Public Quarterly Report

Date of Report: *5th Quarterly Report, December 31, 2025*
Contract Number: 693JK32410012POTA
Prepared for: *PHMSA*
Project Title: *Development of a Blade Toughness Meter (BTM) for In-situ Pipe Toughness Measurement*
Prepared by: Massachusetts *Materials Technologies*
Contact Information: *Simon Bellemare, s.bellemare@bymmt.com,*
For quarterly period ending: December *31, 2025*

1: Items Completed During this Quarterly Period:

Table 1 one shows that no ongoing tasks were completed in this reporting quarter except providing this report.

Table 1 – Tasks completed and invoiced this quarterly period

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
18	*N/A*	*5th Quarterly Report*	*Submit 5th quarterly report*	*0.00*	*0.00*

2: Items Not-Completed During this Quarterly Period:

Table 2 lists three active tasks:

- Task 1.2 related to finite element analysis and related portions of the blade design optimization are still outstanding. Per prior report and discussion with the TAP, work is expected to remain paused and take two quarters to conclude once it is resumed, tentatively as a Q3 or Q4 re-start.
- Item #16 from Task 2.2 has had progress made through improvements to the processing software which enable more automation in the delivery of measurements from the tool into machine learning models for final predictions. Additional automation of some quality control metrics is also included. These work tasks are overviewed in the TAP panel update found in Attachment 1.
- Item #21 from Task 2.4 is near completion and is scheduled for meeting that commitment at the end of Q1 2026.

Table 2 – Items started but not completed this quarterly period

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
4, 7, 11	*1.2*	*Develop a finite element model for the planning-induced microfracture process*	*Progress report with completed Task 1 and Task 2 progress from scope of work.*	*$22,698.50*	*$22,698.75*
16	*2.2*	*Improve prediction model and develop codes to automatically process of field data.*	*A summary of improved prediction model and data processing algorithms submitted.*	*$32,615.05*	*$32,615.05*
21	*2.4*	*Conduct third-party validation of the improved field tool*	*A report on the validation test results submitted*	*$53,065.71*	*$53,066.00*

3: Project Financial Tracking During this Quarterly Period:

The total amount billed for ongoing work can be seen in Figure 1, along with a projected invoice schedule for the entire project.

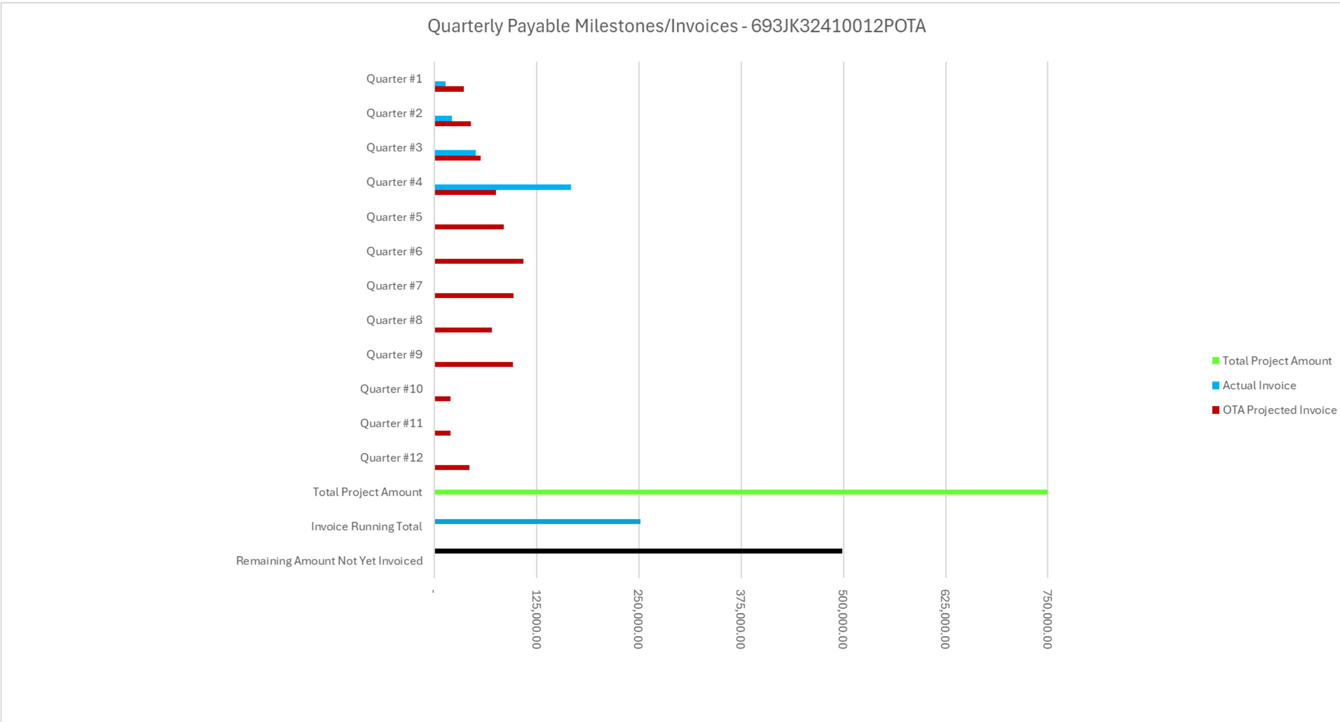


Figure 1 – MMT quarterly payable milestones and invoices

4: Project Technical Status:

Table 3 shows a complete summary of all project progress to date, listed by Task as originally defined in our proposal. For each task, we have listed the percentage achieved and the percentage complete. The numbers are kept the same because, as the Gantt chart and project architecture are laid out, achieving the tasks and milestone objectives is a necessity for the overall success of the technology development – it is not achieved unless it is complete, and vice versa.

Task 2.2 on data analytics and prediction models is nearly complete, with remaining progress contingent on third-party validation performed under Task 2.4. The greatest effort has been identifying and remediating outliers caused by incorrect laboratory testing data. A PPIM paper was prepared and presented to summarize some of the issues and emphasize to pipeline operators and quality review procedures to be exerted to ensure that the laboratory test data meets the required standards for inclusion in the database [Lacy, R., Rizwan i Haque, I., Bellemare, S., & Futch, D. (2026). *Addressing Variation in Laboratory Toughness Testing for Vintage Pipelines Using Planing-Induced Microfracture.* https://doi.org/10.52202/083805-0008].

As a general update, the team has acquired more than 100 samples with some existing laboratory pipe toughness for technology validation and is expanding model development to enhance the determination of longitudinal seam toughness. During this process, the team identified limitations within the available data. For a significant portion of samples, either (1) only Charpy V-Notch (CVN) data was available or (2) the laboratory fracture mechanics test results had to be invalidated. For these samples, new testing was ordered or the sample was put aside, depending on the situation.

This quarter, additional inconsistencies were found in laboratory test data. This included situations where the association between the physical sample and the lab data was lost. In all known cases, the association was broken between the cutting and machining processes. Since mid-December, additional data has been collected using a dual-blade method (standard and sharp blades), along with an increase in the database size. The combination of additional data collected and the removal of database samples with erroneous lab data is expected to provide a measurable improvement in model performance. This task is expected to conclude at the end of the coming quarter alongside completion of the analytics improvements currently underway.

Task 2.4 went through a preliminary blind validation with a third party with 17 samples that exceeded our success metrics. Preliminary blind validation conducted in mid-December yielded a Root Mean Square Error (RMSE) of 23. In Q1 2026, third-party validation will continue with improved models developed as a part of Task 2.2's analytics enhancement work.

Based on the data currently available, the initial commercial accuracy specification for pipe body toughness is defined as a conservative shift of 22 ksi√in for NDE values up to 100 ksi√in, and 22% thereafter. These values reflect a one-sided prediction interval at 90% confidence. While a tighter specification could be achieved by incorporating concepts from ILI validation per API RP 1163, MMT has selected this approach to maintain simplicity when conservatively accounting for tolerance.

More stringent statistical performance criteria remain achievable as additional validation data becomes available, and MMT will seek industry stakeholder input for final accuracy specification.

Finally, preparation for Milestone 3 tasks has begun with the start of Task 3.1 Field Device Optimization and Automation which was based on the feedback from Task 2.1 and will continue through Q3 2026.

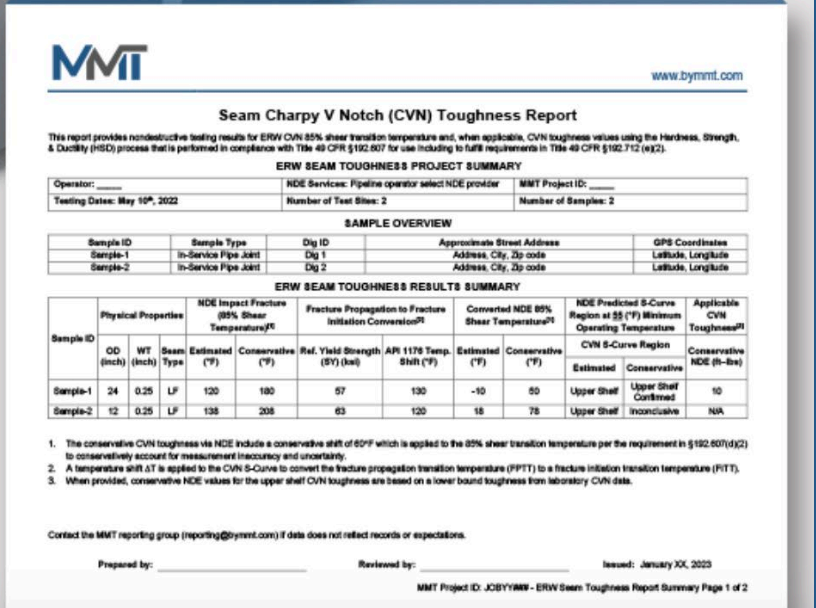
Table 3 – Complete project progress summary

Scope of Work			% Achieved	% Complete
Milestones	**Type**	**Tasks**		
Milestone 1: Blade Optimization for Better	Deliverable	1.1 Literature Review	100	100
	Method	1.2 BTM Finite Element Model Development	33	33
	Hardware	1.3 Blade Design Optimization	100	100
Milestone 2: Field Trials and Evaluation	Hardware	2.1 Field Device Development	100	100
	Software	2.2 Data Process and Analytics Optimization	80	80
	Procedure	2.3 Field Procedure Optimization	100	100
	Deliverable	2.4 Third-Party Validation	60	60
Milestone 3: Test Instrument Design and Evaluation	Hardware	3.1 Field Device Optimization and Automation	0	0
	Software	3.2 Software Development	0	0
	Procedure	3.3 Training Program Development	5	5
	Deliverable	3.4 Engineering Specification for Manufacturing	0	0
Milestone 4: Proof-of-concept for in-line	Method	4.1 Feasibility Study	0	0
	Hardware	4.2 Proof-of-Concept Development	0	0
	Deliverable	4.3 Laboratory Mock-up Testing	0	0

5: Project Schedule:

A complete project progress summary can be seen in Table 3. This summary includes all tasks that have not been started yet as well as percentage progress for ongoing tasks. Overall, the project is continuing along its expected schedule. Milestone 1 tasks, apart from Task 1.2, are complete as of this quarter in accordance with the original submission project timeline. Milestone 2 items are concluding within the original anticipated timeline. The team has made significant progress on 2.2 around an improved process for data collection and data processing/analytics. The team is on track to complete 2.4 Third party validation at the end of Q1 2026. A product requirements document has been developed that lays the groundwork for 3.1 Field Device Optimization and work has started on time for Milestone 3 items which are scheduled for completion at the end of 2026. Milestone 4 is still anticipated to begin in the second half of 2026.

Attachment 1 – Slides prepared for meeting with Technical Advisory Panel



www.bymmt.com

Seam Charpy V Notch (CVN) Toughness Report

This report provides nondestructive testing results for ERW CVN 85% shear transition temperature and, when applicable, CVN toughness values using the Hardness, Strength, & Ductility (HSD) process that is performed in compliance with Title 49 CFR §192.607 for use including to fulfill requirements in Title 49 CFR §192.712 (e)(2).

ERW SEAM TOUGHNESS PROJECT SUMMARY

Operator: _____	NDE Services: Pipeline operator select NDE provider	MMT Project ID: _____
Testing Dates: May 10th, 2022	Number of Test Sites: 2	Number of Samples: 2

SAMPLE OVERVIEW

Sample ID	Sample Type	Dig ID	Approximate Street Address	GPS Coordinates
Sample-1	In-Service Pipe Joint	Dig 1	Address, City, Zip code	Latitude, Longitude
Sample-2	In-Service Pipe Joint	Dig 2	Address, City, Zip code	Latitude, Longitude

ERW SEAM TOUGHNESS RESULTS SUMMARY

Sample ID	Physical Properties			NDE Impact Fracture (85% Shear Temperature)[1]		Fracture Propagation to Fracture Initiation Conversion[2]		Converted NDE 85% Shear Temperature[2]		NDE Predicted S-Curve Region at 55 (°F) Minimum Operating Temperature		Applicable CVN Toughness[3]
	OD (inch)	WT (inch)	Seam Type	Estimated (°F)	Conservative (°F)	Ref. Yield Strength (SY) (ksi)	API 1176 Temp. Shift (°F)	Estimated (°F)	Conservative (°F)	CVN S-Curve Region: Estimated	CVN S-Curve Region: Conservative	Conservative NDE (ft–lbs)
Sample-1	24	0.25	LF	120	180	57	130	-10	50	Upper Shelf	Upper Shelf Confirmed	10
Sample-2	12	0.25	LF	138	208	63	120	18	78	Upper Shelf	Inconclusive	N/A

1. The conservative CVN toughness via NDE include a conservative shift of 60°F which is applied to the 85% shear transition temperature per the requirement in §192.607(d)(2) to conservatively account for measurement inaccuracy and uncertainty.
2. A temperature shift ΔT is applied to the CVN S-Curve to convert the fracture propagation transition temperature (FPTT) to a fracture initiation transition temperature (FITT).
3. When provided, conservative NDE values for the upper shelf CVN toughness are based on a lower bound toughness from laboratory CVN data.

Contact the MMT reporting group (reporting@bymmt.com) if data does not reflect records or expectations.

Prepared by: ____________ Reviewed by: ____________ Issued: January XX, 2023

MMT Project ID: JOBYYMM - ERW Seam Toughness Report Summary Page 1 of 2

R&D Project:
Development of the Blade Toughness Meter (BTM) for In-Situ Pipe Toughness Measurement

Co-sponsored By PHMSA
(Project # 1043)

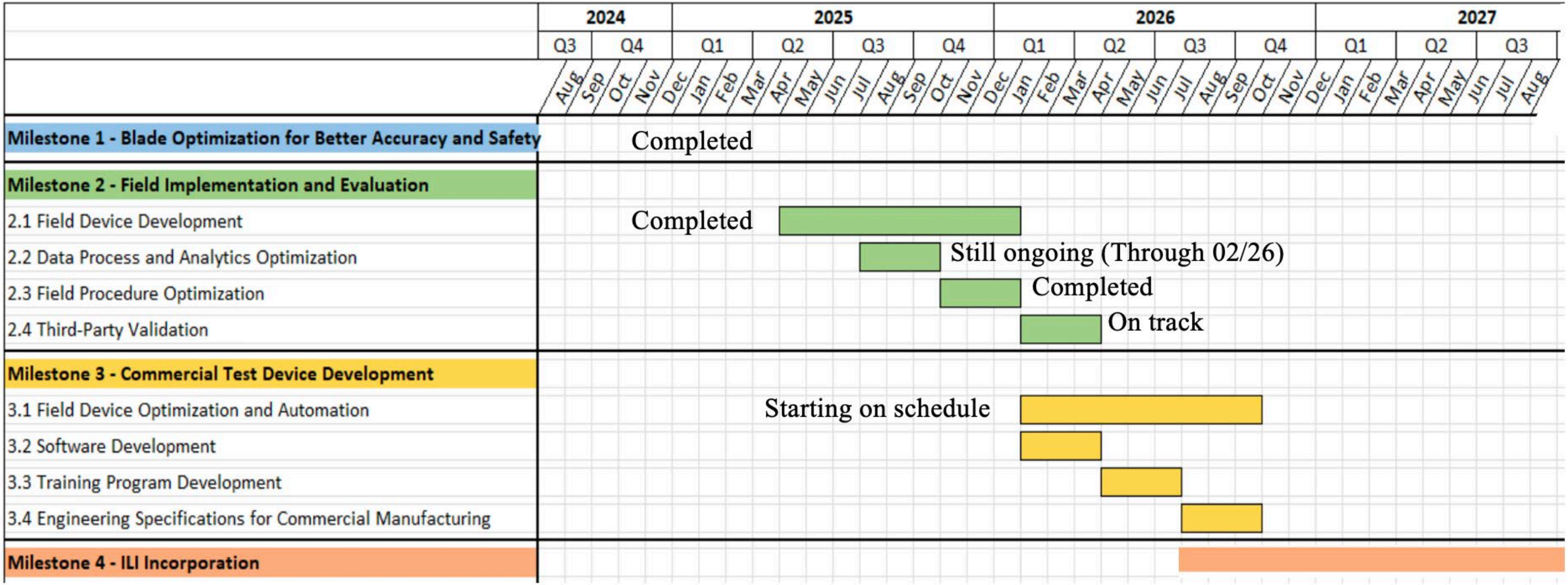
Q4 2025 – Progress Report

TAP meeting on
01/26/2026

Agenda

- Overall progress with the project
- Leveraging work completed in 2025 Q3
  - Task 2.1 Field Device Development
  - Task 2.3 Field Procedures
- 2025 Q4 Work completed (as of 01/23)
  - Task 2.2 updates (Analytics Optimization)
  - Task 2.4 updates (Third Party Validation)
  - Supporting information
  - TAP Q&A
- Request
  - Rescoping Milestone 1.2 into new Milestone 2.5
- Meeting wrap up

Progress on Project Milestones



Leveraging of Tasks 2.1 and 2.3

MMT

Excerpt from

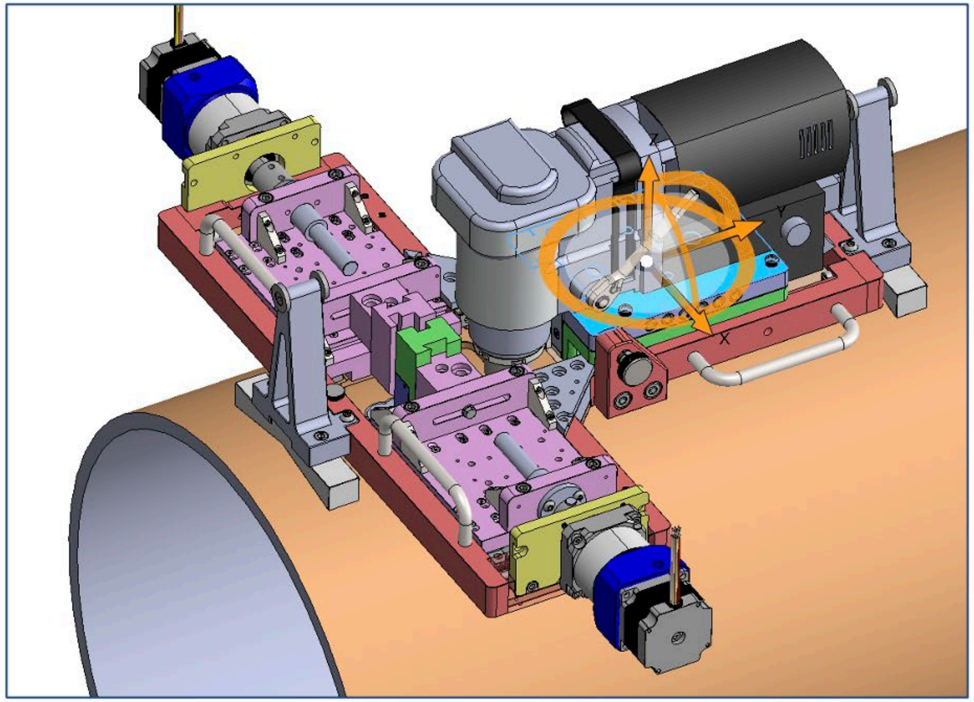
REX2026
PRCI Research Exchange

www.prci.org

Field Device Development

7

Continued warehouse and field use essentially to Milestone 3 success
(The use of the beta unit)



Test repeatability reached
(22 September 2025)

29
commercial pipe tests

6
field pilot projects

2025 Q4 Work Completed

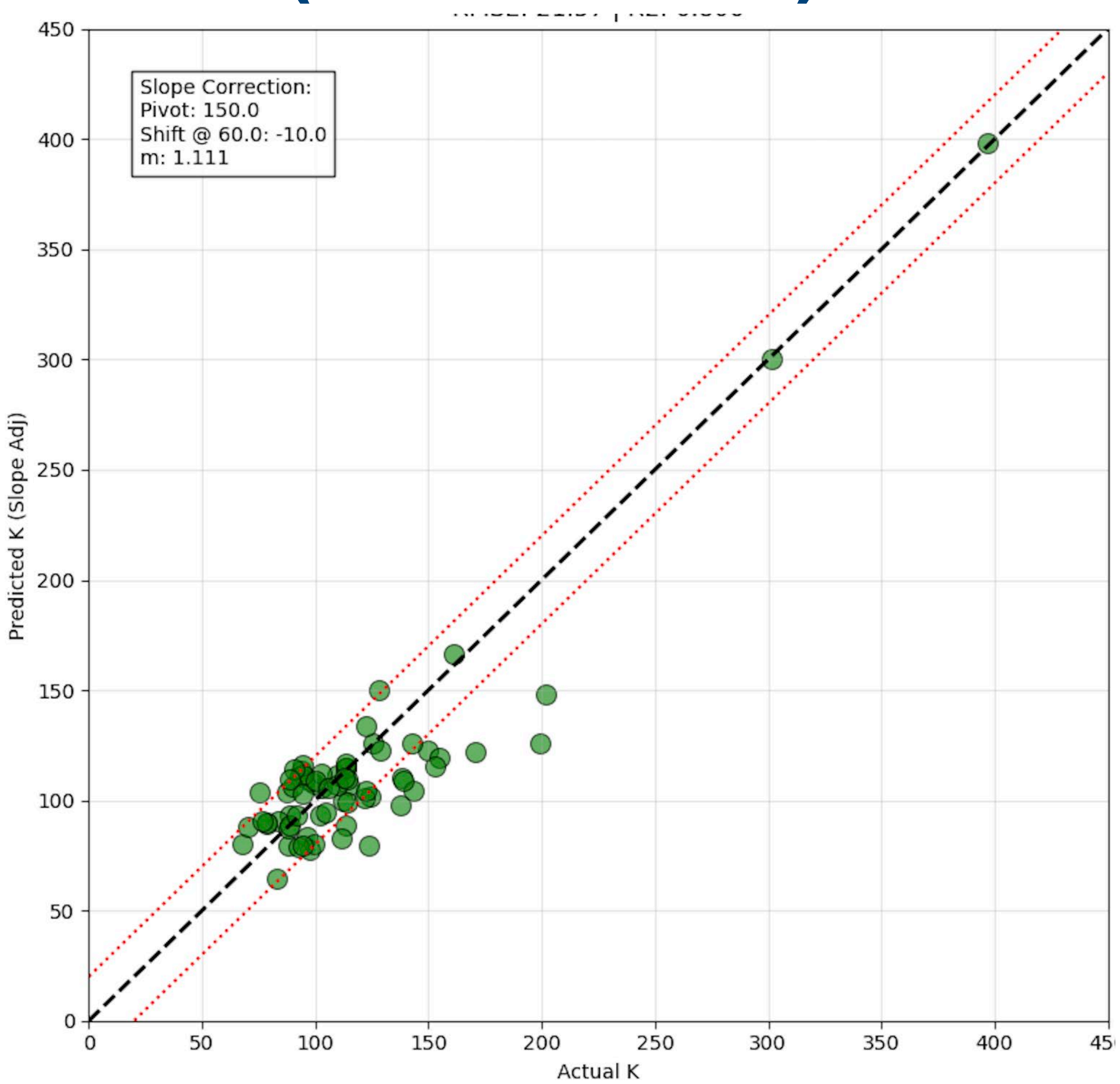
(as of 01/23)

- Two active tasks:
  - Task 2.2 updates (Analytics Optimization): Moved from 66 to 80% complete
  - Task 2.4 updates (Third Party Validation): Moved from 25 to 60% complete

- Status: Two Blind Testing Iterations
  - 15th December 2025: 17 samples: One nonconservative outlier
  - 22nd January 2026: 22 samples: One nonconservative outlier

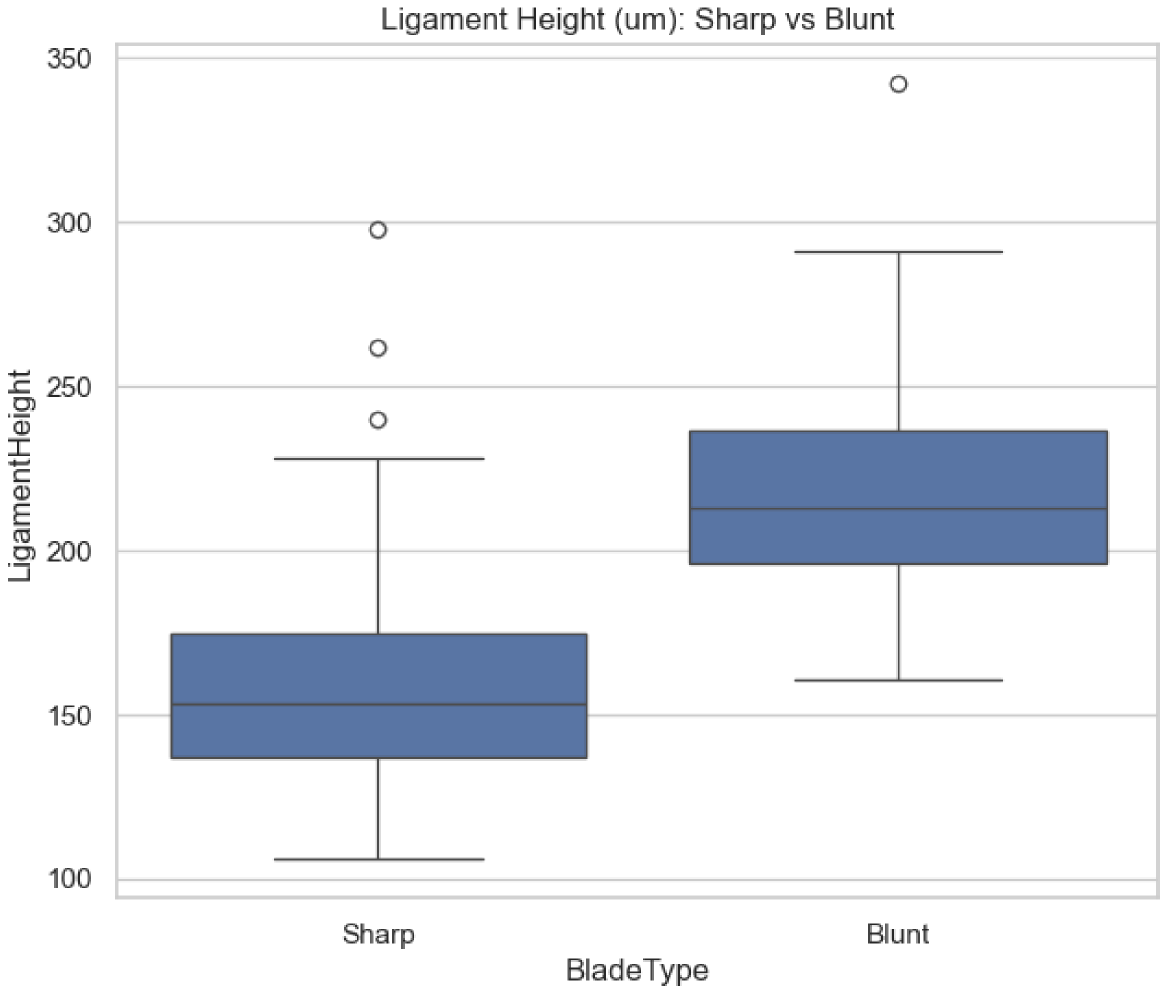
2025 Q4 Work Completed (Continued)

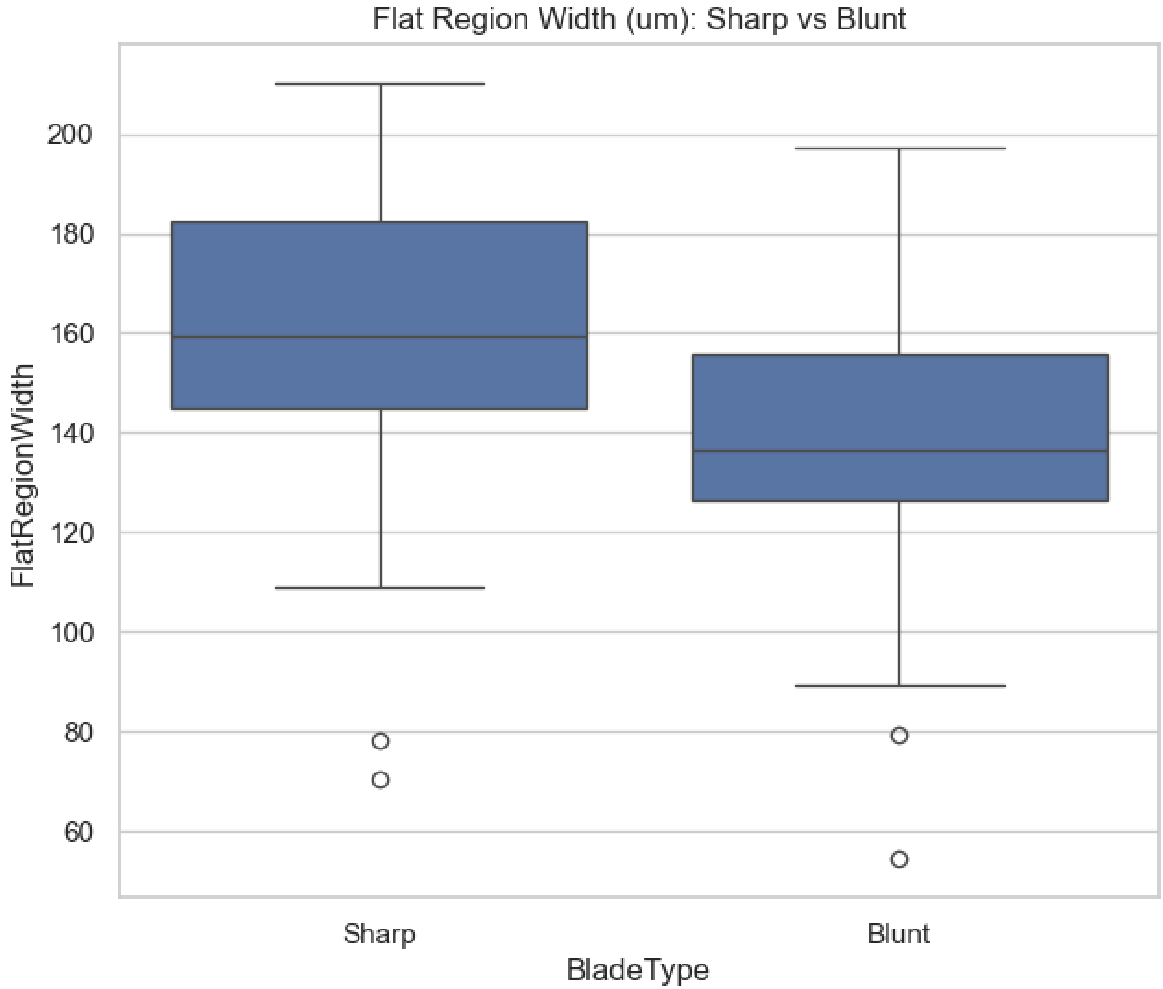
- Overall Calibration Performance More than Acceptable (Exceeds MMT goal)
  - RMSE of 22 ksi √in.
  - R2 of 0.8
- In calibration, approximately 7 overly conservative outliers



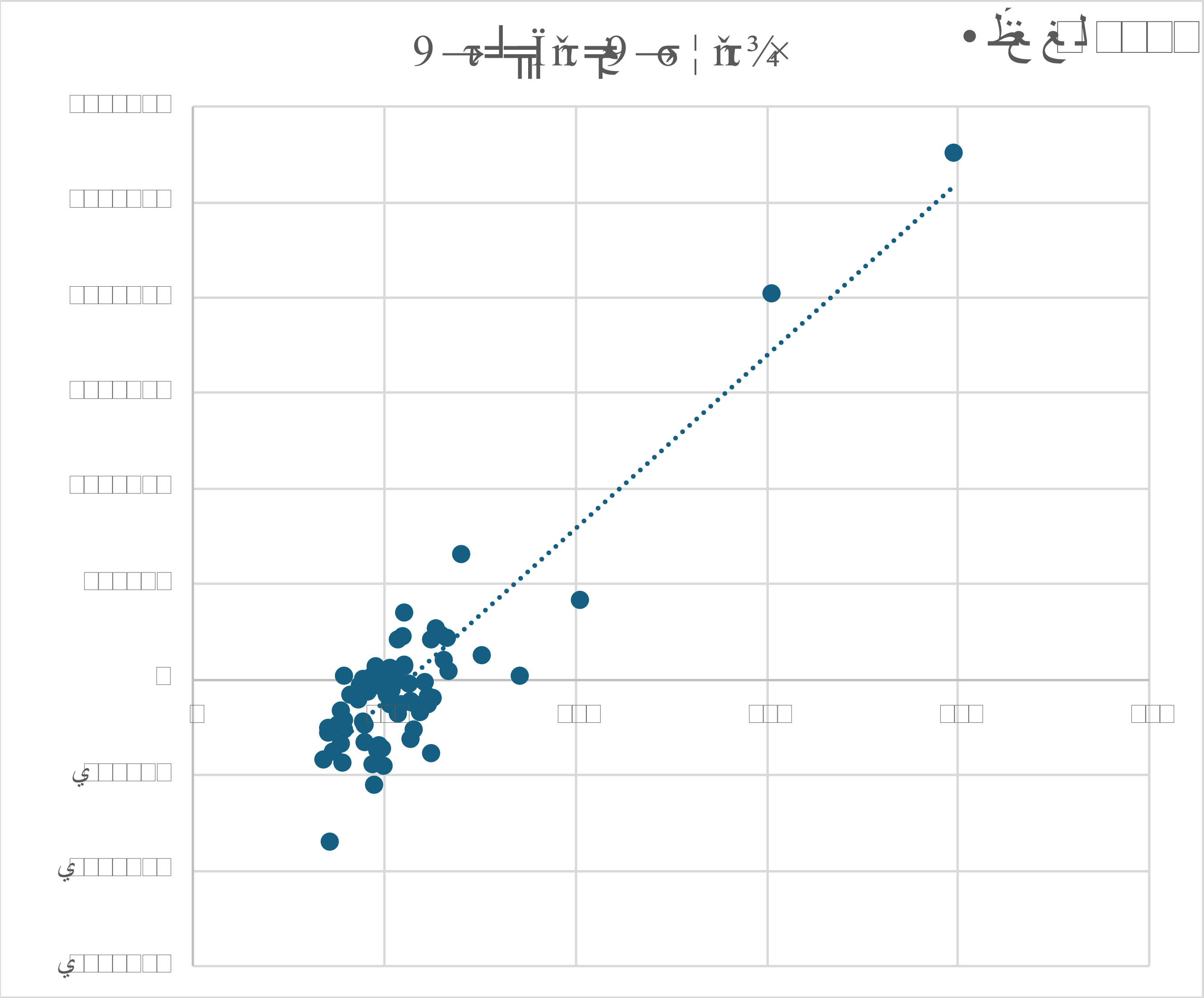
2025 Q4 Work Completed (Continued)

Sharp blades provide a distinct signal (Crack more constrained)





The Raw Analytics as Strong



70 datapoints

“Constraint” Feature:

[490
- 1 x (Sharp Blade Flat Width)
- 2 x (Blunt Blade Flat Width)
+ 6 x (Grain Size)]
x (Surface Yield Strength)^2

Next Key Step

- 3rd Blind Submission: February 26th, 2026
  - Resolve issues with the lab data:
    - Inclusion clusters (You can't find them as much using 2 samples as with 3 samples)
    - Skewed fatigue pre-crack
  - Add another 20 samples (Approximately 15 for calibration and 5 for blind)
  - Rerun the analytics (Data size and complexity between ML and regression models)

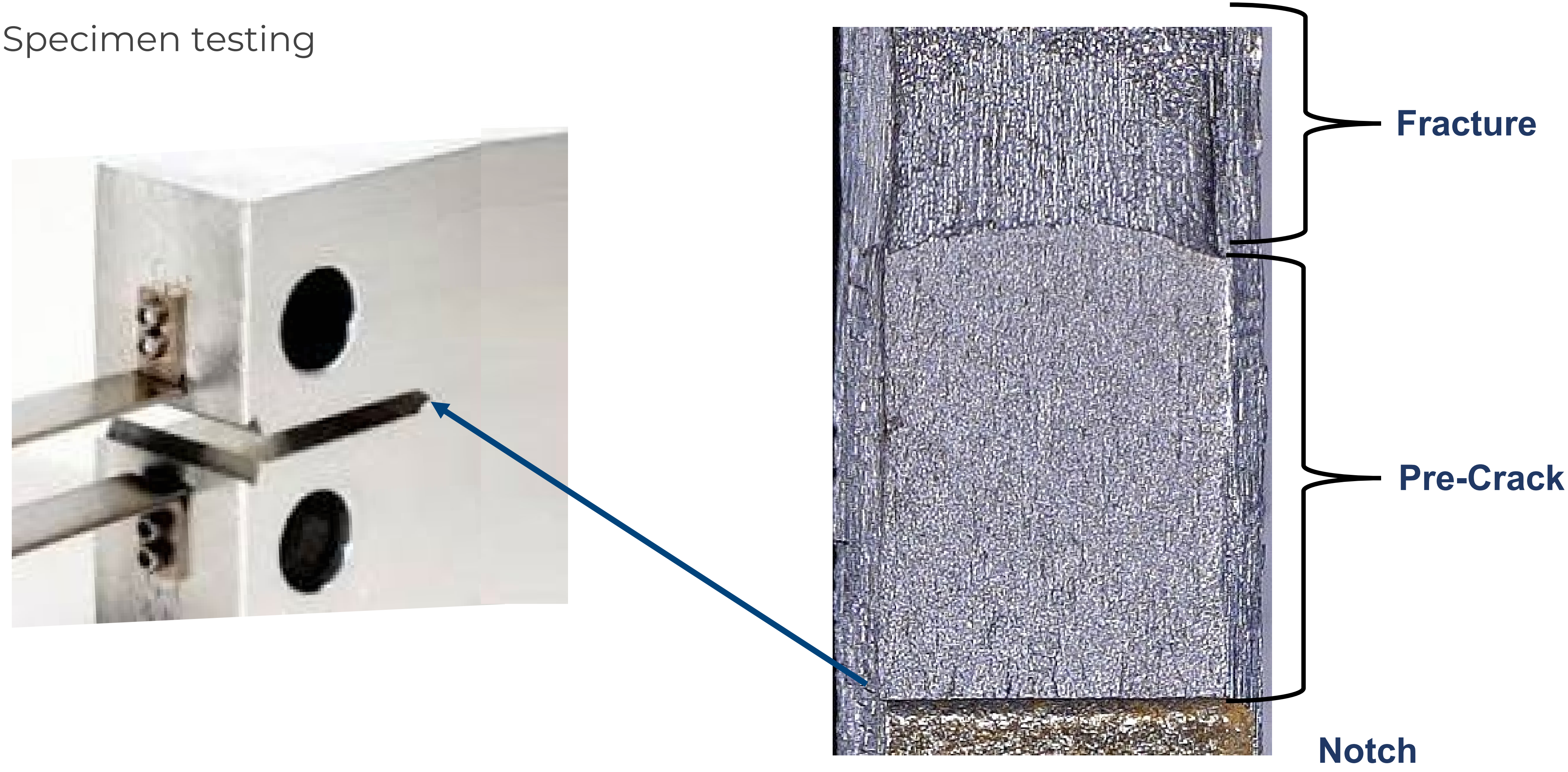
- In-Parallel: Customer-specific projects

  (Project data will be reprocessed with the latest data analytics)

Next slides: Supporting Data

Laboratory Fracture Mechanics Testing

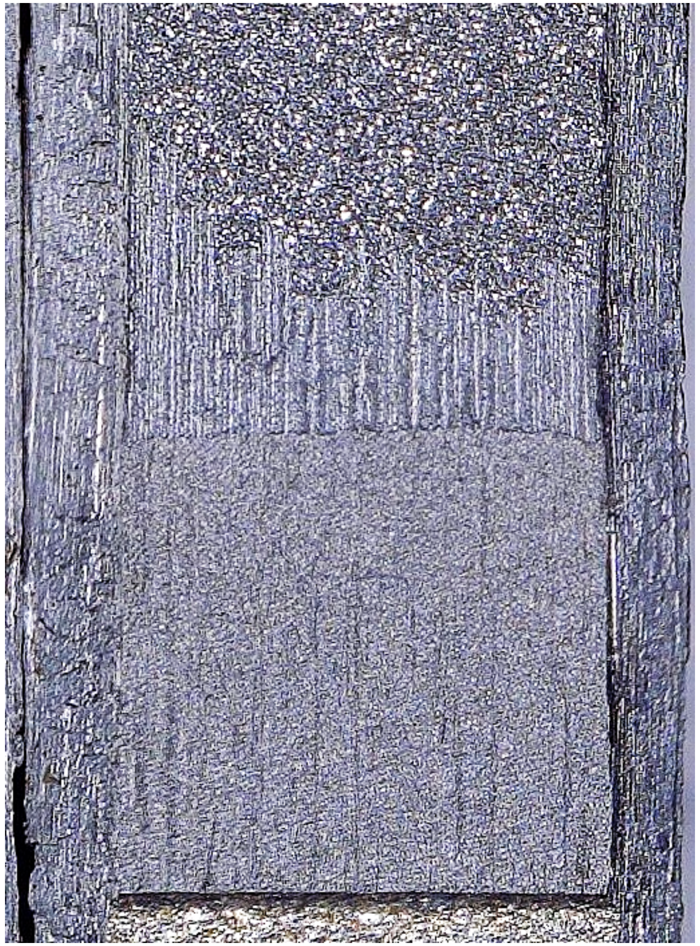
CT Specimen testing



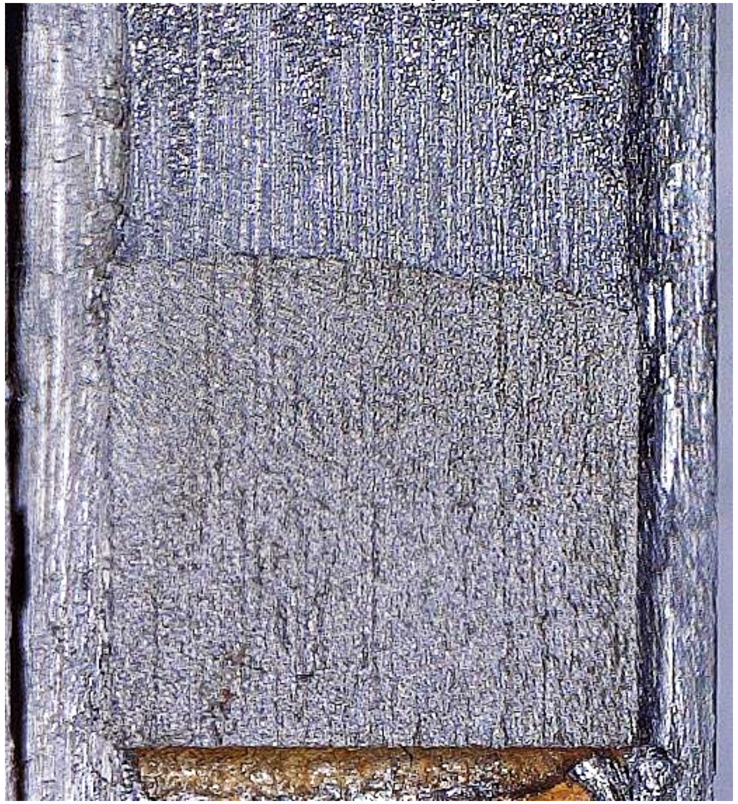
Test-to-Test Variability: Skewed Crack Front

Mid/Low Toughness Steel

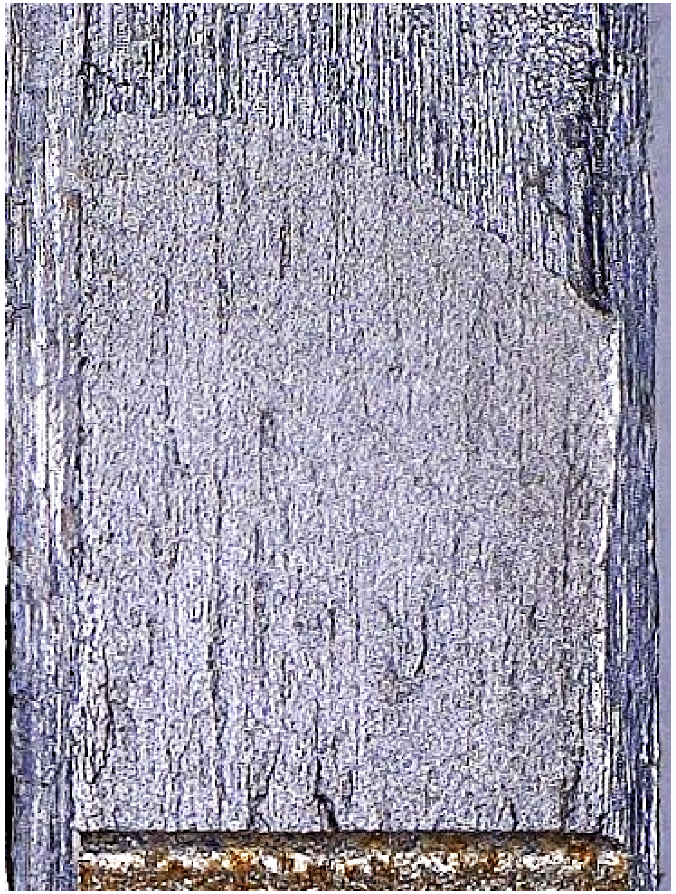
KJ 73.2 Ksi √(in)



KJ 84.4 Ksi √(in)



KJ > 90 Ksi √(in)



Was retested

Change in Scope

- Request:
  - Replace: Milestone 1.2 (Finite Element Analysis)
  - With: Milestone 2.5 (Improvement to models for HSD process seam CVN)

- Reasoning for removing FEA: We don't need it
  - The FEA work was intended to help with blade refinement. Blade refinement was completed with coating and is continuing (as validation projects) with small optimization by experiment
  - Data analytics was going to be a second use, but there is no hope for the work to be completed as far as the parametric study

- Reasoning for new scope: The JIP budget is spent, but an opportunity remains for closing
  - Several pipeline operators fell short on sponsoring and providing samples as part of the JIP project
    - Only about 10 paying sponsors versus the target of 18
    - Samples were insufficient (MMT contributed at the last minute; the 25 samples from the permanent inventory required emergency lab testing)
  - Milestone 1 (Pipe body) can be completed, but the huge opportunity with ERW seam CVN can only be completed with additional outside resources.

Housekeeping and Closing Remarks

- Comments on progress:
  - Additional questions to be answered in the report?

- Re-scoping Task 1.2
  - TAP ok with it?
  - Clarification: Would cover sample handling, testing, and processing for the prediction of CVN S Curve (Leveraged current HSD process for ERW seam CVN)
  - PHMSA Approval Process

- Your support is much appreciated