MASSACHUSETTS MATERIALS TECHNOLOGIES LLC

Massachusetts Materials Technologies LLC
8 Erie Dr, Unit A
Natick, MA 01760
617-502-5636
www.ByMMT.com

Final Material Verification Report

This Final Report provides nondestructive results using the Hardness, Strength, & Ductility (HSD) process that is performed in compliance with Title 49 CFR §192.607

FINAL PROJECT SUMMARY

Operator: Energy Company	**NDE Services:** MMT	**MMT Project ID:** MMT22000
Testing Dates: April 12th, 2022	**No. of Test Sites:** 1	**No. of Samples:** 1

FINAL SAMPLE OVERVIEW

Sample ID	Sample Type	Dig ID	Line ID	Approximate Street Address	GPS Coordinates
Sample A	In-Service Pipe Joint	Dig 1	Line AB	123 Pipe St, Pipe Town, MA 01760	12.345678, -87.654321

FINAL MATERIAL VERIFICATION RESULTS SUMMARY

Sample ID	Physical Properties			Measured NDE Strength		Conservative NDE Strength		API 5L Tensile Grade				
	OD (inch)	WT (inch)	Seam Type	Yield (ksi)	UTS (ksi)	Yield (ksi)	UTS (ksi)	Expected Grade	Conservative Grade		Expected Requirement Check	
									Yield	UTS	Yield	UTS
Sample A	16	0.250	LF-ERW	57.5	74.4	54.5	71.5	X46	X52	X56	Verified	Verified

Nondestructive evaluation (NDE) strength properties are reported as the average measured yield and UTS, as well as the conservative properties calculated by reducing the measured values by the HSD measurement uncertainty at an 80% confidence level for final strength models which is 3.0 ksi for yield and 2.9 ksi for UTS. A conservative API 5L tensile grade is determined by comparing the conservative strength to the minimum requirements for PSL 1 materials, with the sample conforming to all grades up to what is reported. If an expected grade is provided, the strength requirements are checked with the measured values and uncertainty. An expected grade of "N/A" indicates that this information was not available when the report was issued. Additional information and remarks are provided under the detailed results and justification.

Prepared by: John Smith
John Smith

Reviewed by: Jane Johnson
Jane Johsnon

Issued: April 26, 2022

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FINAL DETAILED RESULTS AND JUSTIFICATION

Sample geometry: The outer diameter (OD) and wall thickness (WT) are nominal values provided by the operator and verified during field examination.

Seam type determination: Sample A was an electric resistance welded (ERW) seam that was classified as low frequency (LF). Refer to the attached summary of test procedures, and welded seam reports for additional details on seam type designations.

Measured NDE strength properties: Measured strength properties are reported as the average 0.5% total elongation under load (EUL) yield and ultimate tensile strength (UTS) based on subset values from multiple HSD test on the same sample. Additional data on 0.2% offset yield strength is provided in the attached base metal test reports.

Conservative NDE strength properties: Procedural requirements in §192.607(d)(2) specifies that nondestructive methods for grade verification must conservatively account for measurement inaccuracy and uncertainty. The HSD process for final strength estimates considers HSD base metal tests, microstructure grain size, chemical composition, and sample manufacturing process with an associated measurement uncertainty at varying confidence levels shown in the table below[1], with MMT recommending an 80% confidence level[2]. These measurement uncertainties are subtracted from the measured values to establish conservative lower bound strength properties.

Confidence Level (%)	Yield Uncertainty (ksi)	UTS Uncertainty (ksi)
70	1.9	1.8
80	3.0	2.9
90	4.6	4.4
95	5.9	5.6

API 5L tensile grade: A conservative grade is determined by comparing the conservative strength properties at the specified confidence level to the tensile requirements for API 5L PSL 1 materials for yield and UTS, which are both referenced in 192.607(b)(2). The API 5L grade requirements are minimum values, so the sample conforms to all grades up to what is reported. If an expected grade is provided, the measured strength and measurement uncertainty are compared to the grade requirement to assess conformance using the criterion in the table below. Note that these criteria are based on the NDE strength results and measurement uncertainty at the desired confidence level and may require further analysis and review to substantiate the outcome.

Expected Grade Requirement Check	Criterion	Description
Verified	Measured - Uncertainty ≥ API 5L Grade Minimum	Measured strength exceeds the expected grade requirement at specified confidence level.
Not Verified	Measured + Uncertainty ≤ API 5L Grade Minimum	Measured strength is more conservative than expected grade at specified confidence level
Inconclusive	Measured - Uncertainty < API 5L Grade Minimum	Measured strength is within the uncertainty of the grade requirement at the specified confidence level
	Measured + Uncertainty > API 5L Grade Minimum	

[1] Tabulated HSD measurement uncertainty is applicable to final model results reported as of July 28, 2019.

[2] Palkovic et al., A statistical approach to material verification of expected grade through opportunistic measurements, PPIM, 2020.

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FINAL UT WALL THICKNESS RESULTS

Ultrasonic Testing (UT) wall thickness measurements: Informational ultrasonic thickness measurements that were taken to evaluate average material removal during surface preparation and the wall thickness around the circumference of the pipe body are provided below.

Sample ID	Nominal wall thickness (inch)[1]	Average initial wall thickness (inch)	Average wall after testing (inch)	Percent change in initial wall thickness (%)[2]	Percent change in nominal wall thickness (%)[3]
Sample A	0.250	0.263	0.245	-6.8	-2.0

[1] As identified by Energy Company
[2] Change in initial wall thickness = (Average wall thickness after testing-Average initial wall thickness) / Average initial wall thickness
[3] Change in nominal wall thickness = (Average wall thickness after testing-Nominal wall thickness) / Nominal wall thickness

Sample ID	Average UT circumferential wall thickness measurements (inch)											
	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Sample A	0.260	0.263	0.264	0.264	0.264	0.262	0.262	0.258	0.263	0.260	0.260	0.263

Additional details of the results, procedures, sample test images, individual HSD tests, microstructure grain size, chemical composition, and service limitations are attached to this report.

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Summary of Test Procedures

Last updated: Dec 9, 2020

For each sample, the following nondestructive evaluation (NDE) scope of work is completed in accordance with MMT standard test procedures[1].

- **Identifying test locations**: An initial examination is conducted with visual observations, ultrasonic testing (UT), and magnetic particle inspection to identify suitable test locations.
- **Verification of material grade (e.g. yield and ultimate tensile strength)**: Tensile strength properties are predicted using HSD surface measurements from base metal tests, metallographic grain size, and chemical composition. These predictions are based on MMT's database of over 150 pipe joints with vintages ranging from 1920 to 2016, grades A to X70, and manufacturing processes that include seamless and seam-welded construction. Strength estimates of lap welded joints assume no variation through the pipe wall as a result of a full-body normalization during manufacturing. The HSD process has been validated by subject matter experts through a prior PRCI testing program[2]. For each sample, at least five HSD measurements of material properties are obtained in at least two circumferential quadrants for a minimum of ten measurements. The HSD unit is properly calibrated prior to testing.
- **Metallographic grain size**: Average grain size is measured using the mean-linear-intercept (mli) method from ASTM E112 with surface microscopy of the etched microstructure.
- **Chemical composition**: Chemical composition is measured through independent laboratory testing of burrs removed from the pipe surface. Combustion analysis is used to measure carbon and sulfur content and Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) is used for all other elements. ICP-OES can accurately detect between 0.01 and 95 weight percent for all elements except boron which has a detection limit of 0.0005 weight percent, and measurements are calibrated with a NIST 125B reference material[3].
- **Welded seam**: If applicable, seam types are determined from observations of weld reinforcement, visual examination of the etched weld region, and hardness data measured from HSD tests across the longitudinal seam. Pipe joints are classified as flash, submerged arc welded (SAW), lap-welded, low frequency ERW (LF), high frequency ERW with no post-weld-heat-treatment (HF no PWHT), or high frequency ERW with a PWHT (HF PWHT), based on comparisons with the MMT database that includes over 75 seam-welded pipe joints. Some ERW seams are designated as PWHT ERW if the weld does not exhibit characteristics that allow for a conclusive determination of whether a HF or LF welding process was used, such as an inner heat-affected-zone (HAZ) associated with the narrow HF bondline HAZ or chemistry that is consistent with killed steel. Ongoing development efforts will allow for further differentiation of LF and HF PWHT ERW seams.

[1] Complete MMT field procedures will be provided upon request.
[2] Amend et al., Material Verification – Validation of in situ methods for material property determination, PRCI NDE-4-8, 2018.
[3] Email correspondence with chemical testing laboratory.

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HSD Process & Service Limitations

Last updated: Aug 21, 2020

The HSD process includes proprietary instrumentation, a set of established field procedures, field technician training and certification, nondestructive data collection, and associated data review and data analytics. The results provided for this project were obtained by MMT and/or technicians that were trained and certified by MMT, using the Hardness, Strength and Ductility (HSD) process.

According to Pipeline Research Council International (PRCI) report Catalog No. PR-335-173816[1], the HSD process is "*the best performing technique*" based on third party blind testing of 50 pipe samples of different geometry, manufacturing process, and vintage. Significant improvements have been made to reduce the HSD process measurement uncertainty by more than doubling the reference dataset of pipeline materials used to develop machine learning models that relate nondestructive measurements to conventional laboratory test results. Those improvements are used to generate the measurement uncertainty reported in the detailed results and justification.

Title 49 Code of Federal Regulations (CFR) §192.607 requires that procedures for material verification with nondestructive methods use techniques that have been validated by a subject matter expert based on comparisons with destructive test results, conservatively account for measurement inaccuracy and uncertainty using reliable engineering tests and analyses, and use equipment that has been properly calibrated[2]. Therefore, the HSD process and reported results are not a direct substitute for a laboratory tensile test.

All techniques that rely on multiple steps and data entries, including work performed in the field by technicians without onsite supervision, are subject to risk and potential human error. MMT provides systems to reduce the risk of delivering incorrect results while the possibility of outliers is known and considered in part through the unity charts used to establish the HSD process measurement uncertainty.

Nevertheless, neither MMT nor its field service contractors:

- provide warranties or guarantees on test results, express or implied, including without limitation implied warranties of merchantability and fitness for a particular purpose
- can be held liable for pipeline deficiencies or failures, or damages arising from pipeline deficiencies or failures.

This report sets out our professional opinion, but not a guarantee or a warranty. The testing is intended to add to your knowledge of the pipeline characteristics and help you to understand the risk of owning and/or operating the pipeline. The testing is not intended to and cannot eliminate the risk of ownership. We help you assess these risks; we do not assume them for you.

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[1] Amend et al., Material Verification – Validation of in situ methods for material property determination, PRCI NDE-4-8, 2018.
[2] PHMSA, "Pipeline Safety: Safety of Gas Transmission Pipelines: MAOP Reconfirmation, Expansion of Assessment Requirements, and Other Related Amendments. Federal Register, Vol. 84, No. 190, 2019.

Figure 1: Sample A, site and dig overview

Figure 2: Sample A, first test quadrant and info shown

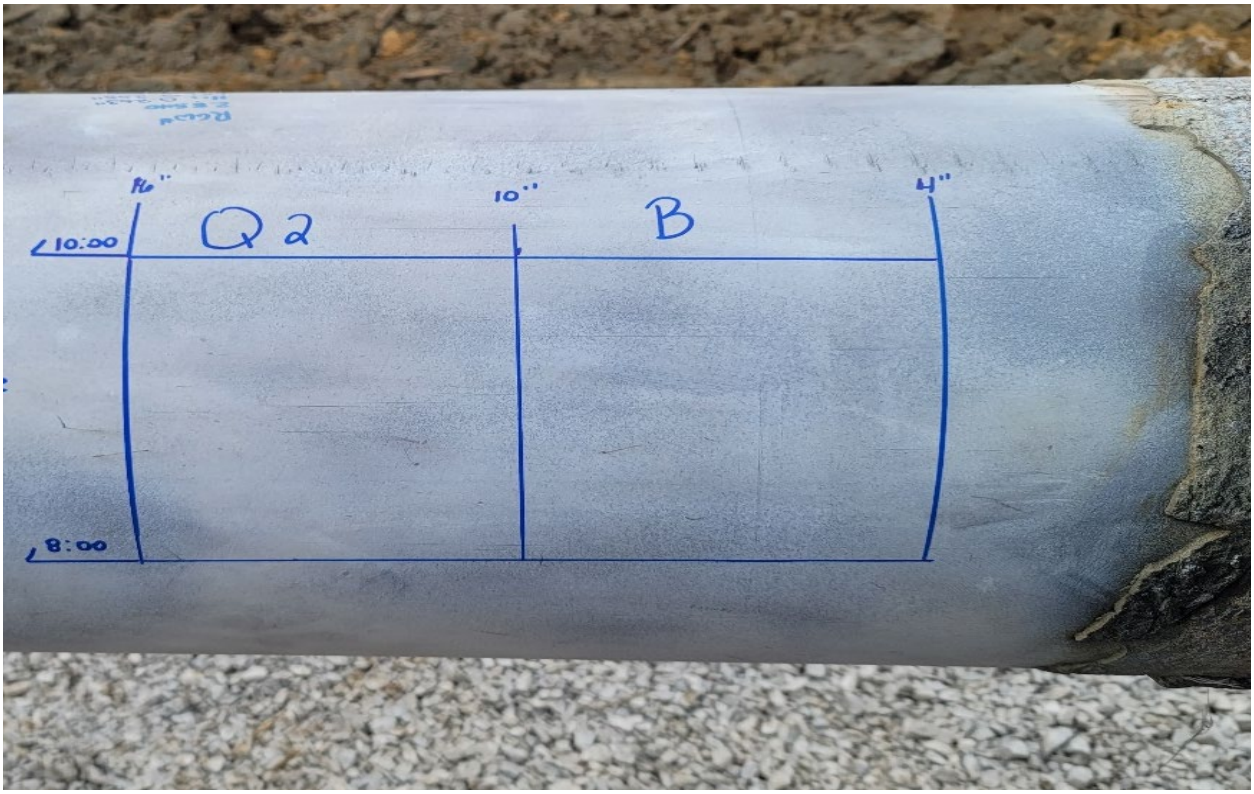

Figure 3: Sample A, second test quadrant and info shown

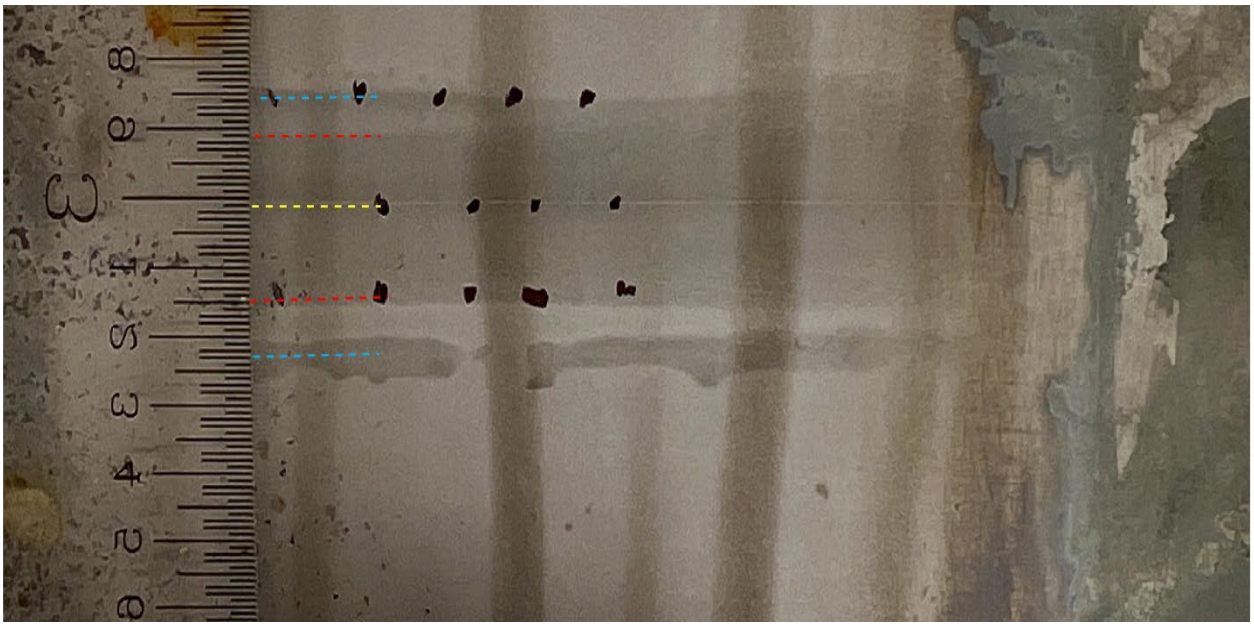

Figure 4: Sample A, examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam. The boundaries of the etched outer HAZ are marked with the dashed red lines, the bondline is shown by the dashed yellow line, and the contact marks are marked with the blue lines. The etched HAZ width is approximately 0.24 inches.

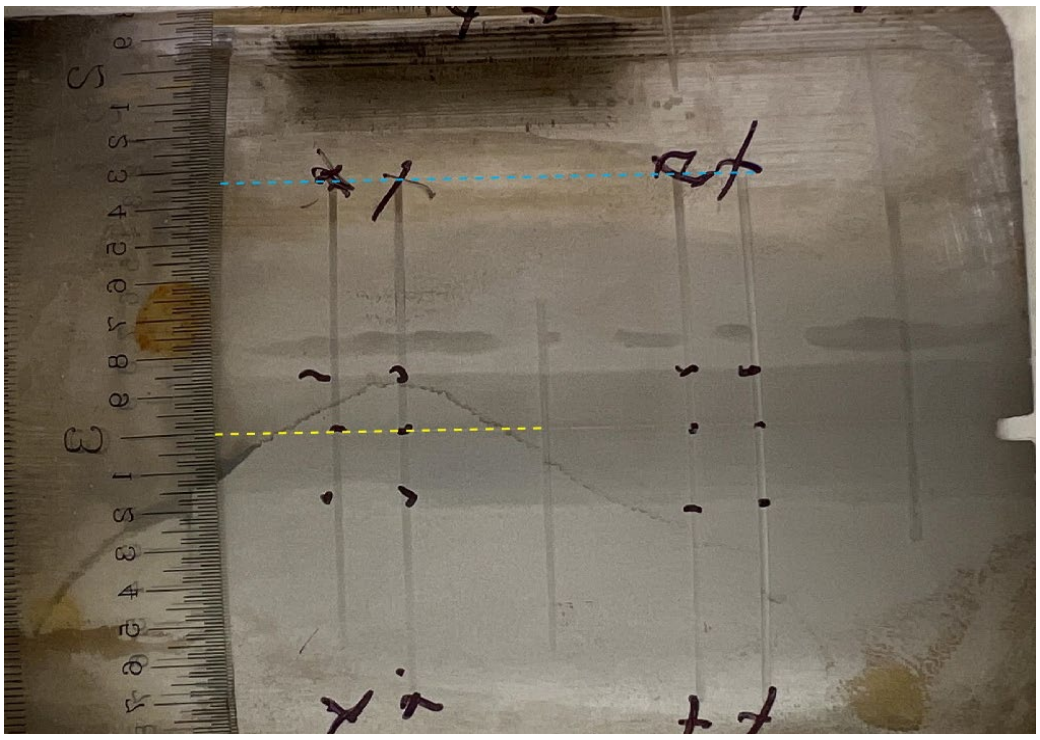

Figure 5: Sample A, HSD test performed across the longitudinal seam. The bondline is located approximately 0.7 inch from the start of the HSD test.

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Material Verification - Base Metal Test Report

Testing Information

Customer	Energy Company	Job ID	MMT22000	Report No.	220412110133	**REV --**
Site Location	123 Pipe St			Test Date	4/12/2022	
	Pipe Town, MA 01760			Test Time	11:01	
GPS Coordinates	12.345678, -87.654321	Dig ID	Dig 1	Technician Initials	JN & DV	
Sample ID	Sample A-Q1	Pipe Size	16 OD x 0.250 WT (in)			
Test Name	Sample A-Q1_BM-01_8000-EB8000_220412110133					
Sample Description	In-Service Pipe Joint - Records indicate that the year of manufacturing is			HSD Serial No.	8000-EB8000	
	1961. The expected API 5L grade is X46.			Calibration Standard	21-AB-10	
Testing Location	40-46" away from the upstream edge of coating at clock position 01:00-03:00			Calibration Status	**PASS**	

Chemical Composition and Grain Size [1]

Base Metal Chemical Composition (wt. %) [2]

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.78	0.008	0.022	0.03	< 0.01	0.02	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size [3]

mli (µm)
14.0

Carbon Equivalent (wt. %)

CE_{PCM} 0.29 $\quad CE_{PCM} = C + \frac{Si}{30} + \frac{Mn+Cu+Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$

CE_{IIW} 0.38 $\quad CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$

[1] Chemical composition and grain size are reported as one set per sample. Results are incorporated into final prediction for individual HSD tests.

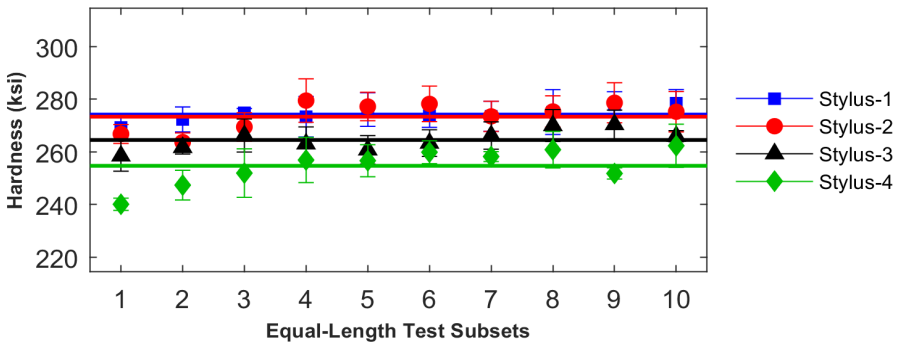
[2] Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface in accordance with MMTF005.

[3] Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy in accordance with MMTF003.

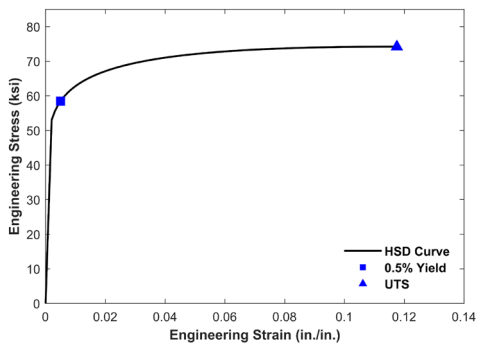
Material Strength Testing [4]

HSD Processing Ver. 2.2

HSD Stylus Hardness = (Stylus Force) / (Contact Area)



Predicted Tensile Stress-Strain Curve



Prediction Ver. H2.4-G2.04-LAB v190728-BLMc

Tensile Properties [5]

	Prediction Subsets										
	1	2	3	4	5	6	7	8	9	10	Overall
0.5% EUL Yield (ksi)	55.3	56.4	57.9	57.3	59.3	58.2	59.3	59.7	59.9	59.0	**58.5**
0.2% Offset Yield (ksi)	53.6	54.8	56.5	55.7	57.9	56.7	57.9	58.4	58.6	57.6	**57.0**
UTS (ksi)	73.1	73.1	73.8	73.7	74.6	74.4	74.7	74.4	74.6	74.8	**74.2**

[4] Material strength testing is performed at multiple locations on the pipe. Final predictions incorporate HSD results, chemical composition, and grain size.

[5] Each prediction subset considers 3 or more HSD measurements based on 10 equal-length groupings along the length of the test. Subsets where predictions are not provided did not meet MMT quality standards. The overall prediction considers the average hardness measurements for the entire test length.

Comments

Prepared: John Smith — John Smith

Approved: Jane Johnson — Jane Johnson

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Material Verification - Base Metal Test Report

Testing Information

Customer	Energy Company	Job ID	MMT22000	Report No.	220412102404	**REV --**
Site Location	123 Pipe St			Test Date	4/12/2022	
	Pipe Town, MA 01760			Test Time	10:24	
GPS Coordinates	12.345678, -87.654321	Dig ID	Dig 1	Technician Initials	JN & DV	
Sample ID	Sample A-Q2	Pipe Size	16 OD x 0.250 WT (in)			
Test Name	Sample A-Q2_BM-01_8000-EB8000_220412102404					
Sample Description	In-Service Pipe Joint - Records indicate that the year of manufacturing is			HSD Serial No.	8000-EB8000	
	1961. The expected API 5L grade is X46.			Calibration Standard	21-AB-10	
Testing Location	10-16" away from the upstream edge of coating at clock position			Calibration Status	**PASS**	
	08:00-10:00.					

Chemical Composition and Grain Size [1]

Base Metal Chemical Composition (wt. %) [2]														Grain Size [3]
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.24	0.78	0.008	0.022	0.03	< 0.01	0.02	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005	14.0

Carbon Equivalent (wt. %)

CE_{PCM} 0.29 $\quad CE_{PCM} = C + \frac{Si}{30} + \frac{Mn+Cu+Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$

CE_{IIW} 0.38 $\quad CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$

[1] Chemical composition and grain size are reported as one set per sample. Results are incorporated into final prediction for individual HSD tests.

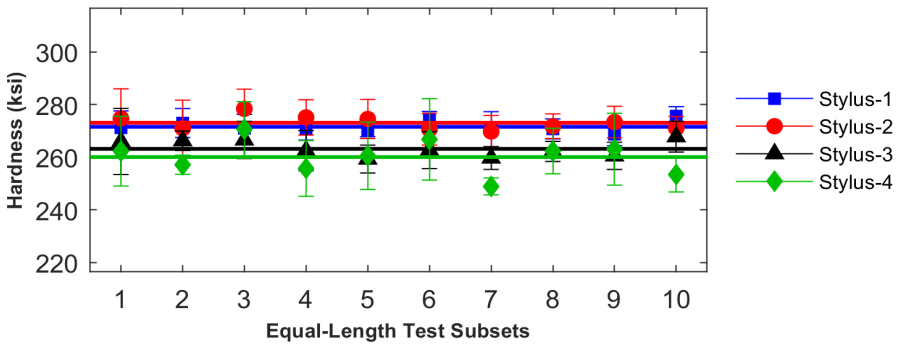
[2] Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface in accordance with MMTF005.

[3] Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy in accordance with MMTF003.

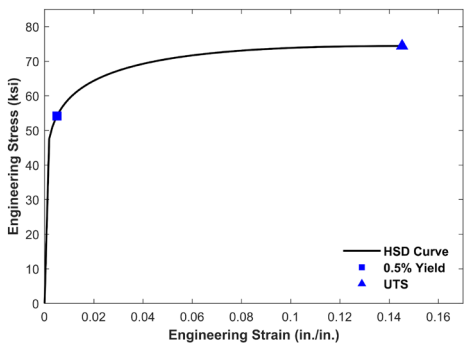
Material Strength Testing [4]

HSD Processing Ver. 2.2

HSD Stylus Hardness = (Stylus Force) / (Contact Area)



Predicted Tensile Stress-Strain Curve



Prediction Ver. H2.4-G2.04-LAB v190728-BLMc

Tensile Properties [5]

	Prediction Subsets										
	1	2	3	4	5	6	7	8	9	10	Overall
0.5% EUL Yield (ksi)	55.0	60.4	55.4	56.7	54.0	59.5	55.7	57.7	53.8	53.9	**54.2**
0.2% Offset Yield (ksi)	53.2	59.1	53.6	55.0	52.0	58.1	54.0	56.3	51.8	51.9	**52.3**
UTS (ksi)	74.5	74.6	75.0	75.2	74.5	74.0	74.8	73.9	74.3	74.3	**74.4**

[4] Material strength testing is performed at multiple locations on the pipe. Final predictions incorporate HSD results, chemical composition, and grain size.

[5] Each prediction subset considers 3 or more HSD measurements based on 10 equal-length groupings along the length of the test. Subsets where predictions are not provided did not meet MMT quality standards. The overall prediction considers the average hardness measurements for the entire test length.

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Material Verification - Base Metal Test Report

Testing Information

Customer	Energy Company	Job ID	MMT22000	Report No.	220412104011	**REV --**
Site Location	123 Pipe St			Test Date	4/12/2022	
	Pipe Town, MA 01760			Test Time	10:40	
GPS Coordinates	12.345678, -87.654321	Dig ID	Dig 1	Technician Initials	JN & DV	
Sample ID	Sample A-Q2	Pipe Size	16 OD x 0.250 WT (in)			
Test Name	Sample A-Q2_BM-02_8000-EB8000_220412104011					
Sample Description	In-Service Pipe Joint - Records indicate that the year of manufacturing is			HSD Serial No.	8000-EB8000	
	1961. The expected API 5L grade is X46.			Calibration Standard	21-AB-10	
Testing Location	10-16" away from the upstream edge of coating at clock position			Calibration Status	**PASS**	
	08:00-10:00.					

Chemical Composition and Grain Size [1]

Base Metal Chemical Composition (wt. %) [2]														Grain Size [3]
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.24	0.78	0.008	0.022	0.03	< 0.01	0.02	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005	14.0

Carbon Equivalent (wt. %)

CE_{PCM} 0.29 $\quad CE_{PCM} = C + \frac{Si}{30} + \frac{Mn+Cu+Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$

CE_{IIW} 0.38 $\quad CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$

[1] Chemical composition and grain size are reported as one set per sample. Results are incorporated into final prediction for individual HSD tests.

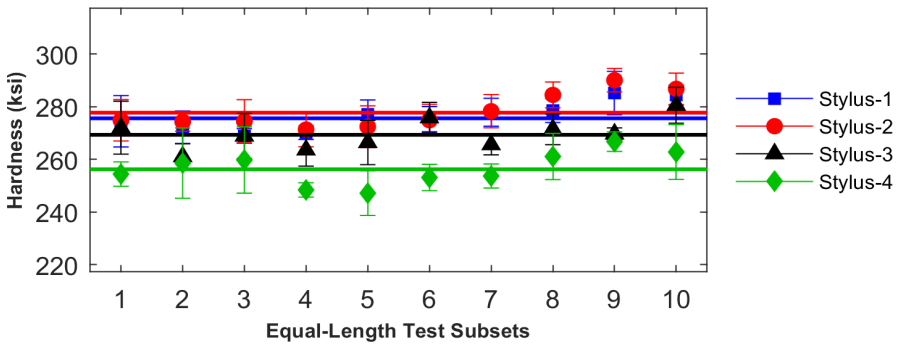
[2] Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface in accordance with MMTF005.

[3] Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy in accordance with MMTF003.

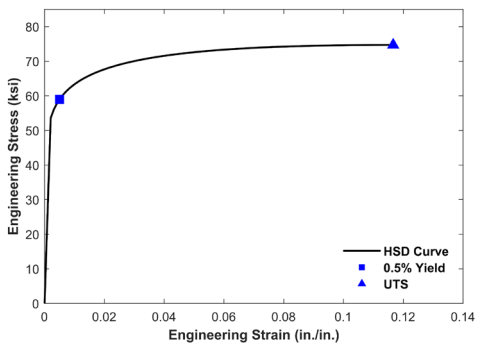
Material Strength Testing [4]

HSD Processing Ver. 2.2

HSD Stylus Hardness = (Stylus Force) / (Contact Area)



Predicted Tensile Stress-Strain Curve



Prediction Ver. H2.4-G2.04-LAB v190728-BLMc

Tensile Properties [5]

	Prediction Subsets										
	1	2	3	4	5	6	7	8	9	10	Overall
0.5% EUL Yield (ksi)	59.0	54.3	58.9	59.5	57.4	55.9	59.1	57.5	60.2	59.9	**59.0**
0.2% Offset Yield (ksi)	57.6	52.4	57.5	58.3	55.9	54.1	57.7	55.9	59.0	58.5	**57.6**
UTS (ksi)	74.6	74.7	74.0	74.0	73.5	74.5	74.7	74.7	75.3	76.0	**74.7**

[4] Material strength testing is performed at multiple locations on the pipe. Final predictions incorporate HSD results, chemical composition, and grain size.

[5] Each prediction subset considers 3 or more HSD measurements based on 10 equal-length groupings along the length of the test. Subsets where predictions are not provided did not meet MMT quality standards. The overall prediction considers the average hardness measurements for the entire test length.

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Material Verification - Welded Seam Report

Testing Information

Customer	Energy Company	Job ID	MMT22000	Report No.	220412103449	**REV --**
Site Location	123 Pipe St			Test Date	4/12/2022	
	Pipe Town, MA 01760			Test Time	10:34	
GPS Coordinates	12.345678, -87.654321	Dig ID	Dig 1	Technician Initials	JN & DV	
Sample ID	Sample A	Pipe Size	16 OD x 0.250 WT (in)			
Test Name	Sample A-Q1_WD-01_8000-EB8000_220412103449					
Sample Description	In-Service Pipe Joint - Records indicate that the year of manufacturing is 1961.			HSD Serial No.	8000-EB8000	
	The expected API 5L grade is X46.			Calibration Standard	21-AB-10	
Testing Location	40-46" away from the upstream edge of coating at clock position 01:00-03:00.			Calibration Status	**PASS**	

Measurements

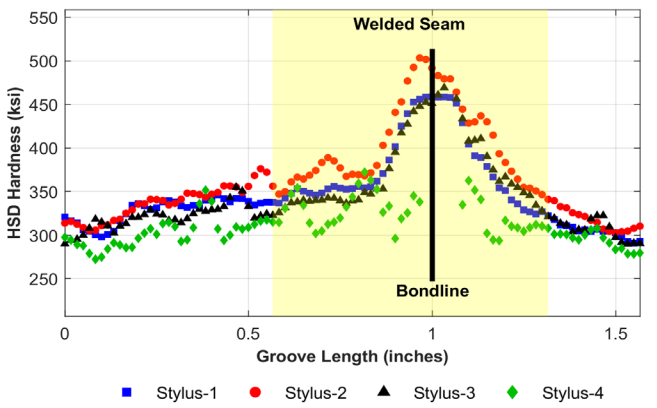
Post-Processing Version: 2.2

HSD Hardness = (Stylus force)/(Contact area) with units of pressure

	Base Metal Average (ksi)	Weld Zone Average (ksi)	Weld Bondline (ksi)	ΔHs Average (%)
Stylus-1	314	379	457	20.6
Stylus-2	319	406	490	27.4
Stylus-3	310	376	454	21.3
Stylus-4	292	327	339	11.7

Weld Bondline: Hardness at the bondline for seam toughness determination is evaluated over a 0.10 inch length of the HSD weld test, centered on the bondline.

ΔHs Average: (Base Metal Average - Weld Zone Average) / Base Metal Average



Results

Macroetch Weld Width:	0.24	inches	**Normalized Macroetch Weld Width:**	96	% of pipe wall thickness

Seam Type Determination

	Submerged Arc Welded (SAW)	X	**ERW [classified seam type or probability below]**
	Flash	98	**Low Frequency ERW (LF-ERW)**
	Lap-Welded	0	**High Frequency no PWHT ERW (HF no PWHT-ERW)**
	See Comments	2	**High Frequency PWHT ERW (HF PWHT-ERW)**

Classification Model Version: v200406-cBayes

ERW seam classification determined with a classification model trained to a database of over 75 ERW pipes.

Seam type determination is based on the comparison of sample measurements to a database of ERW samples that were verified through a laboratory examination of the etched weld cross-section. Unknown samples are assumed to exhibit characteristics that are similar to the known samples in this ERW dataset. The seam type determination is subject to the quality of the images and data collected, as well as the interpretation by the MMT reporting group.

Comments

Prepared: John Smith — John Smith

Approved: Jane Johnson — Jane Johnson

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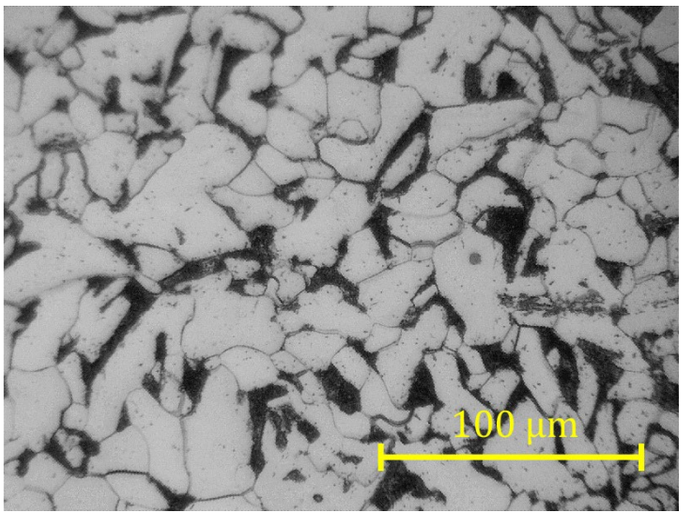
Grain Structure Report

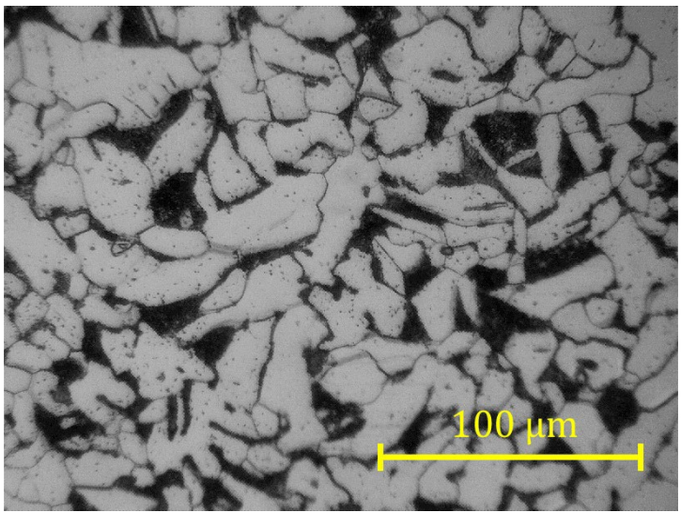
Testing Information

Customer	Energy Company	Job ID	MMT22000	Test Date	4/12/2022
Test Location	123 Pipe St			Operator Initials	JN & DV
	Pipe Town, MA 01760			Surface Finish	1µm Diamond Paste
GPS Coordinates	12.345678, -87.654321	Dig ID	Dig 1	Etchant	2% Nital
Sample ID	Sample A	Pipe Size	16 OD x 0.250 WT (in)		

Measurements

Magnification 500X





Comments

Average mean-linear-intercept grain size measured from 5 different images of the etched steel microstructure is 14.0 ± 0.3 µm.

Prepared: John Smith John Smith **Approved:** Jane Johnson Jane Johnson