# Hanford Statistical Analysis

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# Topics Covered

- Extreme Value
- Circumferential Uniformity (Riser Differences)
- Uncertainty



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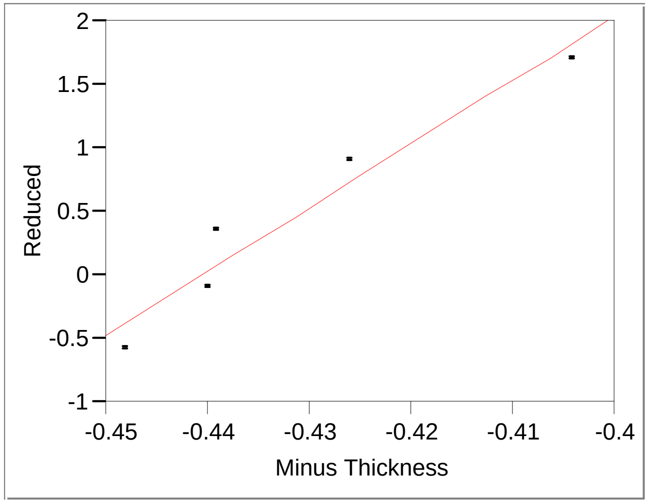
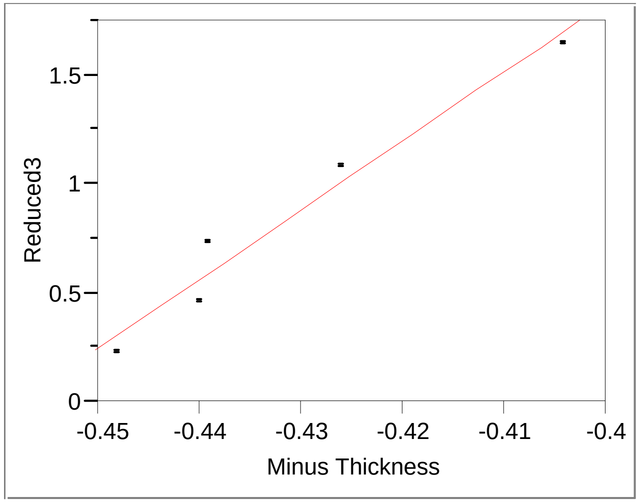
# Extreme Value Distribution Selection

Type I




R-square = 0.940

Type 3 (3-parameter Weibull)




R-square =  0.965

The five points were wall thicknesses for an SRS tank; they used the Type I distribution.



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# Extreme Value Distributions

<u>Type 1</u>: $$F(t) = \Pr[\, X \le t \,] = \exp\left\{ -e^{-(t-\alpha)/\beta} \right\}.$$

<u>Type 2</u>: $$F(t) = \Pr[\, X \le t \,] = \exp\left\{ -\left( \frac{t-\alpha}{\beta} \right)^{-k} \right\}, \quad t \ge \alpha.$$

<u>Type 3</u>: $$F(t) = \Pr[\, X \le t \,] = \exp\left\{ -\left( \frac{\alpha - t}{\beta} \right)^{k} \right\}, \quad t \le \alpha.$$

•These distributions arise from statistical "order statistics", in particular for the minimum or maximum value of many sample values from a population (e.g. the minimum value of many pixels in a 12x15 inch UT image of wall thickness)

•For each of these distributions, the distribution of –*X* is also considered an extreme value distribution. For the Type 3 distribution, the distribution of –*X* is a commonly used three-parameter Weibull distribution



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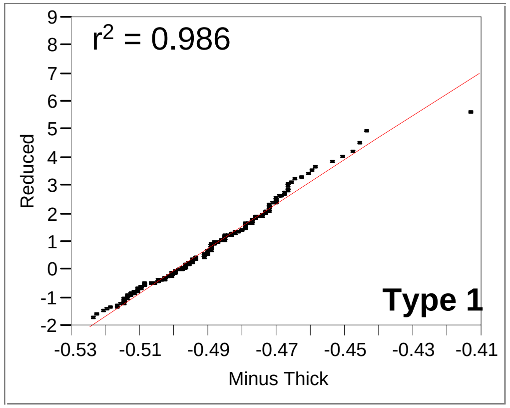
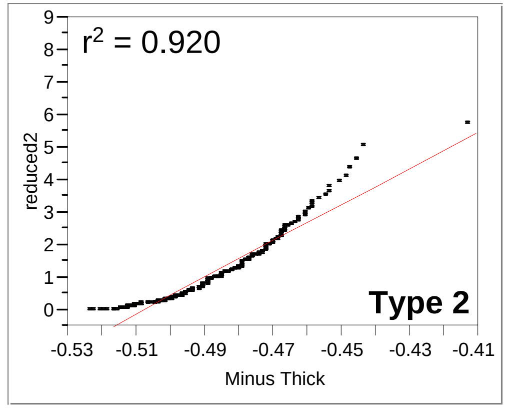
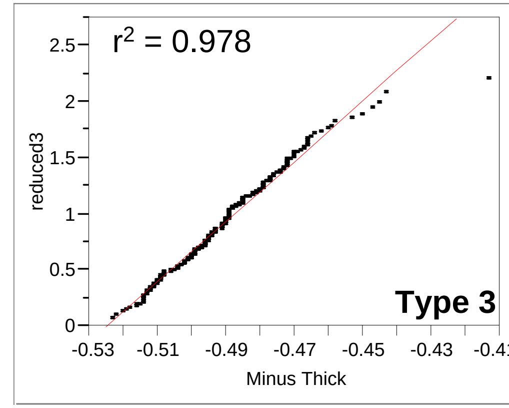
# Extreme Value Distributions for AY-101

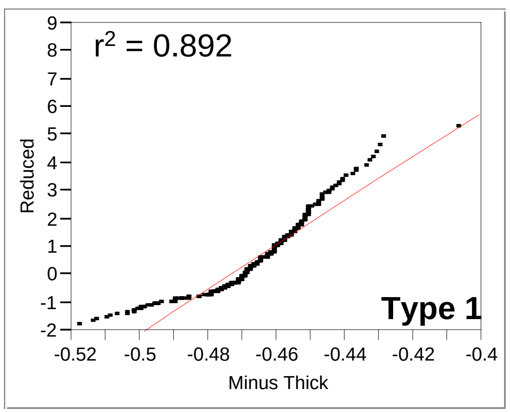
## Plate 3

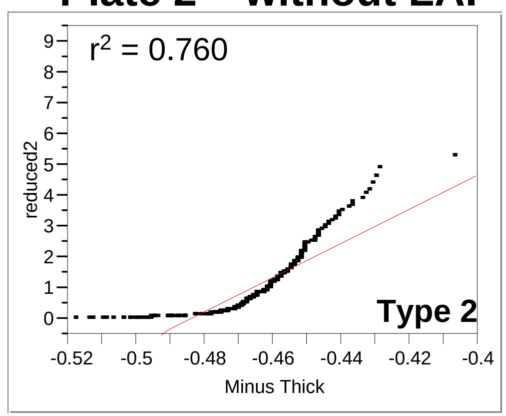


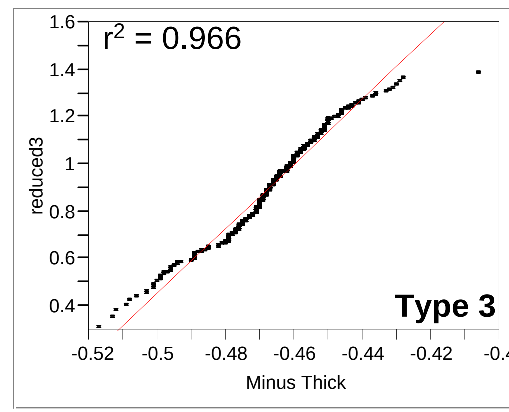




## Plate 2 – without LAI

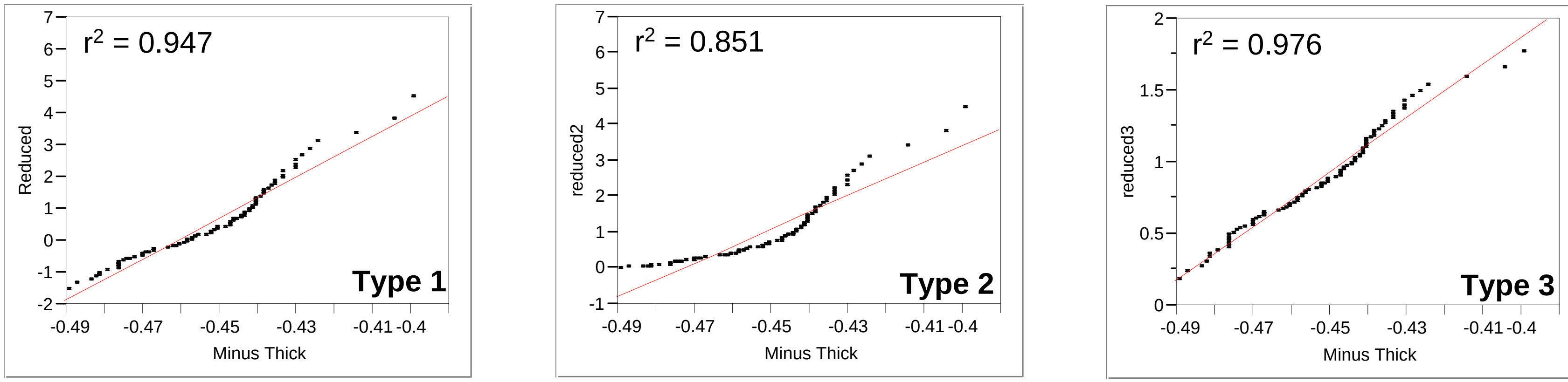


# Extreme Value Distributions for AY-101

## LAI

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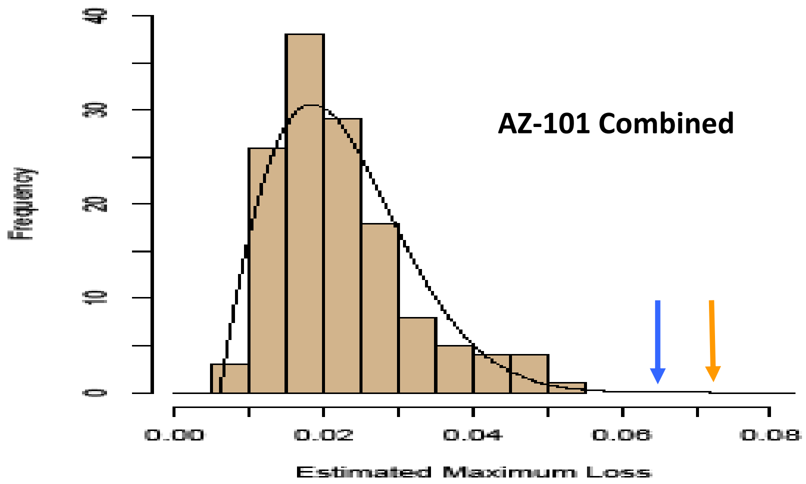
# Extreme Value Estimation for AZ-101




- **Histogram represents losses based on UT-measured wall thicknesses**
- **Blue arrow is extrapolated result expected if entire tank had been inspected; this assumes consistent wall thickness around tank circumference**
- **Orange arrow is 95% statistical uncertainty bound based on numbers of measurements made and goodness of fit of distribution**

- Maximum loss per UT image is used to facilitate grouping across plate courses of different thicknesses; the losses are computed relative to estimated original plate thickness, not drawing nominal values

- Three-parameter Weibull distributions are used to fit these losses; results are examined by plate course and reported individually or in appropriate groupings (above image is over the entire tank since plate course differences were minor)

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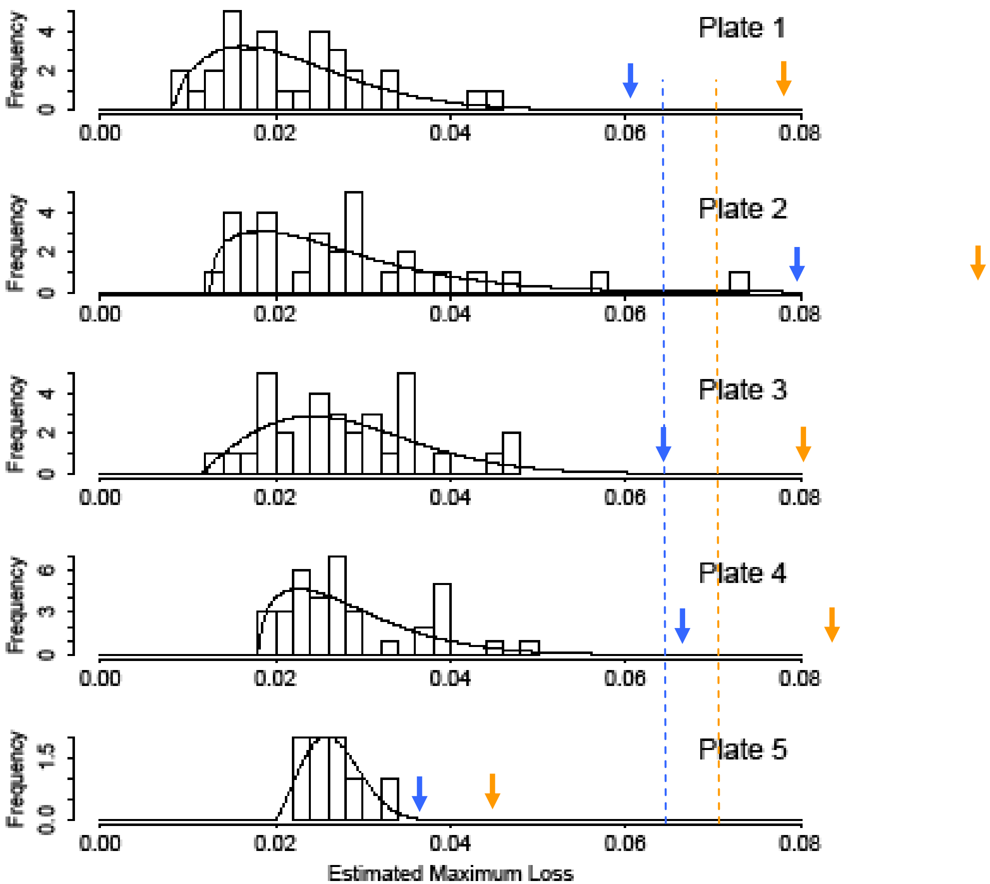
# Extreme Value Estimation for AP-108




- Blue arrows are estimates; orange are confidence bounds for individual plates. Outlying value is not included for Plate 2

- Dotted lines are the estimate/bound for combined plates without the Plate 2 outlying value

- Values are given on the following slide



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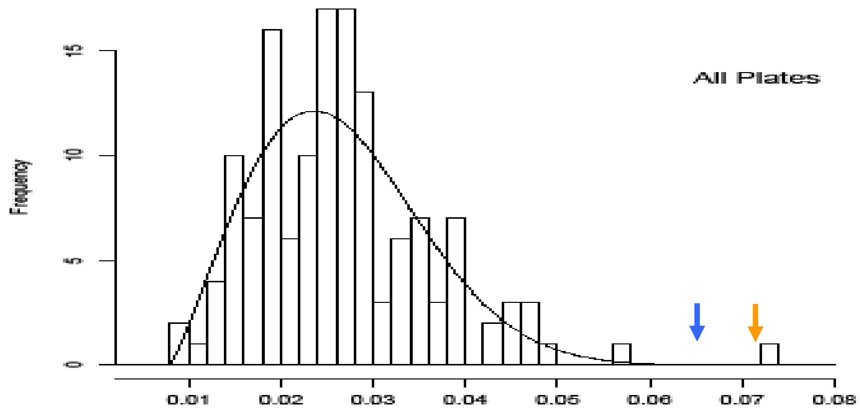
# Extreme Value Estimation for AP-108




| AP-108 Extreme Values | Plate Courses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Combined | 2 with Outlier | Combined with Outlier |
| **Estimate** | 0.061 | 0.080 | 0.065 | 0.067 | 0.036 | 0.065 | 0.099 | 0.071 |
| **95% Bound** | 0.079 | 0.105 | 0.081 | 0.084 | 0.043 | 0.072 | 0.134 | 0.079 |
| **Measurements** | 32 | 31 | 32 | 36 | 8 | 139 | 32 | 140 |

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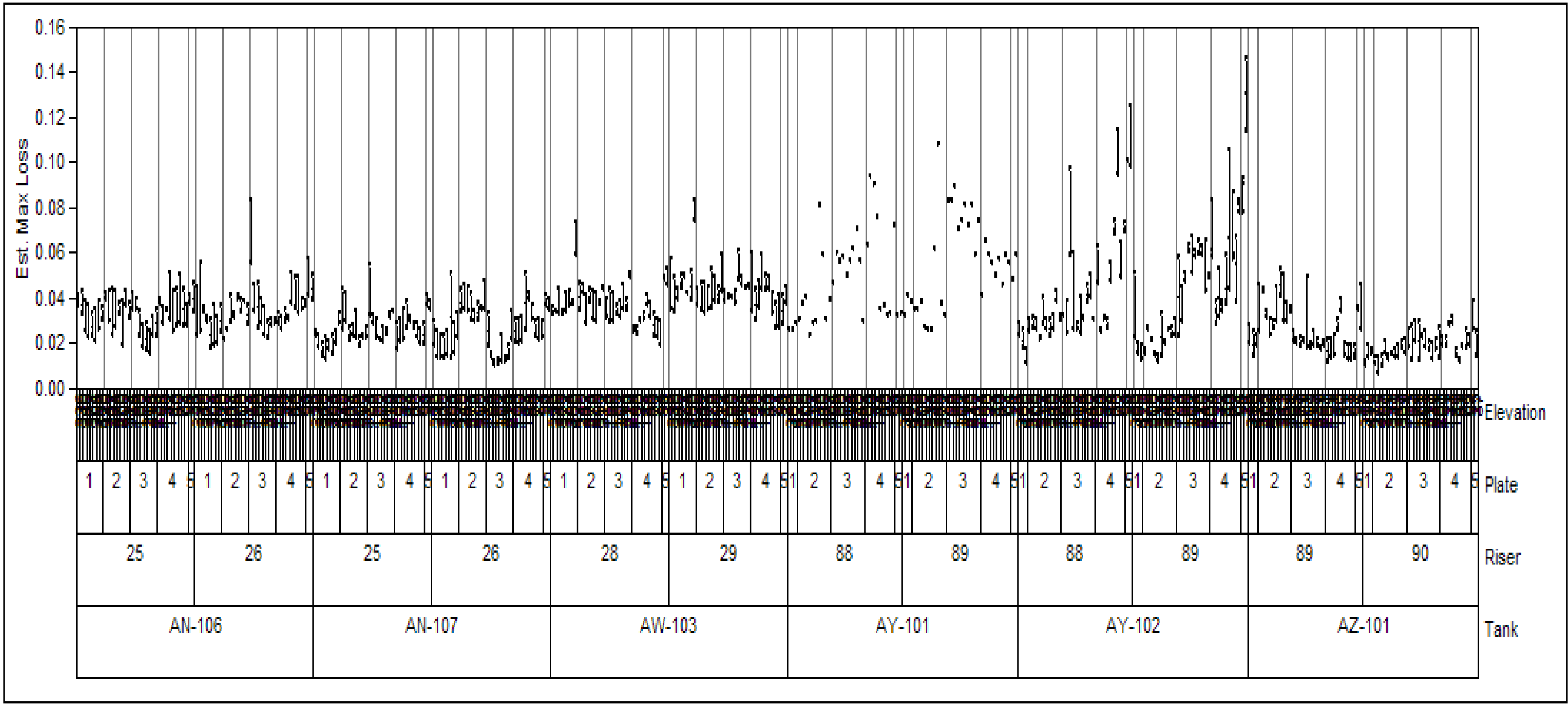
# Circumferential Uniformity (Riser Differences)



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# Circumferential Uniformity (Riser Differences)

**Variance Components (for all tanks)**

| Component | Var Component | % of Total | Plot% | Sqrt(Var Comp) Mils |
|---|---|---|---|---|
| Tank | 0.00009490 | 22.9 | | 9.7 |
| Riser[Tank] | 0.00000000 | 0.0 | | 0.0 |
| Plate[Tank,Riser] | 0.00019599 | 47.4 | | 14.0 |
| Elevation[Tank,Riser,Plate] | 0.00005559 | 13.4 | | 7.5 |
| Within/Path | 0.00006721 | 16.2 | | 8.2 |
| Total | 0.00041369 | 100.0 | | 20.3 |

- Largest source of variability is the difference between plates
- Riser differences are not at all significant



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# Circumferential Uniformity (Riser Differences)

### Variance Components without AY-101 and AY-102

| Component | Var Component | % of Total | Plot% | Sqrt(Var Comp) Mils |
|---|---|---|---|---|
| Tank | 0.00000000 | 0.0 | | 0.0 |
| Riser[Tank] | 0.00000000 | 0.0 | | 0.0 |
| Plate[Tank,Riser] | 0.00049632 | 64.4 | | 22.3 |
| Elevation[Tank,Riser,Plate] | 0.00016291 | 21.1 | | 12.8 |
| Within/Path | 0.00011110 | 14.4 | | 10.5 |
| Total | 0.00077033 | 100.0 | | 27.8 |

### Variance Components for only AY-101 and AY-102

| Component | Var Component | % of Total | Plot% | Sqrt(Var Comp) Mils |
|---|---|---|---|---|
| Tank | 0.00005656 | 37.6 | | 7.5 |
| Riser[Tank] | 0.00000291 | 1.9 | | 1.7 |
| Plate[Tank,Riser] | 0.00002902 | 19.3 | | 5.4 |
| Elevation[Tank,Riser,Plate] | 0.00001096 | 7.3 | | 3.3 |
| Within/Path | 0.00005089 | 33.9 | | 7.1 |
| Total | 0.00015034 | 100.0 | | 12.3 |



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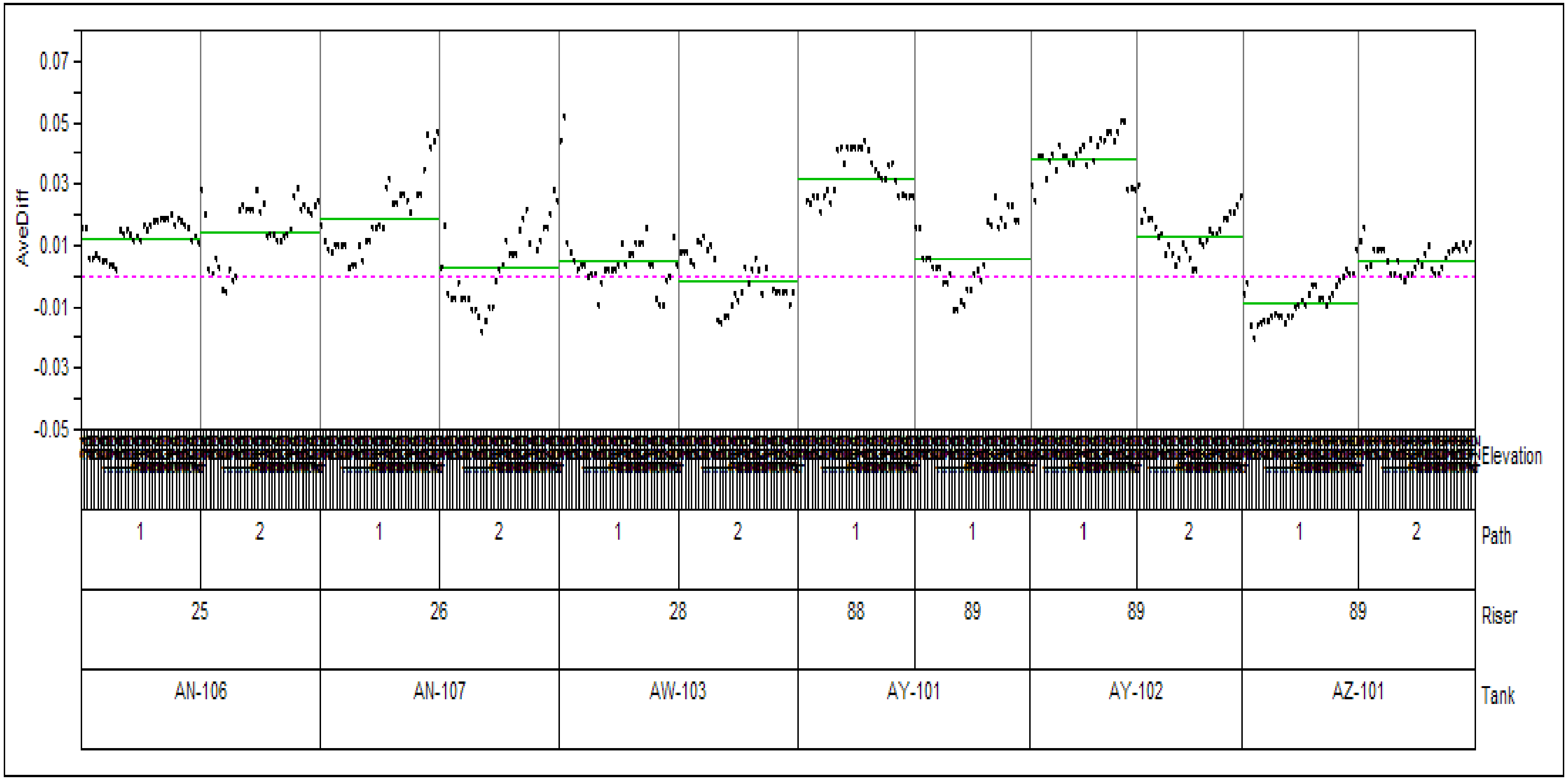
# Old / New Inspection Comparison

Old Minus New UT Averages

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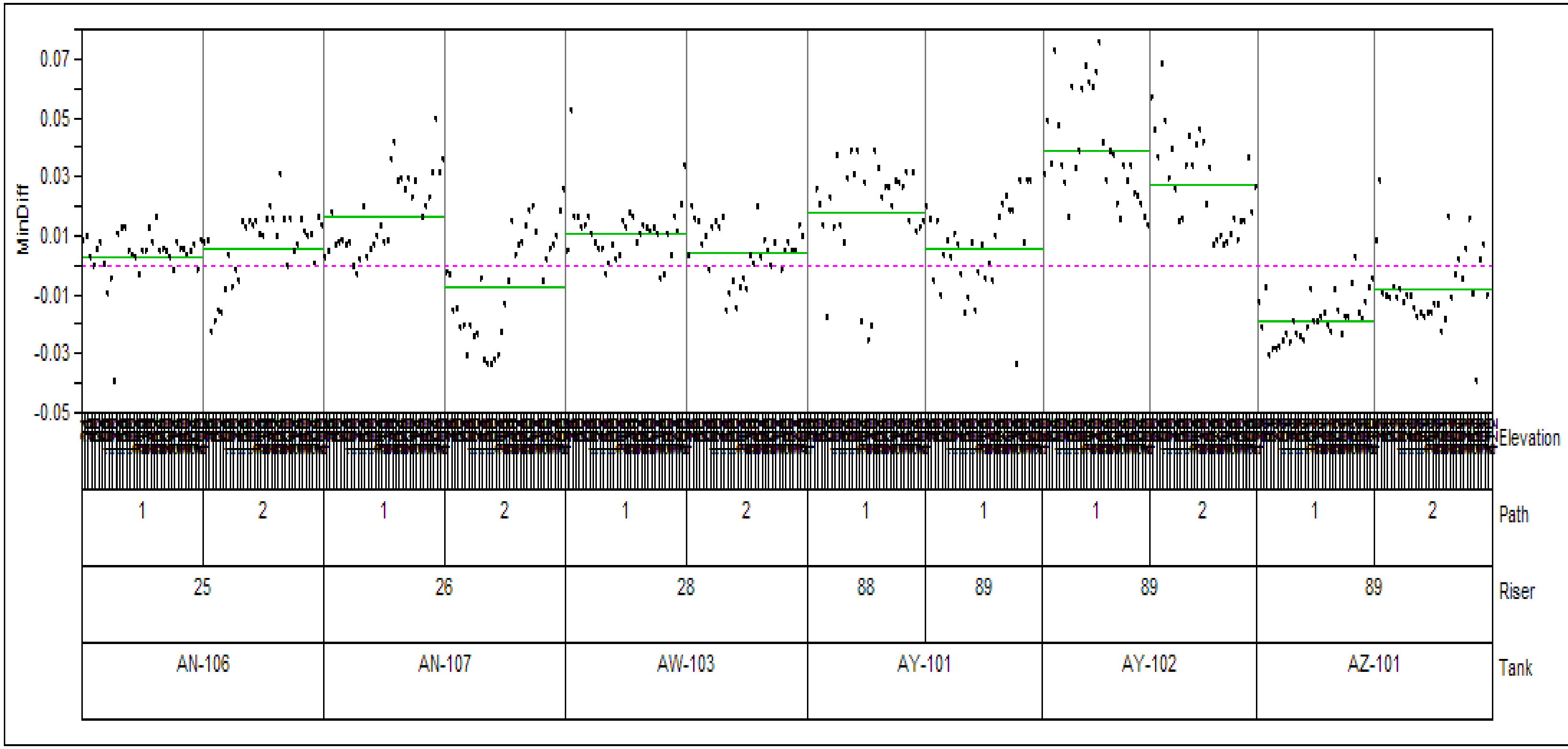
# Old / New Inspection Comparison

Old Minus New UT Minima

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# Old / New Inspection Comparison

| Tank | Scan | Inspection | Original Method | Average Thickness over Nominal | Old Minus New by Scan | Old Minus New Overall | Expected Method Difference | Adjusted Wall Thickness Decrease from Old to New |
|---|---|---|---|---|---|---|---|---|
| AN-102 | 1 | New | Peak Edge | 0.0177 | 0.0129 | 0.0131 | 0.0000 | 0.0131 |
| | | Old | Peak Edge | 0.0306 | | | | |
| | 2 | New | Peak Edge | 0.0126 | 0.0134 | | | |
| | | Old | Peak Edge | 0.0260 | | | | |
| AN-107 | 1 | New | Peak Edge | 0.0270 | 0.0193 | 0.0109 | 0.0000 | 0.0109 |
| | | Old | Peak Edge | 0.0463 | | | | |
| | 2 | New | Peak Edge | 0.0299 | 0.0024 | | | |
| | | Old | Peak Edge | 0.0323 | | | | |
| AP-108 | 1 | New | Peak Edge | 0.0037 | 0.0243 | 0.0230 | 0.0044 | 0.0186 |
| | | Old | Edge | 0.0280 | | | | |
| | 2 | New | Peak Edge | 0.0054 | 0.0218 | | | |
| | | Old | Edge | 0.0271 | | | | |
| AZ-101 | 1 | New | Peak Edge | 0.0059 | -0.0090 | -0.0020 | 0.0044 | -0.0064 |
| | | Old | Edge | -0.0031 | | | | |
| | 2 | New | Peak Edge | 0.0048 | 0.0050 | | | |
| | | Old | Edge | 0.0098 | | | | |
| AN-106 | 1 | New | Peak Edge | 0.0067 | 0.0120 | 0.0131 | 0.0044 | 0.0087 |
| | | Old | Edge | 0.0187 | | | | |
| | 2 | New | Peak Edge | 0.0067 | 0.0141 | | | |
| | | Old | Edge | 0.0208 | | | | |
| AY-102 outliers omitted | 1 | New | Peak Edge | -0.0047 | 0.0378 | 0.0255 | 0.0044 | 0.0211 |
| | | Old | Edge | 0.0331 | | | | |
| | 2 | New | Peak Edge | -0.0028 | 0.0131 | | | |
| | | Old | Edge | 0.0103 | | | | |

- For the first two tanks Peak-Edge was used for both the old and new inspections, so no bias correction is needed

- For the others, Edge for the old and Peak-Edge for the new results in the 4.4 mils bias correction shown in the earlier presentation



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# Uncertainty

- The uncertainty for a given tank UT image average, minimum, or maximum value is difficult to characterize since replicated measurements have not generally been done in tanks

- The Operator / Instrument / Transducer study in the earlier presentation suggested a ± two sigma range to be ± 5 mils for the UT image averages due to just these three sources of variability

- From operator qualification on test plates when one considers both the repeatability between measurements of a specific test plate area, and the differences from the "true" thickness of that area; then a ±two standard deviation uncertainty range for a single measurement is ± 25.0 mils. For repeatability only, without regard for the accuracy in matching the true values (again for pitting and thinning plates combined), the ± two standard deviation range is ± 23.4 mils

- If we consider the thinning Plate 5 alone, the ± two standard deviation range is reduced to ± 16.6 mils



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# Uncertainty cont.

- If adjacent Path 1 and 2 are treated as replicate measurements then their two-sigma variability is ± 21.2 mils

- This suggests we have better repeatability in the field than the qualification study data indicate since the quantity in the first bullet includes the true difference between the two path images as well as measurement uncertainty



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