McNeight, "Log Book," October 8, 1957, Acc. 1957, Series IV, Box 49, Folder 13, 2 and 4–6. This notebook appears to be a compilation of earlier logbooks by various authors (only initials given) with entry dates in 1952 and 1953.
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64. *Ibid.*, 6–7.
65. *Ibid.*, 1–3.
66. Carlisle and Zenzen, *Supplying the Nuclear Arsenal*, 82–83.
67. *Ibid.*, 80–81.
68. Du Pont, S*avannah River Plant Engineering and Design History*, *Vol. 1, Administration*, DPE970 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 9; S. L. Abrams to C. H. Greenewalt, "U.S. Gov't: Atomic Energy Commission—Plant Construction, Design, Op., 1950," August 15, 1950, Hagley, Greenewalt Papers, Acc. 1814, Series III, Box 42, Folder 6.
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71. *Ibid.*, 367.
72. Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 455, 464, August 16, 1950, National Archives, Records of the AEC, RG 326, Box 3, Vols. 6–7, Folder "Vol. 6, (1 of 2), 424–581."
73. Burns to Blair, "History of Negotiation of Contract AT(07-2)-1," September 5, 1958, Hagley, Records of the Atomic Energy Division, Acc. 1957, Series II, Box 5, Folder 1, 7–9. Regarding the seriousness of the Atomic Energy Commission's conviction that presidential approval might bring up questions of the legality of prior Atomic Energy Commission contracts, see Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 469, September 14, 1950, National Archives, Records of the AEC, RG 326, Box 3, Volumes 6–7, Folder "Vol. 6, (1 of 2), 424—581," 515, where the potential for introducing new legislation is also brought up.
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75. *Ibid.*, 18.
76. *Ibid.*, 17 and 19–20; Minutes of the Meetings of the Atomic Energy Commission, Meeting No. 653, January 23, 1952, National Archives, Records of the AEC, RG 326, Box 5, Vol. 9–10, Folder "Vol. 9, (1 of 2), 1–211," 49.
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51. Melanie A. Cabak and Mary M. Inkrot, *Old Farm, New Farm: An Archaeology of Rural Modernization in the Aiken Plateau, 1875–1950*, 23–25, in Savannah River Archaeological Research Papers 9, Occasional Papers of the Savannah River Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, University of South Carolina, 1997. This thorough study of the SRS pre-federal farm properties produced by the Savannah River Archaeological Research Program is an excellent source on the material culture of the many farming families in this area.
52. F. Stuart Chapin, Theodore W. Wirths, Alfred M. Denton Jr., and John C. Gould, *In the Shadow of a Defense Plant: A Study of Urbanization in Rural South Carolina* (Chapel Hill, NC: Institute for Research in Social Science, University of North Carolina, 1954), 16.
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59. *SRP Construction History,* DPES 1403 (1957), 37–38.
60. Tonya Algerine Browder and Richard David Brooks, *Memories of Home: Reminiscences of Ellenton*, in Savannah River Archaeological Research Heritage Series 2, Occasional Papers of the Savannah River Archaeological Research Program, Community History Project, South Carolina Institute of Archaeology and Anthropology, University of South Carolina, 1996. This well-done volume contains a wealth of information about the Ellenton community through oral history accounts and historic photographs.
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62. Browder and Brooks, *Memories of Home*, 53.
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64. U.S. Atomic Energy Commission, Information for the Press (No. 32), January 9, 1952.
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68. Browder and Brooks, *Memories of Home*, 47–78.
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CHAPTER 11

1. The definitive contract states that "The Commission shall make available to the Contractor all information and data in its possession which will be helpful in the design, con struction and operations of the new facilities and shall to the fullest extent practicable make available to the Contractor such of its research and development facilities as are needed for the benefit of the work hereunder. Upon the request of the Contractor, the Commission shall to the fullest extent consistent with its other obligations furnish other assistance in furtherance of the Contractor's performance of the work hereunder." See "Contract AT(07-2)-1 for the Development, Design, Construction, Installation and Operation of Facilities for the Atomic Energy Program of the United States of America, between the United States of America represented by the Atomic Energy Commission and E. I. du Pont de Nemours and Company," (September 30, 1953), National Archives, Records of the Atomic Energy Commission, Office of the Secretary, General Correspondence, 1951–1958, RG 326, Contracts 9, Box 10, 7.
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CHAPTER 14

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3. "Purex" was probably coined as an acronym for Plutonium and Uranium Reduction and Extraction, or something closely approximating that phrase. Other possible sources of the acronym have been noted to be Plutonium Uranium Recovery by Extraction, Purification by Extraction, Plutonium and Uranium Refining by Extraction, and simply Plutonium Uranium Extraction. The acronym may have been coined at the Knolls laboratory. H. Alwyn C. McKay, "Introduction," in *Synthesis, Properties, Reactions and Analysis*, ed. Wallace W. Schulz and James D. Navratil, *Science and Technology of Tributyl Phosphate*, vol. 1 (Boca Raton, Florida: CRC Press, Inc., 1984), 2; and J. Malvyn McKibben, "Chemistry of the Purex Process," *Radiochimica Acta* 36, no. 1/2 (1984). 3.
4. Crawford H. Greenewalt to Carroll L. Wilson, December 20, 1948, Hagley, Acc. 1814, Series III, Box 31, Folder 22, 1; and *Survey of the Plutonium Project*, revised 1983,. Document Number DPW-72-143-1, deleted version (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., March 25, 1949), Hagley, Acc. 1957, Series II, Box 6, Folder 9, 1, Hagley. Redox required the addition of aluminum nitrate for effective separations, but since aluminum nitrate did not dissolve well in the Redox solutions the process required a large volume of solution to work properly, which meant large amounts of waste were produced. The Purex process did not require aluminum nitrate; in addition, the nitric acid used in Purex to serve the same purpose (to act as the salting agent) could be recycled to reduce waste volume. Jolley *et al., The ORNL Chemical Technology Division*, 2–4.
5. Pure TBP was a white translucent, slightly viscous liquid used in industry as a plasticizer and antifoaming agent. J. R. Flanary, "Solvent Extraction Separation of Uranium and Plutonium From Fission Products by Means of Tributyl Phosphate," in *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, vol. 9, *Reactor Technology and Chemical Processing* (New York: United Nations, 1956), 531.

6. J. Malvyn McKibben, “Chemistry of the Purex Process,” *Radiochimica Acta* 36, no. 1/2 (1984). 4; J. L. Swanson, "Purex Process Flowsheets," in *Applications of Tributyl Phosphate in Nuclear Fuel Reprocessing*, ed. Wallace W. Schulz, Leland L. Burger, and James D. Navratil, *Science and Technology of Tributyl Phosphate*, vol. 3, (Boca Raton, Florida: CRC Press, Inc., 1984), 56.
7. In December 1947, the Atomic Energy Commission established the Clinton National Laboratory at Oak Ridge, “as a center for basic research, applied chemical research, and isotope production and research. The AEC program included a vigorous effort in applied chemical engineering directed toward the solution of current problems that were vital to the atomic energy operations.” Jolley *et al., The ORNL Chemical Technology Division*, 1–9.
8. S. A. McNeight, “Log Book,” October 8, 1957, Hagley Museum and Library, Wilmington, Delaware, Records of the Atomic Energy Division, Acc. 1957, Series IV, Box 49, Folder 13, 7 (this notebook appears to be a compilation of earlier logbooks by various authors (only initials given) with entry dates for 1952 and 1953); O. S. Petrescu, “Projects 8980 and 8987, Atomic Energy Division, Engineering Dept.–Explosives Dept. Meeting #7, October 6, 1950,” meeting summary and conclusions, October 6, 1950, Hagley, Acc. 1957, Series IV, Box 44, Folder 8, 2; F. S. Chambers, "Introduction," Document Number DPW-6705, *ca.* 1952, Hagley, Acc. 1957, Series IV, Box 46, Folder 7, 1. Du Pont considered SPRU valuable because it incorporated a type of equipment called mixer-settlers that the company wanted to use at Savannah River.
9. McKay, “Introduction,” *Synthesis, Properties, Reactions and Analysis,* 4.
10. *Savannah River Plant Engineering and Design History, Vol. III, #200-F&H Areas*, DPE-972 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 77 (hereafter cited as *Engineering and Design History, F&H Areas*). J. B. Starks, “The Purex Process,” DPSPU 77-11-1.
11. G. W. Watt to F. S. Chambers, “Comments on the Current KAPL Program and Related Process Problems,” April 23, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 7, 1; Du Pont, *SRP Engineering and Design History, F&H Areas, Vol III*, DPE972, 20.
12. H. Alwyn C. McKay, J. H. Miles, and J. L. Swanson, "The Purex Process," in *Applications of Tributyl Phosphate in Nuclear Fuel Reprocessing*, ed. Wallace W. Schulz, Leland L. Burger, and James D. Navratil, *Science and Technology of Tributyl Phosphate*, vol. 3, (Boca Raton, Florida: CRC Press, Inc., 1984), 2–3; and *Savannah River Plant Engineering and Design History, Vol. IV, #300/700 Areas and General Services and Facilities*, DPE-973, deleted version (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 459 (hereafter cited as *Engineering and Design History*, 300/700 Areas).
13. The chemical change that allowed the plutonium and uranium to be moved from the organic to the aqueous phase and back involved a change in the valence, or electrical charge, of the chemical compounds that the plutonium and uranium form in these solutions. F. L. Culler, “Reprocessing of Reactor Fuel and Blanket Materials by Solvent Extraction,” in *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, vol. 9, *Reactor Technology and Chemical Processing* (New York: United Nations, 1956), 470; Flanary, “Solvent Extraction Separation of Uranium and Plutonium From Fission Products by Means of Tributyl Phosphate,” 539; J. H. Miles, "Separation of Plutonium and Uranium," in *Applications of Tributyl Phosphate in Nuclear Fuel Reprocessing*, ed. Wallace W. Schulz and James D. Navratil, *Science and Technology of Tributyl Phosphate*, vol. 3, (Boca Raton, Florida: CRC Press, Inc., 1984), 33; Swanson, “Purex Process Flowsheets,” 56.
14. Miles, “Separation of Plutonium and Uranium,” 33.
15. Culler, “Reprocessing of Reactor Fuel and Blanket Materials by Solvent Extraction,” 470. Prior to entering Bank 2A, the plutonium (III) was adjusted to the plutonium (IV) valence state in a mixing tank. For removal from the organic phase in Bank 2B, the plutonium was again reduced to the trivalent state.
16. Culler, “Reprocessing of Reactor Fuel and Blanket Materials by Solvent Extraction,” 470; Swanson, “Purex Process Flowsheets,” 60; and *Engineering and Design History*, *F&H Areas*, *Vol. III*, DPE972, 83–84.
17. Du Pont, *SRP Engineering and Design History, F&H Areas, Vol. III*, DPE972, 195; and *Savannah River Plant History, All Areas, July 1953 Through June 1954*, deleted version (Aiken, South Carolina: Savannah River Plant, *ca.* 1955), 1–51.
18. See R. B. Fenninger, “Laboratory Design and Analyses, ANL Visit of Jan. 17, 1951,” memorandum (January 31, 1951), Hagley, Acc. 1957, Series IV, Box 44, Folder 2, 1–2; Du Pont, *SRP Engineering and Design History, F&H Areas*,*Vol. III*, DPE972, 184–185.
19. Edwin N. Moore, Donald A. Orth, Wally B. Sumner, and James A. Purcell, "Development of Pu-239 Processes and Facilities," in *50 Years of Excellence in Science and Engineering at the Savannah River Site, Proceedings of the Symposium., May 17, 2000*, WSRC-MS-00061 (Washington, DC: GPO, 2000), 148; and *Engineering and Design History, F&H Areas*, *Vol. III*, DPE972, 172–173.
20. The word “bomb” was a standard term for the type of pressure chamber used in this operation and was not associated with the weapons-related production mission.
21. Du Pont, *SRP Engineering and Design History, F&H Areas*, *Vol. III*, DPE972, 157–158, 174–178. D. A. Orth, E. L. Field, and J. H. Radke, “Production of Plutonium Metal.” *Industrial Engineering Chemistry 53* (9): 685.
22. Du Pont, *SRP Engineering and Design History, F&H Areas*,*Vol. III*, DPE972, 208; W. C. Perkins, W. S. Durant, and M. L. Hyder, *The Safety of UO_3 Production in the A-Line at the Savannah River Plant*, DP-1449 (Aiken, South Carolina: Savannah River Laboratory, March 1977), 14–15.
23. R. M. Evans to Curtis A. Nelson, May 31, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 9, 4; *Savannah River Plant Engineering and Design History, Vol. I, Administration*, DPE-970 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 54 and 252, Hagley (hereafter cited as *Engineering and Design History, Administration*); and O. S. Petrescu, “Projects 8980 and 8987, Atomic Energy Division, Engineering Dept.—Explosives Department Meeting #12, November 10, 1950,” meeting summary and conclusions, November 10, 1950, Hagley, Acc.1957, Series IV, Box 44, Folder 8, 2.

General Electric's work on the Hanford lines was conducted at its Schenectady, New York, research facility—the General Engineering Laboratory. Research at Argonne National Laboratory and Knolls Atomic Power Laboratory was also incorporated in the Savannah River design. Knolls was noted to have been developing portions of the tritium processing line going to Hanford that were "of prime interest to [Du Pont]," and to have been conducting basic research into tritium separations chemistry and thermal diffusion.Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 19, 279; J. E. Cole, "Trip Report, Knolls Atomic Power Laboratory, November 8 and 9, 1950," memorandum, November 16, 1950, Hagley, Acc. 1957, Series IV, Box 44, Folder 1, 2; and R. M. Girdler, "Tritium Research and Development Program," memorandum, April 5, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 5, 1.

24. By March 1951, the Atomic Energy Commission had scaled back the urgency for tritium, and consideration was given to simply copying the design of the Hanford M-Line for use at Savannah River. However, selection of a method for separating tritium from other hydrogen isotopes (thermal diffusion or low-temperature fractional distillation were the prime candidates) continued to be studied. By May, the plan was to send the Hanford M-Line then being built to Savannah River, but in July the Atomic Energy Commission notified Du Pont that the line would not be available for installation at Savannah River. O. S. Petrescu, "Projects 8980 and 8987, Atomic Energy Division, Engineering Department—Explosives Department Meeting #30, March 16, 1951," meeting notes, March 16, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 8, 2; Girdler, "Tritium Research and Development Program," 1–2; Evans to Nelson, May 31, 1951, 4; J. L. Fahs, "Projects 8980 and 8987, Atomic Energy Division, Engineering Department—Explosives Department Meeting No. 45, July 6, 1951," meeting notes, July 6, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 8, 1.
25. F. S. Chambers to E. R. Gilbert, "Tritium–KAPL Development Program," August 24, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 12, 1; and J. B. Tinker to G. P. Church, "Project 8980–Savannah River Plant, Separations Area–Tritium Recovery Facilities–232 F," December 20, 1951, Hagley, Acc.1957, Series IV, Box 45, Folder 11, 1.
26. *Monthly Progress Report for February 1954*, DPSP 54-1-2, deleted version (Aiken, South Carolina: Savannah River Plant, March 10, 1954), 7 (available at USC-Aiken library).
27. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 269–272; and *Savannah River Plant History, All Areas, July 1953 Through June 1954*, 1–53.
28. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, 265, 273–277, 305; *Savannah River Plant History, All Areas, July 1953 Through June 1954*, 1–53.
29. Rodney P. Carlisle and Joan M. Zenzen, *Supplying the Nuclear Arsenal: American Production Reactors, 1942–1992* (Baltimore: The Johns Hopkins University Press, 1996), 29; Du Pont, *Engineering and Design History, Vol. III, F&H Areas*, DPE972, 114; Du Pont, *SRP Engineering and Design History,Vol. I, Administration*, DPE 970, 44, 204, 206–207; Du Pont, *SRP Engineering and Design History,* Vol. I, *Administration,* DPE 970, 83 225; *Savannah River Plant History, All Areas, August 1950 through June 1953*, 1–10; Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas,* DPE972, 15.
31. C. M. Nicholls, "Criteria for the Selection of Separation Processes," in *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, vol. 9, *Reactor Technology and Chemical Processing* (New York: United Nations, 1956), 456.
32. Du Pont, *SRP Engineering and Design History*, Vol. I, *Administration,* DPE970, 262.
33. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 15.
34. *Ibid*., 15–16.
35. *Savannah River Plant Construction History*, vol. 3, *Construction 100–R P L K & C and 200-F & H Areas* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 211 (hereafter cited as *Construction History, 100 and 200 Areas*), NTIS.
36. *Ibid*., 183-211.
37. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 105. World War II separations processing at Hanford was housed in 221-T and three other buildings. Initially, designs for Savannah River also called for separate buildings, each with reinforcement and shielding suitable to the process steps contained therein. These buildings were to house extraction, concentration, purification, and recovery facilities, and they were to be grouped around a fifth building for offices, change areas, chemical preparation, and control rooms. This plan evolved during the design process into a single building with a central administration and control hub from which four process wings extended. But the design was altered significantly to incorporate what Du Pont described as a "more suitable functional design." The four Hanford buildings were the Canyon or Cell Building (Building 221), the Concentration or Bulk Reduction Building (224), the Isolation Building (231), and the Service Building (271), which also contained offices. *A Brief History of the T-Plant Facility, Hanford Site*, WHC-MR-0452, Add. 1, online at URL: http://www.hanford.gov/history/mr0452/mr0452.htm.
38. The name had been used to describe the separations buildings at Hanford, even though those buildings were not completely open on the interior—they had an open corridor for the overhead equipment maintenance crane, but the processing area was a row of individual cells similar to those in the first radioisotopes processing facility at Oak Ridge.
39. W. Lee Poe, A. W. Joyce, and R. I. Martens, "Np and Pu Separation at the Savannah River Plant," in *Industrial & Engineering Chemistry, Process Design and Development,* 3(4), 1964, 316; and [Donald A. Orth], "SRP Experience in Storing and Processing of Irradiated Fuel to Recover Plutonium and Uranium," typescript (*ca.* 1976), 12, personal files of Donald A. Orth, Aiken, South Carolina.
40. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 106.

41. *Ibid.*; and Donald A. Orth, "Savannah River Plant Chemical Processing Experience," typescript, (*ca.* 1976), 3, personal files of Donald A. Orth, Aiken, South Carolina.
42. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 106–107; Poe *et al*., "Np^{237} and Pu^{238} Separation at the Savannah River Plant," 316.
43. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 146–149.
44. *Construction History, 100 and 200 Areas*, 184, 186, 213. Several design changes were made during construction. The truck well was enlarged, uranium nitrate evaporators were moved from the warm canyon to an outside area near the A-Line because of explosion hazards, evaporator cooling systems were changed from a recirculating to a once-through system to avoid contamination of pumps and other cooling equipment, and the cooling system was altered to maintain pressure at all times to prevent the radioactive solution from backing up into the cooling system.

    One important piece of equipment related to the cooling system was the sensitive, quick-response pressure sensor called a "Cash regulator" that monitored the flow through the cooling system coils. The name of the regulator was derived from the manufacturer, Cashco, then located in Decatur, Illinois—the company had previously been known as the A. W. Cash Company.

    Other problems and changes during construction involved the gang valves that supplied steam to the jet siphons used for solution transfer (they did not operate properly and had to be modified), and the acid-resistant finish for walls and floors (the expense of safely applying the highly flammable paint originally selected resulted in the decision to leave some surfaces unfinished or to use alternate paints. *Savannah River Plant History, All Areas, August 1950 through June 1953*, 1-11–1-14; and W. Lee Poe, personal communication, August 31, 1998.
45. *Construction History, 100 and 200 Areas*, 213; and *Monthly Progress Report for March 1955*, DPSP 55-1-3, deleted version (Aiken, South Carolina: Savannah River Plant, April 1955), 129–130 (available at USC–Aiken library).
46. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972,106–107.
47. For information related to the changing tritium mission, see Du Pont, *SRP Engineering and Design History, Vol. I, Administration*, DPE970, 54, 207; Petrescu, "Projects 8980 and 8987, Atomic Energy Division . . . Meeting #30," 2; Girdler, "Tritium Research and Development Program," 1–2; J. L. Fahs, "Projects 8980 and 8987, Atomic Energy Division, Engineering Department—Explosives Department Meeting No. 33, April 6, 1951," meeting notes, April 6, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 8, 3; Evans to Nelson, May 31, 1951, 4; Fahs, "Projects 8980 and 8987, Atomic Energy Division . . . Meeting No. 45," 1; Chambers to Gilbert, "Tritium—KAPL Development Program," 1; Du Pont, *SEP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 19, 277.
48. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE972, 278; Du Pont, *Engineering and Design History, Vol. I, Administration*, DPE 970, 218; *Savannah River Plant Engineering and Design History*, vol. 1, *Text and Exhibits*, B-989-3-5 (Pittsburgh: Blaw-Knox Company, June 30, 1954), 142 (hereafter cited as *Engineering and Design History, Text and Exhibits*).

    Between October and December, 1951, Du Pont and the Atomic Energy Commission exchanged a series of letters in which they discussed plans for the tritium facility. A summary of the design criteria in one of the letters stated that original completion schedules and production goals provided by the commission were now to be reinstated, but the type of construction was to be considerably changed. At that time, Du Pont described the "minimum facility… [as] a Transite (or equivalent) on steel frame building and only the most essential service auxiliaries which cannot be separated from the operation. Flexibility for future expansion as a criteria has been eliminated." Correspondence to which this letter makes reference is given as (Hagley collection) G. H. Christensen to G. P. Church, dated October 1, 1951; R. M. Evans to C. A. Nelson, dated October 16, 1951; G. H. Christensen to R. M. Evans, dated November 1, 1951; and C. A. Nelson to R. M. Evans, dated December 6, 1951. J. B. Tinker to Curtis A. Nelson, "Project 8980—Savannah River Plant Separations Area—Tritium Recovery Facilities—232 F," December 17, 1951, Hagley, Acc.1957, Series IV, Box 45, Folder 11, 1–2.
49. Du Pont, *SRP Engineering and Design History, Vol. I, Administration*, DPE270, 220; *Engineering and Design History, Text and Exhibits*, 143; and *Engineering and Design History, Vol. III, F&H Areas*, DPE972, 285.
50. Du Pont, *Engineering and Design History, Vol. I, Administration*, DPE270, 228–229; A. J. McCullin, "Project 8980—Savannah River Plant, Civil Section Diary," November 30, 1950–August 23, 1954, (entry for January 2, 1953), Hagley, Acc. 1957, Series III, Box 17, Folders 5 and 6, 189.
51. In April, design responsibilities were transferred from Blaw-Knox to Voorhees, Walker, Foley, and Smith to expedite design progress and alleviate some of the workload Blaw-Knox was carrying.
52. McCullin, "Project 8980—Savannah River Plant, Civil Section Diary," 203 (entry for April 7, 1953), 214 (entry for June 30, 1953), 216 (entry for July 17, 1953), 217 (entry for July 20, 1953), and 218 (entry for July 24, 1953), Hagley; Du Pont, SRP *Engineering and Design History, Vol. III, F&H Areas*, DPE972, 277, 299–307; Du Pont, SRP *Engineering and Design History, Vol. I, Administration*, DPE270, 234.

    The equipment setup designed for the H Area facility was similar to that in F Area except that it included improvements for transferring reactor assemblies into the building, more versatile decanning machines, and the monorail that was used in 232-F to transfer assemblies to the furnaces was replaced by a bridge crane. The designs of most of the processing equipment had also been refined to operate more efficiently. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 308; McCullin, "Project 8980–Savannah River Plant, Civil Section Diary," 220 (entry for September 1, 1953), 234 (entry for December 8, 1953), and 257 (entry for April 7, 1954), Hagley.
53. *Construction History, 100 and 200 Areas*, 186, 213, 299.

54. The first designs were for a three-story building with a fourth-level penthouse, with or without a basement. A design for a larger three-story structure with no basement was later developed to house equipment with enough capacity to process uranium nitrate from both F and H Area canyons.

55. The choice was based on the firming up of decisions about the equipment to be housed in the building: The "first level would be suitable for the denitration reactors, second and third levels for the two hydrate evaporators and columns which drain to the reactors, while the penthouse provided the height necessary to allow gravity flow of the UO_3 powder from the cyclone through the pulverizer and blender to drum loading and storage. A basement was included to provide accessibility and space for the denitration gas heaters, air ducts, and blowers." Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 209.

56. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 208–210.

57. *Ibid*., 367–372.

    Hanford had both sand and Fiberglass filters, and both types were considered by Du Pont. Lapple was originally hired to determine which type would be better, and he recommended glass or synthetic fibers for the filtering medium, saying that such material could effectively retain radioactive particulate matter at considerably less cost than a sand filter, and would likely do so with a longer life span. Du Pont engineers were not convinced; after further study they decided to use sand filters because Hanford had had good experience with theirs, the details of design and construction were well enough known that developing the much larger filters needed for Savannah River would not pose insurmountable problems, the stability and safety of sand filters appeared to be greater, and the costs of fiber filters were not clearly known. Lapple continued to work with Du Pont engineers in the design of the Savannah River sand filters.Du Pont, *SRP Engineering and Design History, Vol. I, Administration,* DPE270, 225; *Savannah River Plant History, All Areas, August 1950 through June 1953*, 1–57.

58. D. A. Orth, G. H. Sykes, and G. A. Shurr, "The SRP Sand Filter: More than a Pile of Sand," paper presented at the 14th ERDA Air Cleaning Conference, 1975; G. A. Shurr and J. E. Johnston, "Characterizing Sand Grains to Optimize Filter Performance Tests," paper presented at the 13th USAE Air Cleaning Conference, 1974.

59. G. A. Schurr, "The Deep Bed Sand Filter–More than a Pile of Sand," typescript (June 2, 1976), 1; Orth, *et al*., "The SRP Sand Filter: More than a Pile of Sand"; Shurr and Johnston, "Characterizing Sand Grains."

60. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 425, 436; *Construction History, 100 and 200 Areas*, 214; John Porter, personal communication, August 31, 1988.

61. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 411–412, 416.

62. *Construction History, 100 and 200 Areas*, 196.

63. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 411.

64. *Ibid*., 412.

65. *Ibid*., 387.

66. [Orth], "SRP Experience in Storing and Processing of Irradiated Fuel," 5.

67. William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 52; [Orth], "SRP Experience in Storing and Processing of Irradiated Fuel," 6; *Monthly Progress Report for January 1955*, DPSP55-1-1, deleted version (Aiken, South Carolina: Savannah River Plant, February 1955), 7–8 (available at USC-Aiken library); *Monthly Progress Report for March 1955*, 7; Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272,208.

68. Bebbington, Du Pont at the Savannah River Plant, 52; Du Pont, *SRP Engineering and Design History, Vol. I, Administration*, DPE270, 233; Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 195; [Orth], "SRP Experience in Storing and Processing of Irradiated Fuel," 6; W. A. Jenkins, "Laboratory Project for Isolation of Plutonium," memorandum, July 25, 1955, Hagley, Acc. 1957, Series IV, Box 47, Folder 2, 1. 3.

69. *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, DPSP-55-454-2, deleted version (Aiken, South Carolina: Savannah River Plant, February 1974), 35, 52, 71, 163, NTIS; John Porter, personal communication, June 15, 1998; W. Lee Poe, personal communication, August 31, 1998; *Gang Valve Corridor Improvements, Buildings 221-F&H*, DPE-2154 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., March 1961), Hagley, Acc. 1957, Series III, Box 14, Folder 8, 2; A. D. Duff, Jr., to J. A. Burns, "Weekly Activities Report No. 600," June 7, 1962, Hagley, Acc. 1957, Series III, Box 11, Folder 12, 1; and J. A. Monier, Jr., to Julian D. Ellett, March 27, 1967, Hagley, Acc. 1957, Series VI, Box 64, Folder "SRL Computer," 1.

70. [Orth], "SRP Experience in Storing and Processing of Irradiated Fuel," 6; Bebbington, *Du Pont at the Savannah River Plant, 71;* and *Monthly Progress Report for January 1956*, DPSP 56-1-1, deleted version (Aiken, South Carolina: Savannah River Plant, February 1956), 259 (available at USC-Aiken library).

71. *Monthly Progress Report for January 1956*, 259–260; and *Monthly Progress Report for February 1956*, DPSP 56-1-2, deleted version (Aiken, South Carolina: Savannah River Plant, March 1956), 7–8 (available at USC-Aiken library).

    The original B-Line was converted to the recovery of B-Line process materials (which contained small amounts of plutonium) and off-standard plutonium from the line to avoid a buildup of plutonium residues. The original recovery facility had not worked well because of the small mixer-settler unit. This unit was replaced by an anion column in approximately 1957 (the cation equipment used for coupling was converted to an anion column), which may have been the first anion column used in the national weapons complex. This column was used for recovery until new anion recovery facilities were brought online in 1959. Anion exchange columns were noteworthy for their "ease of decontaminating the plutonium from all normally encountered impurities" and because of their simplicity. *Savannah River Plant History,*

Separations Areas, July 1954 Through December 1972, 24; Bebbington, *Du Pont at the Savannah River Plant*, 71; Interview with Donald A. Orth, November 30, 1999; Donald A. Orth, personal communication, December 14, 1998; and J. L. Ryan and E. J. Wheelwright, "Application of Anion Exchange to the Reprocessing of Plutonium," in *Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy*, vol. 17, *Processing Irradiated Fuels and Radioactive Materials* (Geneva: United Nations, 1958), 137 and 142.

72. The project was informally called the F-Area remount and F-Area ream-out project. Donald A. Orth, personal communication, November 4, 1998.

73. Bebbington, *Du Pont at the Savannah River Plant*, 71 and 120; William P. Bebbington to Hood Worthington, "DP-289, Mixer Settler Development—Semiworks Tests of 'Jumbo' Pump-Mix Mixer Settler," June 9, 1958, Hagley, Acc. 1957, Series IV, Box 49, Folder 2, 1–2; and *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 35, 84.

74. *Monthly Progress Report for April 1959*, DPSP 59-1-4, deleted version (Aiken, South Carolina: Savannah River Plant, May 1959), 202 and 206 (available at USC-Aiken library); *Monthly Progress Report for July 1959*, DPSP 59-1-7, deleted version (Aiken, South Carolina: Savannah River Plant, August 1959), 211 (available at USC-Aiken library); Orth, personal communication, November 4, 1998.

When exposed to radiation, TBP tended to degrade from tributyl phosphate to di- and monobutyl phosphate (DBP and MBP, respectively). Both of these were bad for the process because they did not release fission products to the waste stream as effectively as TBP. Decanters were large reservoirs beneath the mixer-settlers; their purpose was to allow the aqueous and organic phases to settle and separate for a longer period of time. However, the TBP and solvent routed through the decanters suffered from longer exposure to the radiation given off by the fission products in the mixer-settlers, especially in the first cycle units. The TBP soon became less efficient at serving its purpose and had to be replaced. By not using the decanters, processing was improved.

Solvent washers were used to contact the TBP with caustic and dilute nitric acid to remove residual plutonium, uranium, and fission products, as well as degraded solvent (DBP and MBP). The initial canyon washers used a batch process that limited throughput; new continuous washers were installed during the increased through put project. The new washers proved inefficient because their design provided insufficient contact time between the solvent phase and the alkaline aqueous phase. The design provided a very small mixing chamber with intense agitation. Experimental work showed that the chemical reactions involved in transfer from organic to aqueous phase were relatively slow. Speeding the agitation to influence transfer caused poor settling emulsions. Improved operation was obtained eventually with a sleeve that extended through the tank to provide a tall mixing chamber, with mixing paddles through the height of the chamber. This was considered the best approach, short of new washers, and gave minutes instead of seconds of effective washing time.

Finding a better organic solution with which to dilute the TBP involved a great deal of research and effort. The first diluent used was Ultrasene, which degraded fairly easily when exposed to radiation because it was a branched hydrocarbon, and therefore less stable—in radioactive environments, the molecules tended to break apart where branches joined. Adakane, a non-branched or straight-chain diluent that degraded less easily, was in use by 1960; however, Adakane was very expensive. About the same time, biodegradable detergents were being developed, which called for the replacement of aromatic hydrocarbons in the original detergents with straight-chain parrafins and led to the development of processes to produce them. The first inventory of a straight-chain normal paraffin, Dodecane, was purchased at great cost in 1961, but the demand for biodegradable detergents also increased the availability of such paraffins, bringing prices down. Normal paraffins became an inexpensive and effective means of diluting the TBP, and are the standard diluent today.

The final correction for the Jumbos was not in place until 1966, when centrifugal contactors were installed. Centrifugal contactors could very quickly bring the aqueous and organic streams into contact with each other and separate the phases, further reducing the solvent degradation problem. Because of the size of the Jumbos, the organic phase was in contact with the high-radiation aqueous phase carrying the fission byproducts for 7 to 15 minutes per stage. The centrifugal contactors reduced the contact time significantly, to 6 to 12 seconds per stage. These units replaced the Jumbos of the first cycle Bank 1A, which handled the most radioactive solutions in the process. They not only reduced the contact time, they also made startup and shutdown of the process faster and simpler. And, centrifugal contactors were more versatile and improved the nuclear safety of the canyon. Orth, personal communication, November 4, 1998; Donald A. Orth and Thomas W. Olcott, "Purex Process Performance Versus Solvent Exposure and Treatment," *Nuclear Science and Engineering* 17(4), December 1963: 593 and notes 16–21; Bebbington, *Du Pont at the Savannah River Plant,* 120, 199; Donald A. Orth, "Purex: Process and Equipment Performance," typescript (*ca.* 1985), 5–6, personal files of Donald A. Orth, Aiken, South Carolina; and Centrifugal Mixer-Settlers, Building 221-F, Savannah River Plant, DPE-2164 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., March, 1961), Hagley, Acc. 1957, Series III, Box 14, Folder 9, 2–3.

75. *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 70.

76. Orth, personal communication, November 4, 1998.

The experience with the change to the trifluoride route to metal is discussed in the introduction to Donald A. Orth, "Plutonium Metal from Trifluoride," *Industrial and Engineering Chemistry 2* (2), April 1963: 121. The trifluoride process was there noted to have "filtrate losses . . . sufficiently low to be discarded," a diplomatic way of dealing with a problem of the process—although peroxide precipitation had higher filtrate losses, they could be recovered by recycling; trifluoride filtrate losses could not be recycled and so had to be discarded.

77. *Progress Report, April 1959*, DPSP 59-1-4, deleted version (Aiken, South Carolina: Savannah River Plant, May 1959), 224–226, (available at USC-Aiken library).
78. D. G. Karraker, *Solvent Extraction of Enriched Uranium in Conventional Purex Equipment*, DP-481 (Aiken, South Carolina: Savannah River Laboratory, June 1960), 4, NTIS; [Orth], "SRP Experience in Storing and Processing of Irradiated Fuel," 6; *Progress Report, February 1959*, DPSP 59-1-2, deleted version (Aiken, South Carolina: Savannah River Plant, March 1959), 202, (available at USC-Aiken library); and Clark H. Ice to Hood Worthington, "DP-481, Solvent Extraction of Enriched Uranium in Conventional Purex Equipment," DP-481TL, June 23, 1960, 1.
79. Poe *et al*., "Np^{237} and Pu^{238} Separation at the S*avannah River Plant,"* 314, 316*; Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 103, 115.
80. Poe *et al*., "Np^{237} and Pu^{238} Separation at the S*avannah River Plant,"* 314, 316*; Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 121.
81. Building 235, originally called the Metallurgical Building, had been constructed to manufacture plutonium weapons components. In 1954, the building was placed in layaway before operations began; in 1956 the Atomic Energy Commission noted that the equipment installed there was for the manufacture of a component that had become obsolete, but it was considering installing equipment to produce new weapons components. The building was never used for that purpose but was instead converted to various metallurgical production facilities. *Savannah River Plant History, All Areas, July 1953 Through June 1954*, 1–72; and unknown author to H. F. Brown, "Scope of Work: Contract AT (07-2)-1," Document Number DPW-56-366, August 13, 1956, Hagley, Acc. 1957, Series IV, Box 47, Folder 9, 3.
82. Poe *et al*., "Np^{237} and Pu^{238} Separation at the Savannah River Plant," 316; *Progress Report, March 1961*, DPSP 61-1-3DV, deleted version (Aiken, South Carolina: Savannah River Plant, April 1961), 224, (available at USC-Aiken library); *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 121, 173,185; R. H. Smith and H. E. Hootman, "Dismantlement and Decontamination of a Plutonium-238 Facility at the Savannah River Site," in *Waste Management* '94, ed. Roy G. Post, vol. 2 (Tucson: University of Arizona, 1994), 2029.
83. D. A. Orth, "SRP Thorex Processing Experience," *Nuclear Technology* 45, 63, 1979; *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 150, 166–167, 176, 186–190; D. A. Orth, J. M. McKibben, W. E. Prout, and W. L. Scotten, "Isolation of Tranplutonium Elements," ISEC '71:534.
84. Bebbington, *Du Pont at the Savannah River Plant*, 114.
85. *Progress Report, March 1961*, 243; *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 153, 171.
86. "Report to Board of Directors," DPW-71-170-12 (November 21, 1955), Hagley, Acc. 1957, Series IV, Box 48, Folder 17, 8; Bebbington, *Du Pont at the Savannah River Plant*, 72; Monthly Progress Report for January 1956, 8–9; and *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 60, 76.
87. "Report to Board of Directors," November 21, 1955, 4.
88. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 300; "Board of Directors Meeting–November 19, 1956," DPW-71-170-13, November 19, 1956, 5, Hagley, Acc. 1957, Series IV, Box 48, Folder 17, 5; *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 61, 76.
89. S*avannah River Plant History, Separations Areas, July 1954 Through December 1972*, 30; Bebbington, *Du Pont at the Savannah River Plant*, 73.
90. Bebbington, *Du Pont at the Savannah River Plant*, 73.
91. *Ibid*., 113; *Savannah River Plant History, Separations Areas, July 1954 Through December 1972*, 125, 137–138, 173, 199; Rex D. Buley and Don J. Green, "Tritium Processing and Containment at the Savannah River Site," *Fusion Technology 28* (3, part 2), October 1995, 1308.
92. "Report to Board of Directors," DPW-71-170-6, November 15, 1965, Hagley, Acc. 1957, Series IV, Box 48, Folder 17, 4–5.
93. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 344.
    The decision to divide the necessary tankage between the areas was reached in April 1951. Du Pont's J. E. Cole noted at the time that this division would also lessen the likelihood that Upper Three Runs Creek would be contaminated if the tanks leaked. Du Pont, *SRP Engineering and Design History, Vol. I, Administration,* DPE270, 211; McCullin, "Project 8980—Savannah River Plant, Civil Section Diary," 46 (entry for April 10, 1951).
94. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 345.
95. *Linking Legacies*, 178; and Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 344, 346.
96. M. W. Davis, Jr., to F. C. Mead, Jr., "Waste Disposal at the Savannah River Plant," August 21, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 12, 3.
97. Du Pont, *SRP Engineering and Design History, Vol. I, Administration*, DPE970, 253; Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 338–341, 346.
98. J. B. Tinker to D. E. Irons, "Project 8980—Savannah River Plant, 241 Waste Disposal Tanks," January 30, 1952, Hagley, Acc. 1957, Series IV, Box 45, Folder 912, 1, Du Pont, SRP E*ngineering and Design History, Vol. I, Administration*, DPE970, 253–254; *Construction History, 100 and 200 Areas*, 183–184, 213.
99. Du Pont, *SRP Engineering and Design History, Vol. IV, 300/700 Areas*, DPE973, 442.
100. Davis, Jr., to Mead, Jr., "Waste Disposal at the Savannah River Plant," August 21, 1951, 2; G. K. Oertel, J. L. Crandall, and J. L. McElroy, "Treatment and Conditioning of Wastes from Nuclear Fuel Reprocessing Plants in the United States of America," in *Radioactive Waste Management, 2* (Vienna: International Atomic Energy Agency, 1984), 209.
101. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 350.

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104. *Monthly Progress Report for November 1957*, DPSP 57-1-11, deleted version (Aiken, South Carolina: Savannah River Plant, December 1957), 7, 202 (available at USC-Aiken library); *Investigation of Waste Tank Leakage, Savannah River Plant*, *Interim Report,* DPE-2207 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., April 1962), Hagley, Acc. 1957, Series III, Box 14, Folder 12, 2; and *Progress Report, March 1961*, 222.
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112. Committee on Geologic Aspects of Radioactive Waste Disposal, *Report to the U.S. Atomic Energy Commission* (Washington, DC: National Research Council, May 1966), Hagley, Acc. 1957, Series III, Box 30, Folder 8, 3–5. More information about the bedrock storage proposals is available in Committee on Geologic Aspects of Radioactive Waste Disposal, *Report to the U.S. Atomic Energy Commission*; "Progress and Problems in Programs for Managing High-Level Radioactive Wastes" (Comptroller General's Report to the Joint Committee on Atomic Energy, 1969), Hagley, Acc. 1957, Series III, Box 43, Folder 7; *Evaluation of the Concept of Storing Radioactive Wastes in Bedrock Below the Savannah River Plant Site; and Radioactive Waste Management at the Savannah River Plant: A Technical Review* (Washington, DC: National Academy Press, 1981).
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117. *Engineering and Design History, Text and Exhibits*, 140; R. M. Girdler, "Chicago Meeting—September 18–19, 1951, Separations Development Program," memorandum, October 3, 1951, Hagley, Acc. 1957, Series IV, Box 45, Folder 7, 2; and F. S. Chambers to L. C. Peery, "Plutonium Isolation," April 5, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 5.
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119. *Engineering and Design History, Text and Exhibits*, 143; F. S. Chambers to Lombard Squires, "Separations Development Programs for Fiscal Year 1953," memorandum, March 24, 1952, Hagley, Acc. 1957, Series IV, Box 46, Folder 1, 4.
120. T. J. Colven, Jr., G. M. Nichols, and T. H. Siddall, *Interim Technical Report, TNX Evaporator Incident January 12, 1953*, DP-25 (Aiken, South Carolina: Savannah River Laboratory, May 15, 1953), 8, NTIS; *Savannah River Plant History, All Areas, August 1950 through June 1953* (Aiken, South Carolina: Savannah River Plant, *ca.* 1954), 5–25, NTIS.

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122. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 77.
123. *Construction History, 100 and 200 Areas*, 206; LeVerne P. Fernandez, "Savannah River Site Canyons–Nimble Behemoths of the Atomic Age," in *50 Years of Excellence*, 134.
124. "Orientation to Board of Directors—12/17/1962," DPW-71-170-3, December 17, 1962, Hagley, Acc. 1957, Series IV, Box 48, Folder 17, 1.
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126. *Ibid*., 251–252.
127. *Ibid*., 357–360.
128. *Ibid*., 354–356.
129. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 367.
130. *Construction History, 100 and 200 Areas*, 204.
131. A. A. Kishbaugh, *Mixer-Settler Development, Semiworks Tests of a 'Jumbo' Pump-Mix Mixer-Settler*, Document Number DP-289 (Aiken, South Carolina: Savannah River Laboratory, May 1958), Hagley, Acc. 1957, Series IV, Box 49, Folder 2, 4–5.
132. B. L. Taber, *Design Data Report, 200H Area—Buildings 241, 242 and 242-1H, Additional Waste Handling Facilities, Prestressed Concrete Storage Tanks and Tank Farm Evaporator*, DPWA-60-207 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., September 1960), 100, Hagley, Acc. 1957, Series III, Box 8, Folder 17.
133. Du Pont, *SRP Engineering and Design History, Vol. III, F&H Areas*, DPE272, 346; *Construction History, 100 and 200 Areas*, 206–207.

CHAPTER 15

1. S. A. McNeight, "Log Book," October 8, 1957, Hagley Museum and Library, Wilmington, Delaware, Acc. 1957, Series IV, Box 49, Folder 13, 12 (this notebook appears to be a compilation of earlier logbooks by various authors [only initials given] with entry dates for 1952 and 1953).
2. R. M. Evans to Curtis Nelson, "Technical Facilities for the Savannah River Plant," July 20, 1951, Hagley, Acc. 1957, Series IV, Box 44, Folder 10, 1–6.
   On the second page of this letter, Evans draws an analogy between Du Pont's nylon development and the needs of the laboratory at Savannah River: "both initial plant designs are the result of urgent pressure for prompt production circumscribing the extent and completeness of the development program on which the design was based. Both are large enterprises in their respective spheres and require very substantial investments. And in both significant improvement in the capacity of the initial plant and in the product cost per dollar investment can result only from further research and development."
3. McNeight, "Log Book," 12–20. The letters between Evans and Nelson were not located during research but are quoted extensively by McNeight. The letter from Evans to Nelson dated July 20, 1951, is quoted on pages 13 through 17, and the letter dated October 16, 1951, is quoted on pages 19 through 20.
4. McNeight, "Log Book," 19–20.
5. *Science and Engineering with du Pont at Savannah River* (Aiken, South Carolina: Savannah River Plant, *ca.* 1960), 8.
6. David A. Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy, Du Pont R&D, 1902–1980* (New York: Cambridge University Press, 1988), 365.
7. *Savannah River Plant History, All Areas, July 1953 Through June 1954*, deleted version (Aiken, South Carolina: Savannah River Plant, *ca.* 1955), 2–41.
8. *Savannah River Laboratory Research and Development* (Aiken, South Carolina: Savannah River Laboratory, November 1963), 2.
9. *Science and Engineering at the Savannah River Plant and Laboratory* (Aiken, South Carolina: Savannah River Laboratory, *ca.* 1970), no page.
10. Interview with Nathaniel Stetson, October 15, 1999.
11. U.S. Department of Energy, Office of Environmental Management, *Linking Legacies: Connecting the Cold War Nuclear Weapons Productions Processes to their Environmental Consequences*, DOE/EM-0319 (Washington, DC: GPO, 31 Jan 1997), 199.
12. *Ibid.,* 203.
13. Milton H. Wahl, *History: Savannah River Laboratory, June 1951 to June 30, 1953,* Document Number DPST-54-432 (Aiken, South Carolina: Savannah River Laboratory, 1954), 4; "CMX" has been noted to stand for "Corrosion Mockup Experimental." David Muhlbaier, Sam Mirshak, Vascoe Whatley, and Elwyn Wingo, "Experimental Thermal-Fluids Program in Support of Reactor Operations," in *50 Years of Excellence in Science and Engineering at the Savannah River Site, Proceedings of the Symposium May 17, 2000*, WSRC-MS-00061 (Washington, DC: GPO, 2000), 81. No derivation for the acronym TNX is known. The same designation was used for the Du Pont department under which the Hanford Engineer Works was built and operated; a connection was not located during the research for this project.
14. William P. Bebbington, *History of Du Pont at the Savannah River Plant* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, 1990), 190.
15. W. M. Heston, *History: Savannah River Laboratory, July 1, 1955 to June 30, 1956,* DPST-57-509 (Aiken, South Carolina: Savannah River Laboratory, November 22, 1957), 5–6.

16. Wahl, *History: Savannah River Laboratory*, 6–7.
17. *Ibid.*,12.
18. *Ibid.*, 5; "With Versatile Equipment, People, SRL Performs Vital Research," *Savannah River Plant News*, February 23, 1962, 4.
19. R. M. Evans to Curtis A. Nelson, November 5, 1951, Hagley, Acc. 1957, Series IV, Box 45, Folder 9, 1.
20. Wahl, *History: Savannah River Laboratory*, 5.
21. Bebbington, *History of Du Pont at the Savannah River Plant*, 191, 201; E. I. du Pont de Nemours and Company, *History of the Savannah River Laboratory, Volume IV–General,* DPST-62-200-IV (Aiken, South Carolina: Savannah River Laboratory, 1984).
22. Heston, *History: Savannah River Laboratory, July 1, 1955 to June 30, 1956*, 6.
23. Bebbington, *History of Du Pont at the Savannah River Plant*, 191.
24. *Ibid.*, 197; *History: Savannah River Laboratory, Volume IV–General,* 4, 9.
25. Wahl, *History: Savannah River Laboratory*, 6.
26. Bebbington, *History of Du Pont at the Savannah River Plant*, 191.
27. Du Pont, *Savannah River Plant Engineering and Design History, Vol. IV, #300/700 Areas and General Services and Facilities*, DPE 973 (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 445 (hereafter cited as E*ngineering and Design History, 300/700 Areas*).
28. *Ibid.,* 449.
29. Wahl, *History: Savannah River Laboratory*, 4.
30. *Ibid.,* 4; Du Pont, *SRP Engineering and Design History, Vol. IV, 300/700 Areas,* DPE973, 445.
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33. Muhlbaier *et al.,* "Experimental Thermal-Fluids Program in Support of Reactor Operations," in *50 Years of Excellence*, 81.
34. *Research and Development at the Savannah River Laboratory* (Aiken, South Carolina: Savannah River Laboratory, *ca.* 1965), 6.
35. Muhlbaier *et al*., "Experimental Thermal-Fluids Program in Support of Reactor Operations," in *50 Years of Excellence,* 82.
36. *Ibid.,* 83.
37. *Ibid.,* 83.
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40. Du Pont, *Savannah River Plant* E*ngineering and Design History, Vol. IV, 300/700 Areas.* DPE973, 446, 449.
41. Du Pont, *Savannah River Plant Engineering and Design History, Vol. 1, Administration* (Wilmington, Delaware: E. I. du Pont de Nemours and Company, Inc., January 1957), 85 (hereafter cited as *Engineering and Design History, Administration*).
42. *Savannah River Plant History, All Areas, July 1953 Through June 1954*, deleted version (Aiken, South Carolina: Savannah River Plant, *ca.* 1955), 2–49.
43. Wahl, *History: Savannah River Laboratory,* 4.
44. William P. Bebbington to Hood Worthington, " Mixer Settler Development—Semiworks Tests of 'Jumbo' Pump-Mix Mixer Settler," June 9, 1958, DP-289, Hagley, Acc. 1957, Series IV, Box 49, Folder 2, 1–2.
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53. "SR Lab Paved Way for Start-up, Now Pioneers in New Processes," *Savannah River Plant News*, February 15, 1957, 5.
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CHAPTER 16

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