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IGU

Advanced Calculation Methods to Improve Pipeline Integrity Management

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Outline of Presentation

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Additional details on this research can be found in the associated paper submitted to this WGC Conference.

Acknowledgements

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- Oren Lever, Gas Technology Institute
- Brian Miller, Gas Technology Institute

Sponsor

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- Further information on OTD natural gas R&D can be found at their website.

Background

NTSB and U.S. DOT/PHMSA Drivers

- The United States (U.S.) National Transportation Safety Board (NTSB) recommended pre-1970 gas transmission lines be subjected to a hydrostatic pressure test with a spike test.
- A basis is that manufacturing and construction defects are considered stable if the line had a post-construction hydrostatic pressure test of at least 1.25 times maximum allowable operating pressure (MAOP).
- Pending U.S. Department of Transportation Pipeline and Hazardous Materials and Safety Administration (DOT PHMSA) regulations require a post-construction hydro-test under certain conditions. This same regulation includes requirements to determine material properties like yield strength, tensile strength, and chemical makeup of the pipelines.

Objectives – Program 1

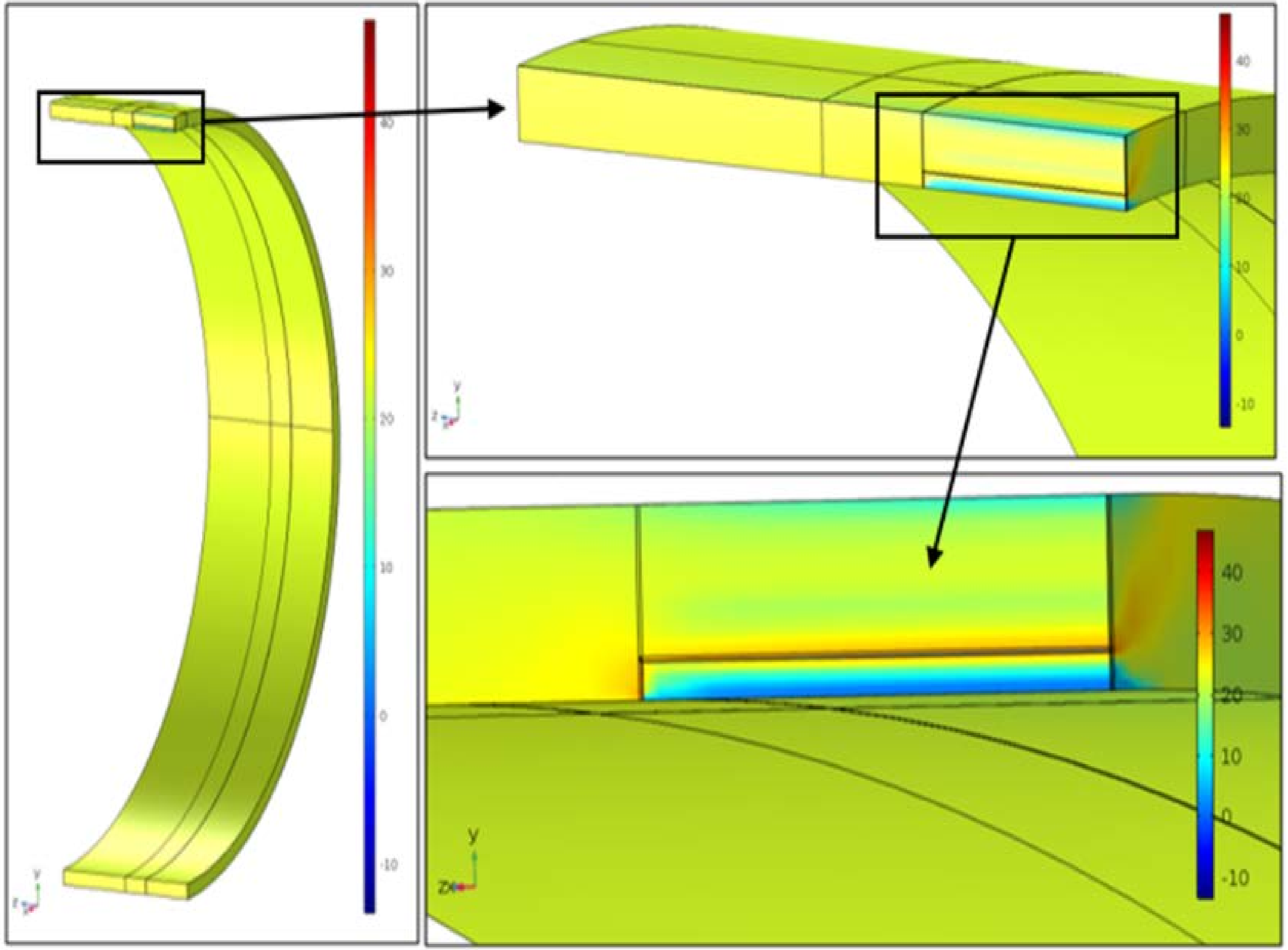
Hydro-testing Alternative Program

- Develop a Critical Flaw and Wall Loss Model and Calculator to confirm if an inspection technology would detect a crack-like flaw and/or wall loss that would fail a pressure/hydro test.
- Provide an integrity assessment solution for pipelines that cannot be taken out of service to perform a hydro test.
- Ensure the safety of the pipeline while providing cost savings to complying with new/pending regulations.
- Avoid problems with hydro-testing, such as risk of introducing water that cannot be removed or accelerating crack growth for susceptible materials.

3D model with crack propagation

Hydro-testing Alternative Program

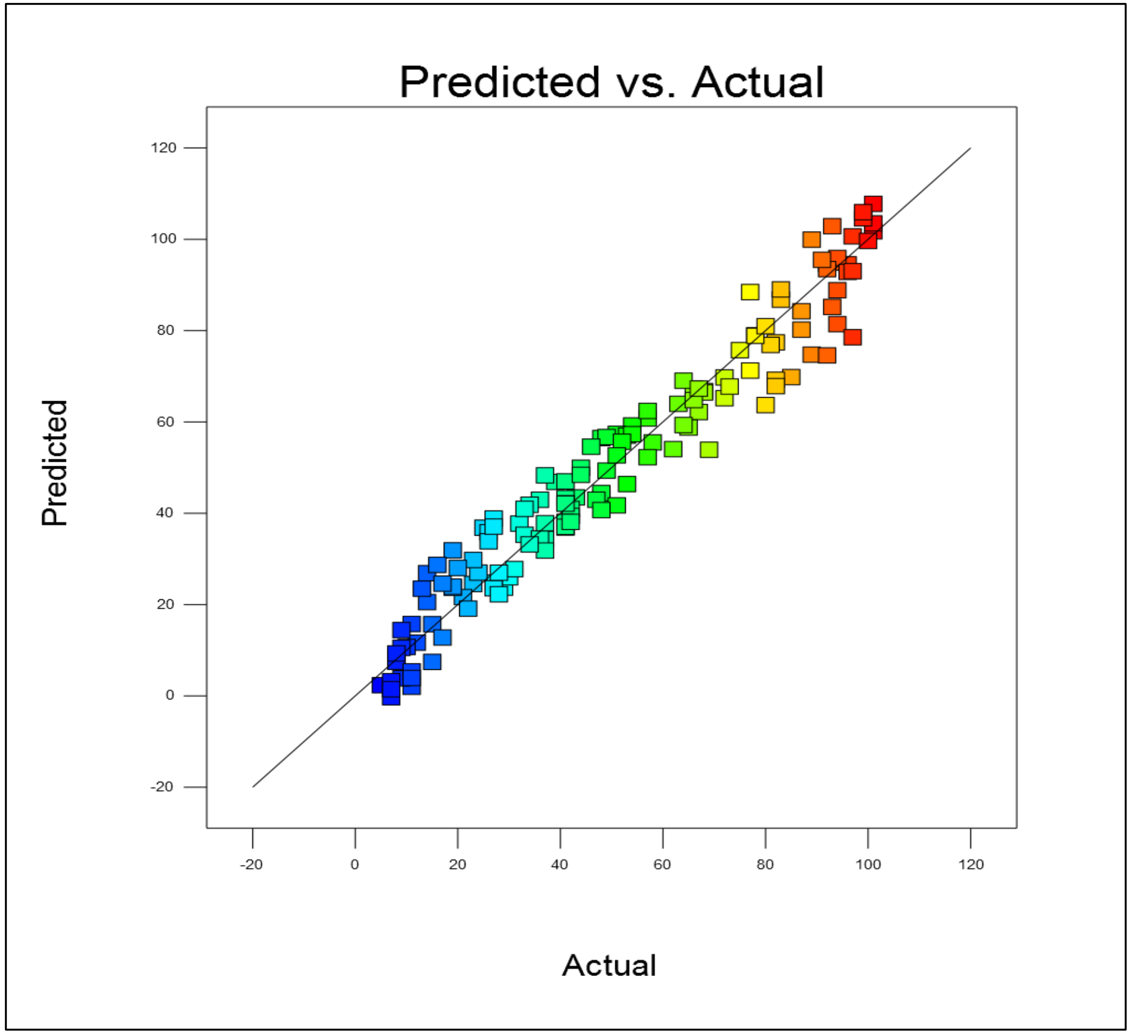
- The general geometric details of the 3D FE model of a pipe with a rectangular axial crack.
- Symmetry was assumed along the pipe's axis.
- By simulating ductile damage, this 3D model can capture radial crack propagation as internal pressure is increased.



FEM results for critical pressure

Hydro-testing Alternative Program

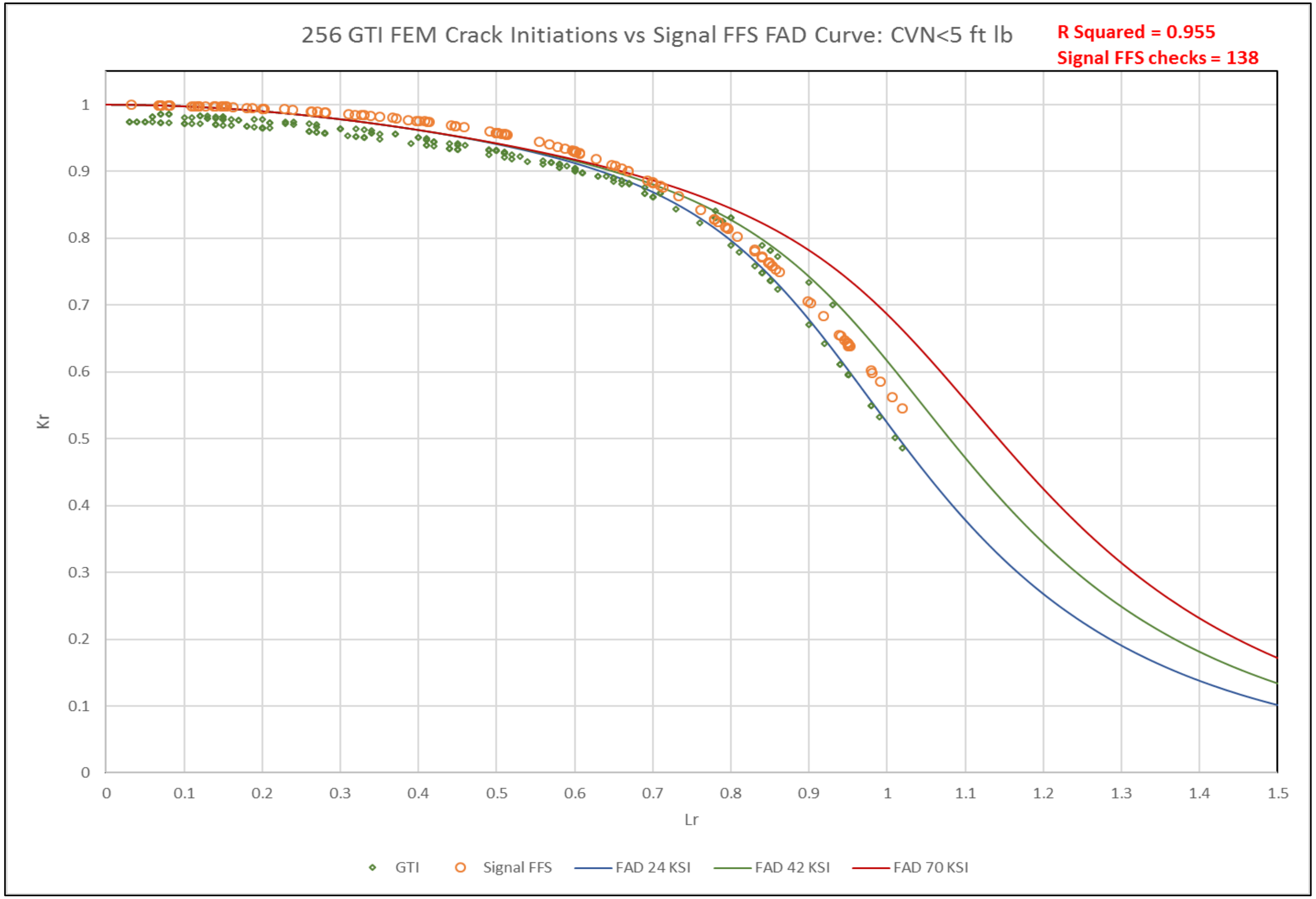
- 177 3D FEM analyses.
- Crack length and depth from 5% to 80% wall thickness; diameters from 4" IPS to 42"; wall thicknesses from ¼ to ½ inch; yield strength from 24 KSI to 70.3 KSI.
- The predicted vs. actual plot from the model ANOVA of the FEM results for critical pressure is shown in the figure to the right.



Validation of FEM crack initiations

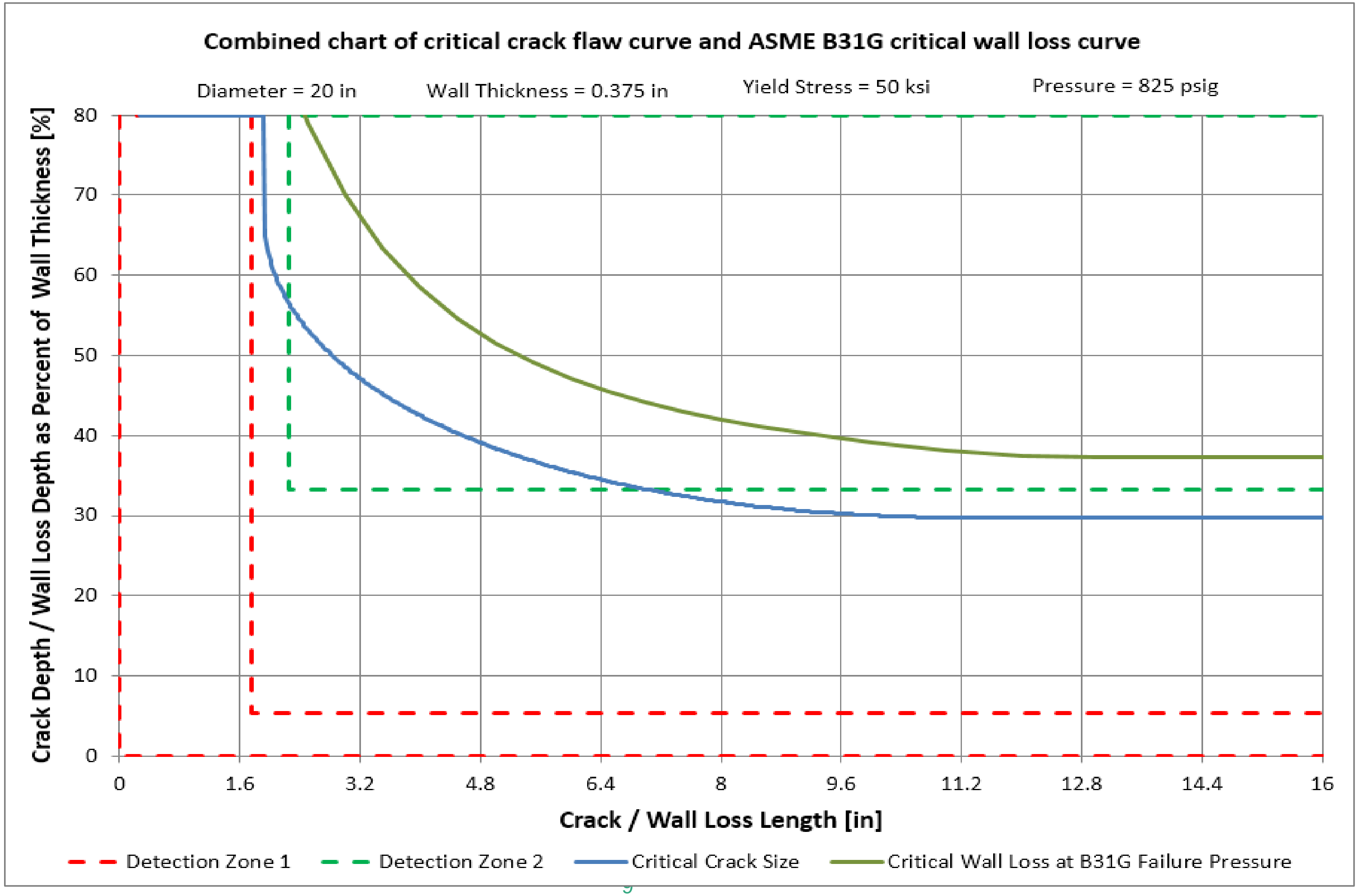
Hydro-testing Alternative Program

- FAD curves are a method for plotting the fracture driving force.
- The y axis reflects the material toughness – Kr is defined as the ratio between the stress intensity of the configuration to the material toughness in stress intensity units.
- The x axis reflects the ratio between the driving stress and a reference stress usually taken to be the yield stress of the material.



Results – Critical Curves

Hydro-testing Alternative Program



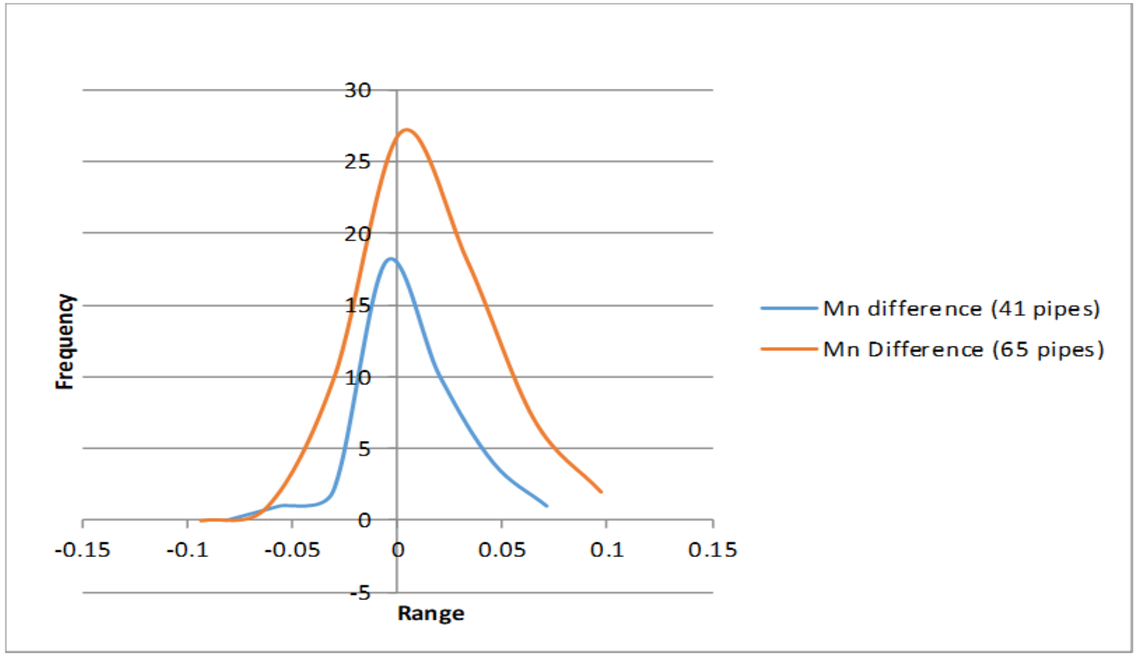
Objectives – Program 2

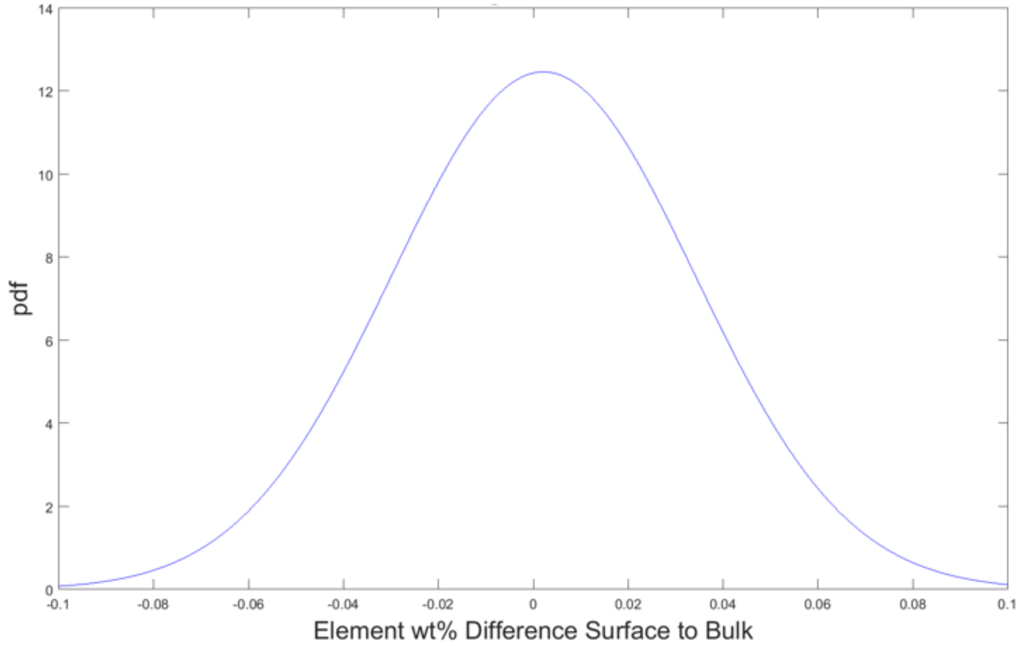
Develop Surface-to-Bulk Material Correlations to Facilitate Materials Validation

- Allow the use of surface: indentation, chemistry analysis, and optical microscopy as efficient and cost-effective tools for material property validation.
- Develop a pipeline steel database with probability distributions for variance between the surface and bulk properties.
- Develop validated surface-based material prediction models.
- Decrease the need to take a line out of service to cut out samples, thereby reducing the complexity, disruption, and cost of complying with existing and pending federal regulations.

Chemistry Difference Distributions

Surface-to-Bulk Correlations for Materials Validation





- One example of experimental chemistry distributions of the difference in surface to bulk levels on manganese is shown above on the left.
- The fitted normal distribution of the same information is shown in the distribution function on the right.

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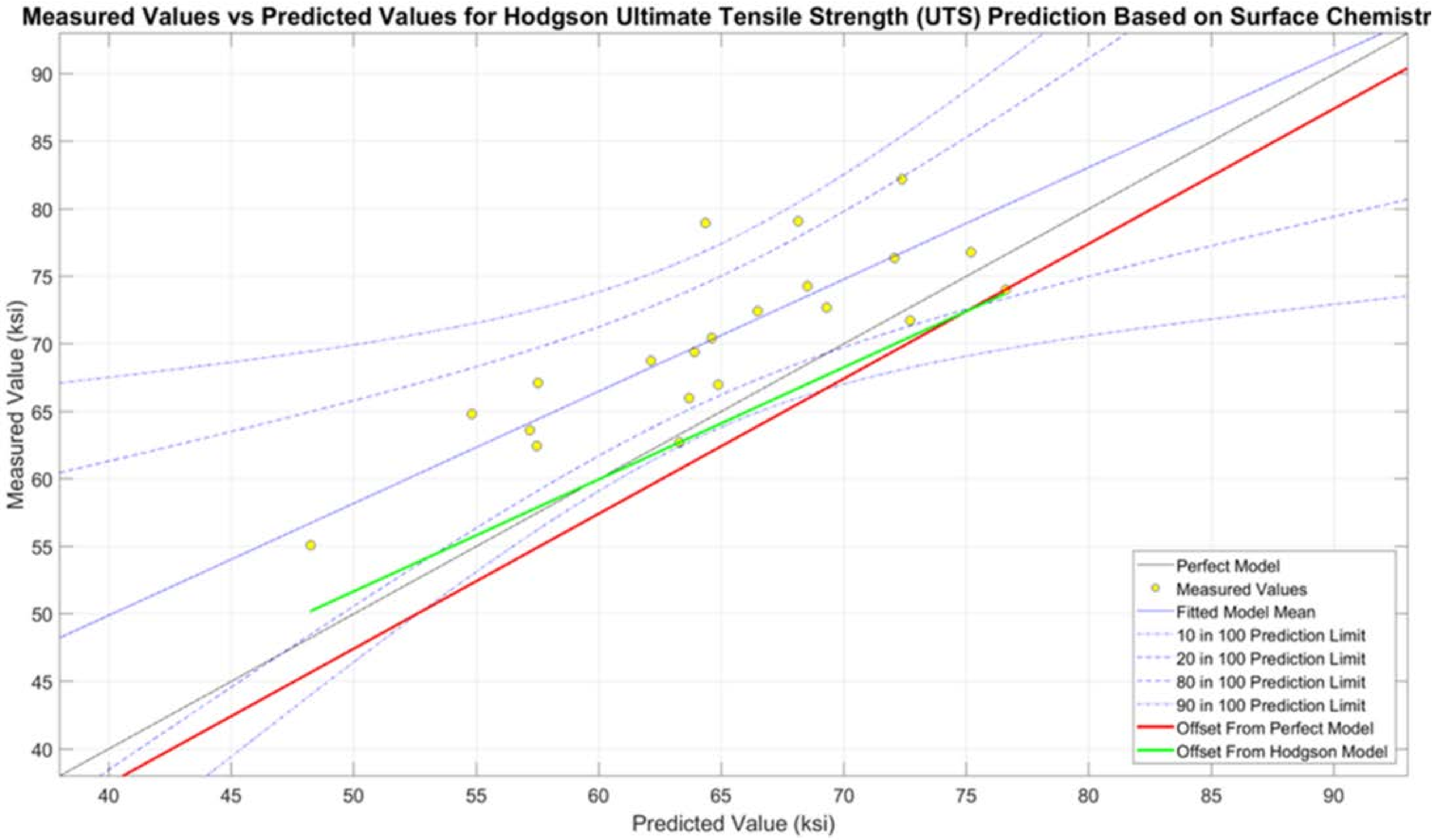
Measured vs. Predicted Values for Tensile Strength for One Chemical Model

Surface-to-Bulk Correlations for Materials Validation



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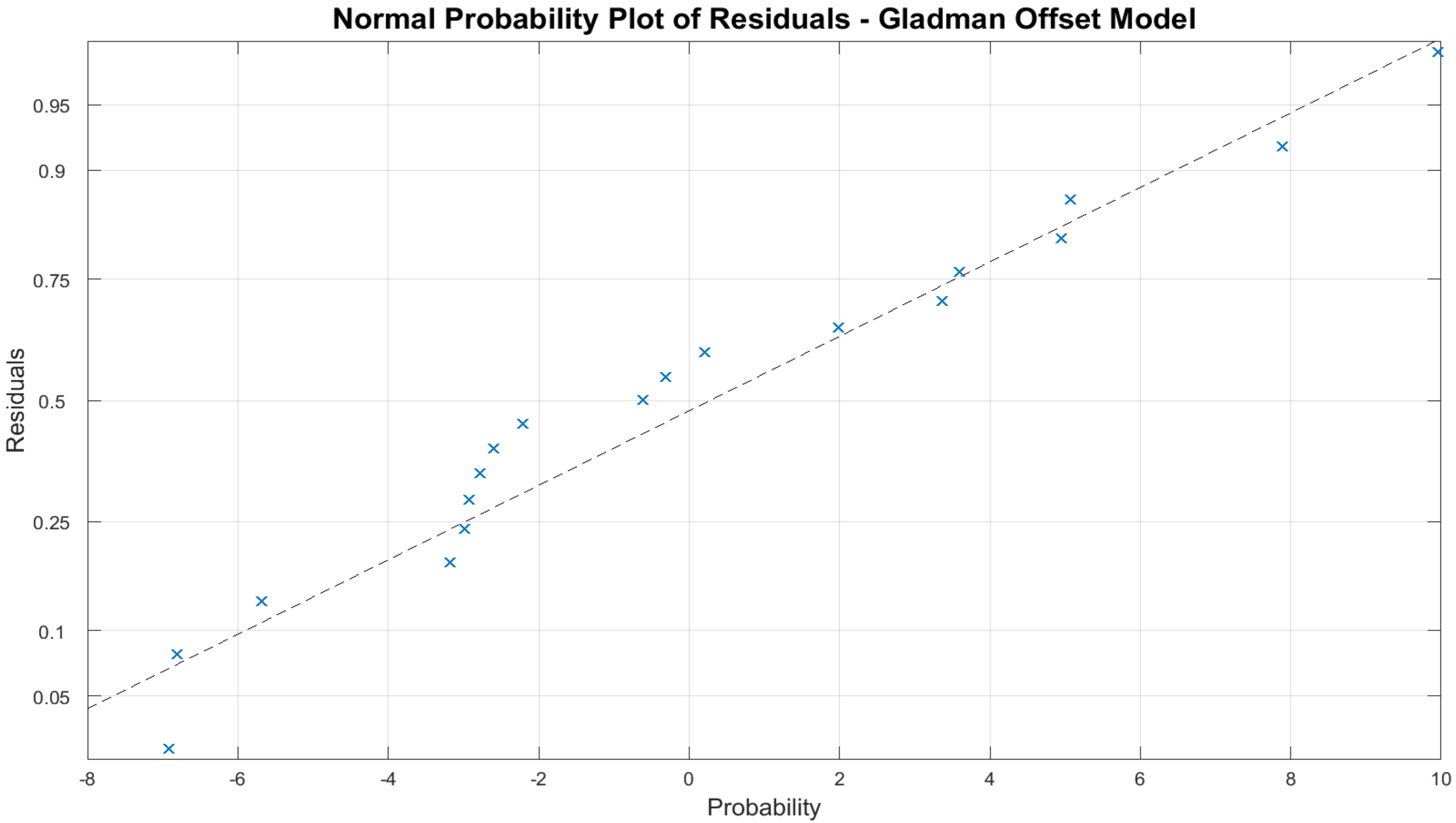
Normal Probability Plot of Residuals for Gladman Yield Strength Model

Surface-to-Bulk Correlations for Materials Validation

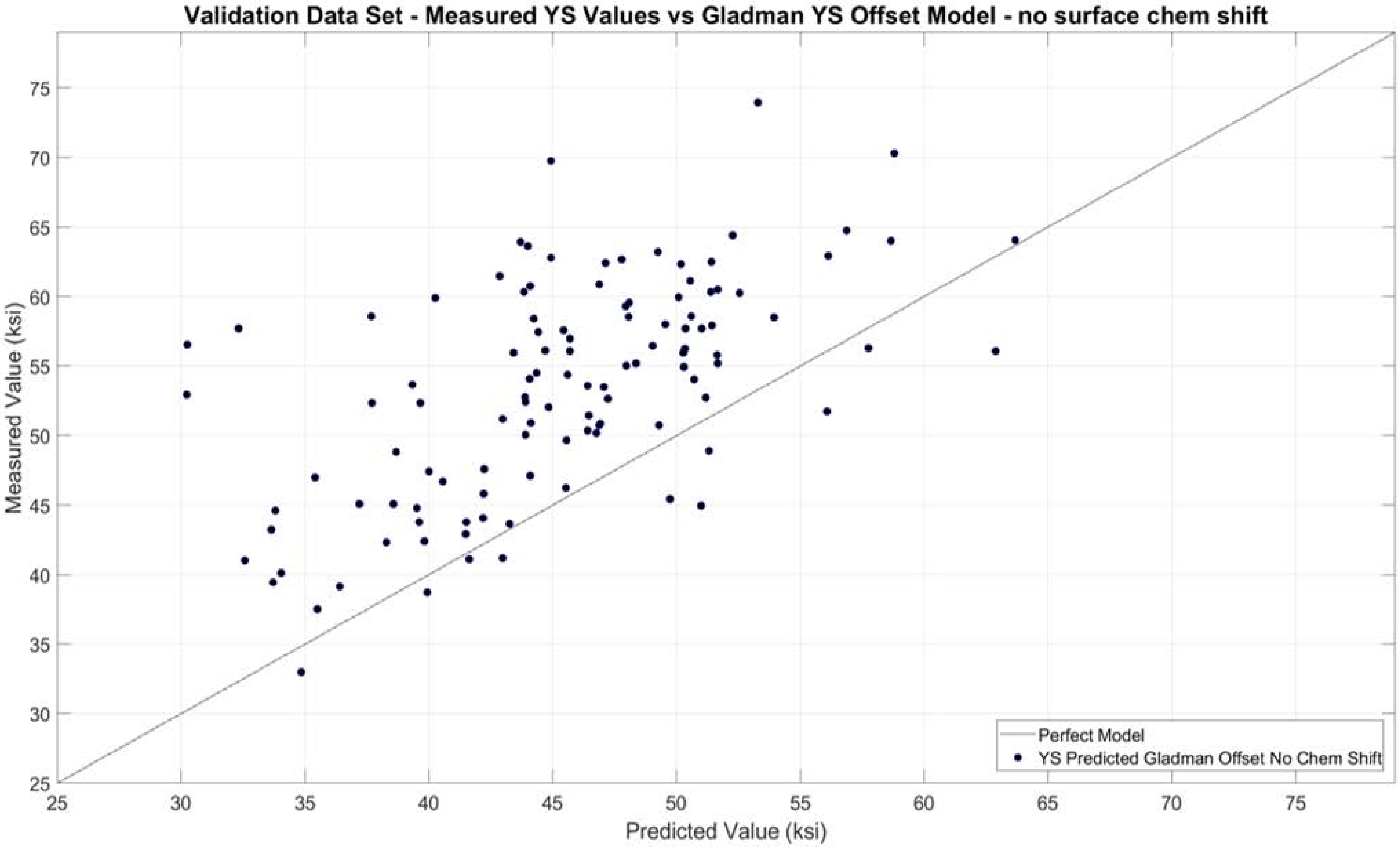


Validation Plot of Gladman Offset Model for Yield Strength from Surface Chemistry

Surface-to-Bulk Correlations for Materials Validation

Excellent validation of the Gladman Offset Model which was set at ~90% prediction limit and as such predicts no more than 11 points below the unity line for the 113 samples - there were 10 below the line.

The results also showed that the relations were independent of pipeline vintage or steel type – for both surface to bulk mechanical properties and chemistry differences between surface and bulk.



Overall Conclusions

Advanced Calculation Methods to Improve Pipeline Integrity Management

Two research and development programs were recently completed at the Gas Technology Institute (GTI) related to pipeline integrity management.

(1) Developed and deployed a Critical Flaw and Critical Wall Loss Calculator that allows operators to determine if an inspection technology could detect a defect that would fail a pressure/hydro test.

(2) Developed material/physical models that provide operators the ability to characterize material properties including yield and tensile strength and chemistry without taking the line out of service or cutting out samples.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