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10 February 2021

Customer: Gas Technology Institute

Project ID: MMT Project GTI19006

Subject: Final report for nondestructive HSD Testing for 70 cutout samples located at GTI facilities in Des Plaines, IL during May 2019.

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Reviewed by: Steven Palkovic, PhD

Acknowledgement: MMT wishes to acknowledge the sponsorship of this program by PHMSA and OTD.

This report is a revision of an initial draft submission dated 1 August 2019 which includes updated nondestructive tensile strength estimates for several samples that GTI indicated are seamless pipe joints. Seam types for Electric Resistance Welded (ERW) samples have also been revised using updated ERW seam type classification models.

1. Project Summary

This document summarizes results from testing with the Hardness, Strength, and Ductility (HSD) Tester. The HSD is a portable instrument that measures the mechanical properties of metals through a frictional sliding test that deforms a shallow layer of surface material. The depth of deformation is less than 0.002 inches (50 μm) deep which is considered nondestructive for testing on transmission pipelines. This test program was conducted at the Gas Technology Institute facility at 1700 S. Mt. Prospect Rd, Des Plaines, IL 60018 during the month of May 2019. Massachusetts Materials Technologies (MMT) performed blind testing on 70 pipe samples at the facility. Overview images of the samples tested are provided in Appendix A.

2. Test Procedures

One base metal region around the circumference of each pipe joint was prepped for nondestructive evaluation (NDE) of the material yield and ultimate tensile strength. For a selected 25 electric-resistance-welded (ERW) pipes, an additional region centered on the weld was prepped to classify the seam as low frequency (LF-ERW), high frequency (HF-ERW), or high frequency normalized (HFN-ERW). The following details the work that was completed for each joint in accordance with MMT standard test procedures [1], and with an HSD unit that was calibrated daily prior to testing.

2.1 HSD Base Metal Tests

HSD base metal testing is performed on the outer surface of a pipe joint. A suitable test region is prepped to a 2000 grit finish which removes the presence of any decarburized material and eliminates potential surface defects or imperfections. The HSD Tester is then mounted to the pipe and performs a test circumferentially around the outer diameter. From each sample, two or more 1.3-inch long base metal tests are performed, generating over 200 measurements of the material response. These measurements are used to predict the 0.5% total elongation under load (EUL) yield strength and ultimate tensile strength (UTS) of the surface material tested using the methodology described in Section 3.1.

2.2 Base Metal Metallography

Surface imaging of the steel microstructure is performed in the same location of HSD base metal testing. A diamond paste and felt bobbin are used to further polish a region on the pipe surface, and then a 2% Nital solution is applied with a cotton swab to etch the material until a chemical reaction is observed. The etched microstructure is imaged using a portable microscope and camera with a 50x magnification lens. These images are then processed with an in-house software to segment grain boundaries and determine the average grain size using the mean-linear-intercept (mli) method [2]. A raw and segmented image for a steel material is shown in Fig. 1.

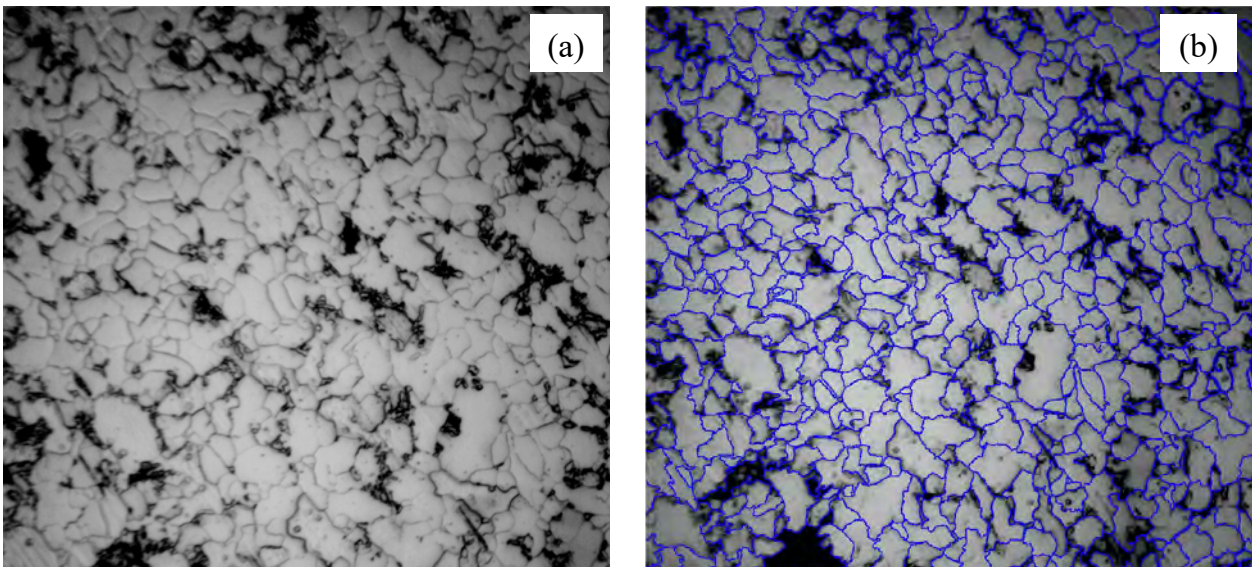

Fig. 1: **(a)** Imaged etched steel microstructure and **(b)** the segmented grain boundaries used to determine the average mean-linear-intercept grain size.

2.3 Base Metal Chemical Composition

Chemical composition is measured through independent laboratory testing of burrs removed from the pipe surface. Burrs are collected using a die grinder at a location on the pipe surface that has

been prepped to a 120-grit finish and is near the HSD base metal testing location. 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].

2.4 Welded Seam Etched HAZ Width

The HAZ surrounding a longitudinal ERW seam can be visually assessed by performing a macro-etch of the weld on the outer surface of the pipe joint. The test location is prepped to a 2000 grit finish and a 5% Nital solution is applied with a cotton swab to etch the material until a chemical reaction is observed. After etching, an apparent HAZ and bondline will be visible as discolored regions on the pipe surface. If additional contrast is required, Fry's Reagent may be applied to act as a stain that further defines features of the welded seam. The etched weld region and a reference scale is photographed so that the width of the apparent etched HAZ width (L_{HAZ}) can be determined. Representative images of LF, HF, and HFN-ERW seams are provided in Fig. 2 along with the measured L_{HAZ}.

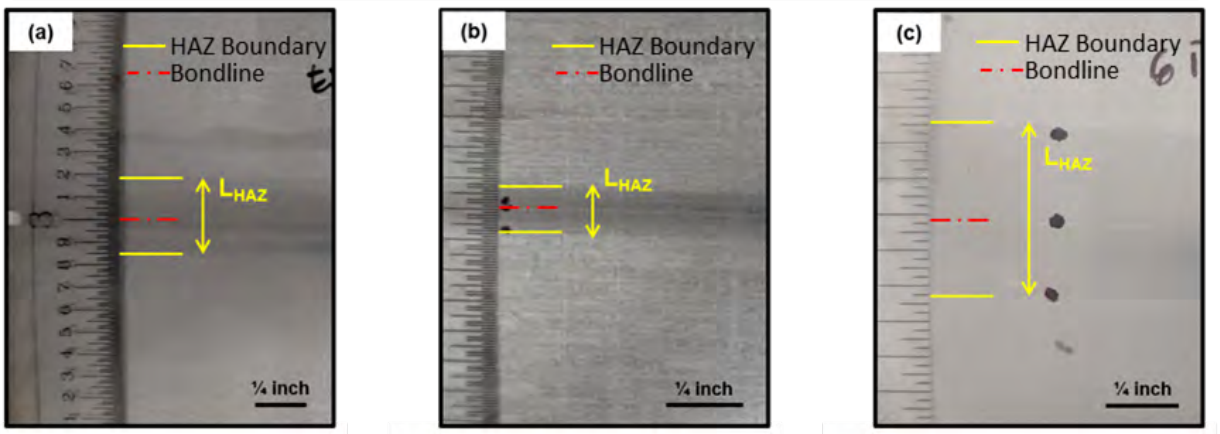

Fig. 2: Representative etched welded seams for **(a)** LF-ERW, **(b)** HF-ERW, and **(c)** HFN-ERW.

2.5 HSD Welded Seam Tests

The HSD can measure variations in hardness along the length of a test to characterize welding processes and assess the effectiveness of post-weld-heat-treatments. For HSD welded seam tests, a region centered on the weld is prepped to a 2000 grit finish. The HSD is then positioned to conduct a test that starts in the base metal and travels circumferentially across the entire weld and then back to the base material on the other side of the seam. Representative hardness profiles collected across different types of ERW pipe joints are shown in Fig. 3.

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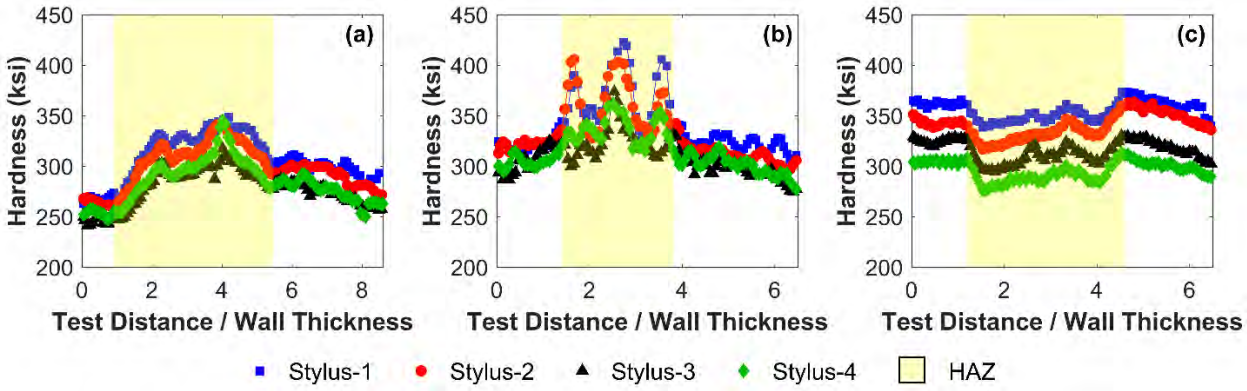

Fig. 3: Hardness measured along the length of HSD weld tests performed on **(a)** LF-ERW, **(b)** HF-ERW, and **(c)** HFN-ERW pipe joints. The heat-affected-zones (HAZ) are shown by the shaded region.

3. Analysis Methods

3.1 Fundamentals of the HSD Tester

HSD testing is a portable implementation of the contact mechanics technique known as frictional sliding. During a frictional sliding test, a stylus indents a sample surface under a known load and then slides along the surface to generate a permanent groove, as shown schematically in Fig. 4. During a test, the normal force (P) and the width of the groove (a) are measured. The force and groove width are used to calculate the frictional sliding hardness with units of pressure given by,

$$\mathrm{H} = \frac{8\mathrm{P}}{\pi a^2} \qquad (1)$$

where the projected contact area resisting the applied normal force is a semi-circle. The magnitude of deformation applied during the test is related to the attack angle (ϕ) that describes the relative angle between the stylus and the undeformed surface. For a spherical stylus, the attack angle varies based on the stylus radius (R), depth of penetration, and height of material pile-up around the stylus. The attack angle can be calculated from the measured groove width and the known stylus radius with,

$$\phi = \frac{\pi}{2} - \cos^{-1}\left(\frac{a}{2R}\right). \qquad (2)$$

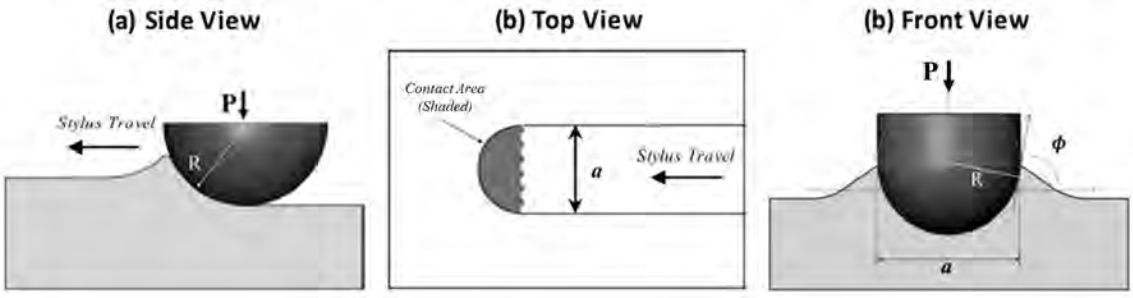

Fig. 4: Schematic views of a spherical stylus engaging with a substrate under load to create a shallow groove as it travels along the surface.

The measured hardness and attack angle are used to calculate a representative stress σ_r and representative strain ε_r. This relationship was established through finite element analysis of the frictional sliding response for a wide range of power-law hardening materials that are typical of engineering metals. The correlation between frictional sliding and tensile testing was first defined by Bellemare et al. for a conical stylus [4-6]. A similar approach was used to extend this analysis to spherical styluses, and the resulting functions are proprietary to MMT. HSD testing applies this concept by incorporating 4 styluses with different geometries to measure the material response at different locations along the uniaxial stress-strain curve. A complete uniaxial true stress (σ_t) versus true strain (ε_t) curve can then be obtained by performing a least-squares regression to the independent stylus measurements using Hollomon's equation [7],

$$\sigma_t = K\varepsilon_t^n \qquad (3)$$

The true stress-strain curve can be converted to engineering units to obtain the 0.5% total elongation under load (EUL) yield strength and ultimate tensile strength (UTS). A representative stress-strain curve for a steel material is shown in Fig. 5.

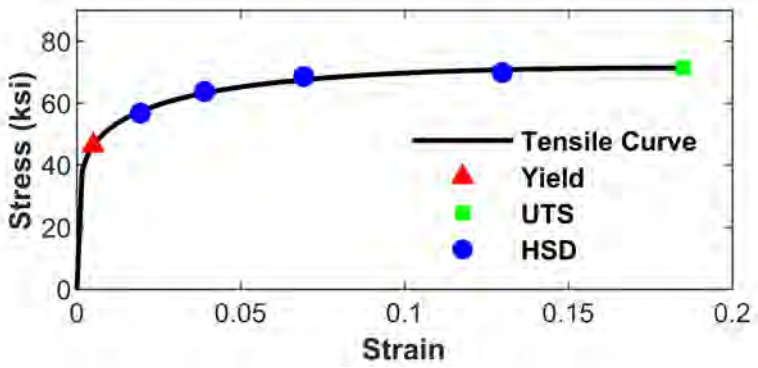

Fig. 5: Engineering stress-strain curve obtained from a power-law fit to 4 stylus measurements collected with the HSD. The predicted tensile yield and UTS are also shown.

3.2 Combined Prediction of Pipe Strength Properties

The HSD provides a direct measurement of mechanical properties for the surface material that is deformed during a frictional sliding test. This will generally differ from the traditional metrics of pipeline strength that are typically based on full-wall thickness laboratory tensile coupons. These differences are illustrated in Fig. 6, which shows the yield strength distribution through the pipe wall thickness that was calculated with a finite element analysis model of different stages of manufacturing for a cold formed seam-welded pipe joint. Based on a series of tests, including those performed through PRCI NDE 4-4, the higher curve on the plot labelled "1% Radial Expansion" is a typical surface to mid-wall variation for vintage transmission pipelines. For vintage ERW pipes, radial compression through rolling is more common to control the outside diameter but is leading to the same trend [8]. These results indicate that the HSD surface measurement will generally be higher than a full-wall thickness tensile coupon because of the additional strain hardening that the outer surface material experiences during fabrication.

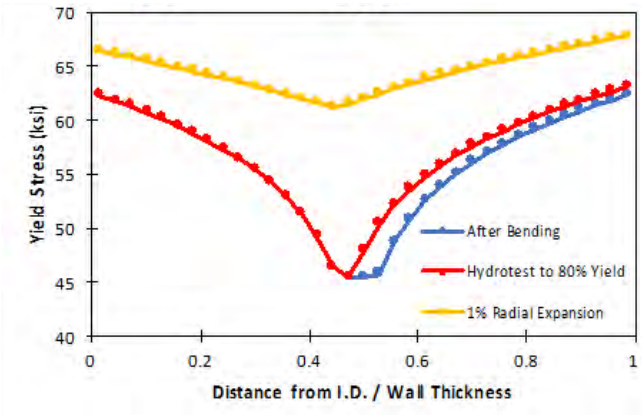

Fig. 6: Calculated yield strength distributions through the pipe wall at different stages of manufacturing.

To account for differences in strength properties of HSD surface tests and full-wall thickness tensile coupons, additional NDE characteristics are considered. The HSD surface strength is combined with information of the pipe seam type, surface microstructure grain size, and surface chemical composition. For this program, three different models are used to combine these inputs and assess their predictive performance on the 70 blind pipe samples. These models include a multiple linear regression (MLR), Bayesian linear regression (BLR), and an Artificial Neural Network (ANN). All of the models have been trained to a database of 167 unique pipe joints that include seamless, flash-welded, ERW, and submerged-arc-welded construction covering a wide range of pipe vintages and steel grades. The mechanical properties for this database include 0.5% EUL yield strengths spanning from 29 to 80 ksi (200 to 550 MPa), UTS measurements ranging from 50 to 104 ksi (340 to 720 MPa), and yield / UTS ratios ranging from 0.56 to 0.96. MMT has previously implemented an MLR model that was trained to a smaller database of pipe samples, most notably on a recent blind testing program performed on 50 blind samples that was hosted by the Pipeline Research Council International (PRCI) [9]. The tensile properties reported herein are for transverse or longitudinal strap specimens based on the requirements of API 5L for the given pipe geometry and seam type [10].

3.3 Weld Classification

MMT has developed a methodology for classifying ERW pipe joints as low frequency (LF-ERW), high frequency (HF-ERW), or high frequency normalized (HFN-ERW). The weld classification is based on the measured welded seam etched HAZ width (L_{HAZ}) and analysis of the hardness variation between the base metal and the weld from HSD weld tests. These measurements are used to calculate the normalized etched HAZ width L_{HAZ}/t, where t is the pipe wall thickness, and the normalized HSD hardness change, $\Delta H = (H_{WD} - H_{BM})/H_{bm}$, where H_{WD} is the average hardness of the HAZ surrounding the seam and H_{BM} is the average hardness of the surrounding base metal that are obtained from HSD weld tests (see Fig. 3). This approach has been applied to a welded seam database of ERW pipe samples where the welding process was confirmed through a destructive visual examining of the etched pipe wall cross-section containing the seam. Since the production of the initial draft of this report, MMT has expanded its ERW pipe database for seam determination to 87 unique pipe joints obtained outside of this program. Fig. 7 shows

the updated decision boundaries that have been determined through multiple classification models applied to the database. For this program, the Support Vector Machine (SVM) model was applied because of the strong classification performance, the intuitive shapes of the decision boundaries, and the ability to obtain an estimate of the likelihood of a new measurement belonging to each weld class.

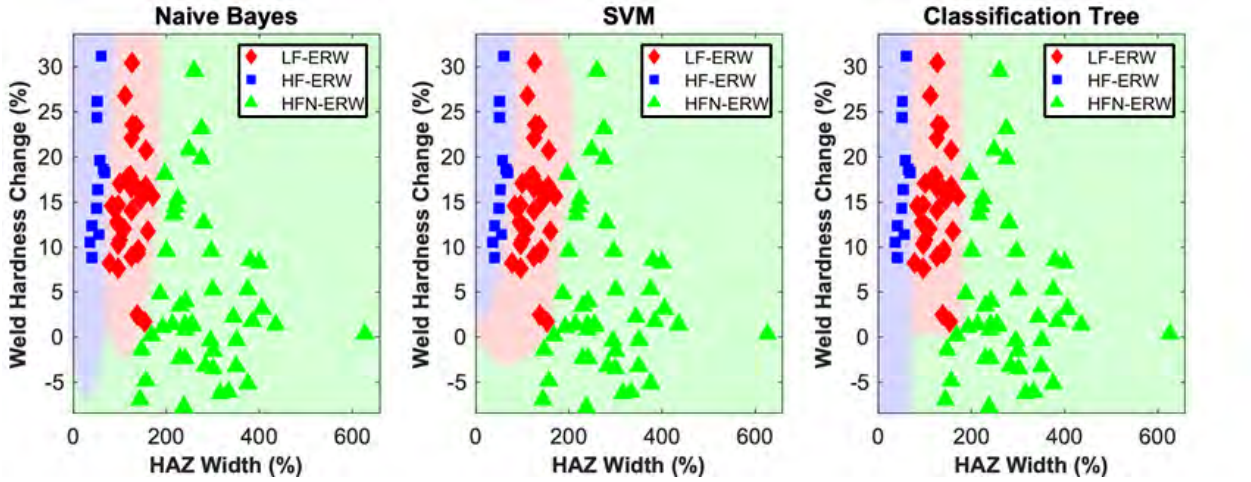

Fig. 7: Seam classification models generated from MMT database of 87 unique ERW pipe samples. Blue indicates HF-ERW, red indicates LF-ERW, and green indicates HFN-ERW.

4. Results

The nondestructive measurements collected of the HSD surface yield and ultimate tensile strength, mean linear intercept average grain size, and chemical composition are provided in an attached summary database. This database also includes the predicted full-wall thickness tensile coupon measurements using the MLR, BLR, and ANN combined regression models. The average and standard deviations of strength predictions are based on the consideration of subsets that are used to bin data and assess variation for a given test and sample. These subsets are shown in the attached individual base metal reports, which include the predictions from the BLR model along with a summary of the nondestructive measurements collected on that sample.

The seam type for the 25 ERW samples that were selected for welded seam classification are highlighted in the attached summary database, and specified as LF, HF, or HFN-ERW as determined with the SVM classification algorithm. Measurements of the etched HAZ width are shown in the attached figures in Appendix B and are included in the individual HSD welded seam reports that indicate the normalized weld hardness variations and the predicted ERW seam type based on the SVM classification algorithm. A comparison of the different classification model predictions for the ERW seam types is provided in Fig. 8. These results show that all of the models are in agreement for the samples selected. For sample 107, the apparent HAZ could not be identified due to the quality of the seam etch and image. MMT measurements indicated a yield strength of 33.8 ksi for this sample. According to the manufacturing trend of pipeline steel, low strength pipes, such as this sample, are attributed to vintages of pre 1940s [11], which was before the advent of HF technology and when LF was the only welding process available for ERW seams.

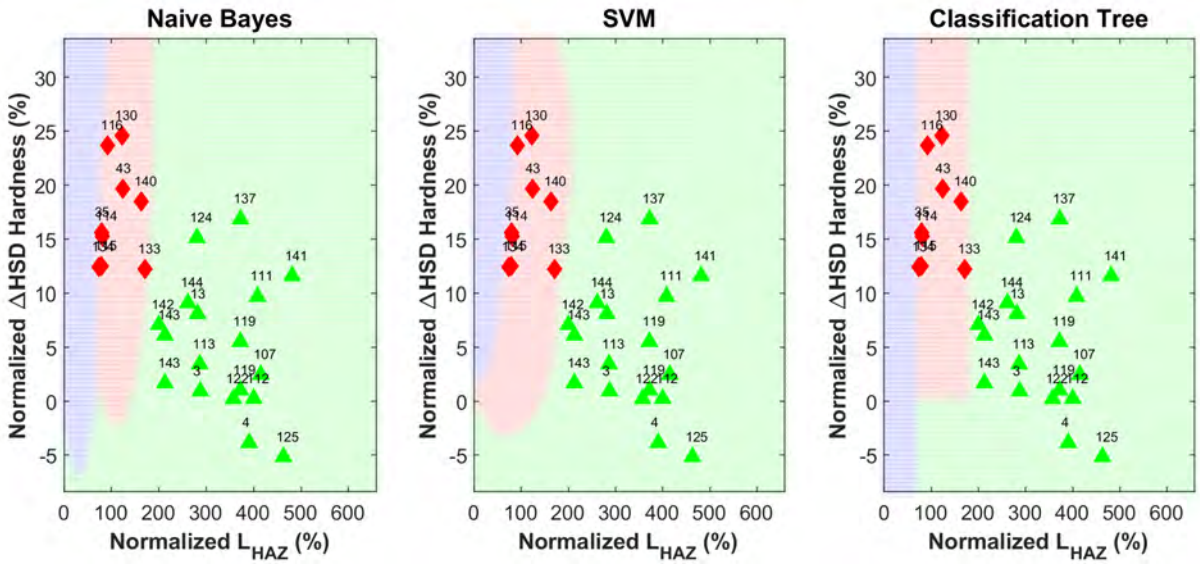

Fig. 8: Seam classification from three different classification models for 25 GTI ERW pipe joints. Blue indicates HF-ERW, red indicates LF-ERW, and green indicates HFN-ERW. The sample number is indicated near the point.

5. Concluding Remarks

This blind testing program provided an additional opportunity to further our understanding of the relationship between nondestructive measurements and traditional laboratory benchmarks of tensile properties for oil and gas transmission pipelines and to compare the effects of different ERW manufacturing processes on the surface characteristics of pipes. The data driven regression and classification models provided here will continue to become more robust and refined as new nondestructive and laboratory validated data is added to the predictive models. Once the laboratory test results of this program are provided to MMT, the additional data will be incorporated into the current predictive model to improve accuracy and confidence. With the added data, MMT's predictive database will build to 237 pipes for base metal strength predictions and 112 pipes for ERW seam classification. This overall effort will continue to support the viability of NDE methods for performing accurate and reliable material verification of in-service pipeline materials.

References Cited

1. MMT field procedures will be provided, if requested
2. ASTM E112 Standard Test Methods for Determining Average Grain Size
3. Email correspondence with chemical testing laboratory
4. S.C. Bellemare, M. Dao and S. Suresh, “The frictional sliding response of elasto-plastic materials in contact with a conical indenter,” International Journal of Solids and Structures, 44(6), 2007.
5. S.C. Bellemare, M. Dao and S. Suresh, “Effects of mechanical properties and surface friction on elasto-plastic sliding contact,” Mechanics of Materials, 40, 2008.
6. S.C. Bellemare, M. Dao and S. Suresh, “A new method for evaluating the plastic properties of materials through instrumented frictional sliding tests,” Acta Materialia, 58, 2010.
7. J.H. Hollomon, “Tensile deformation,” Aime Trans., 1945.
8. S.C. Bellemare, “Hardness, Strength, and Ductility (HSD) Testing of Line Pipes Initial Validation Testing Phase I,” NDE 4-4 Catalog No. PR-610-163756-R01, Sep 2017
9. S.D. Palkovic, K. Taniguchi and S.C. Bellemare, “Hardness, Strength, and Ductility (HSD) Testing of Steel Pipelines for Tensile Strength Properties,” NDE 4-8 Catalog No. CWA-17-001.MMT, Nov 2018.
10. American Petroleum Institute, “API 5L Specification for Line Pipe,”
11. N. Switzner, P. Veloo, M. Rosenfeld, T. Rovella, and J. Gibbs, “An Approach to Establishing Manufacturing Process and Vintage of Line Pipe Using In-Situ Nondestructive Examination and Historical Manufacturing Data”, Proceedings of the 13th International Pipeline Conference, 2020.

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Customer: Gas Technology Institute

Project ID: MMT Project GTI19006

Subject: **Appendix A: Overview images of samples tested.**

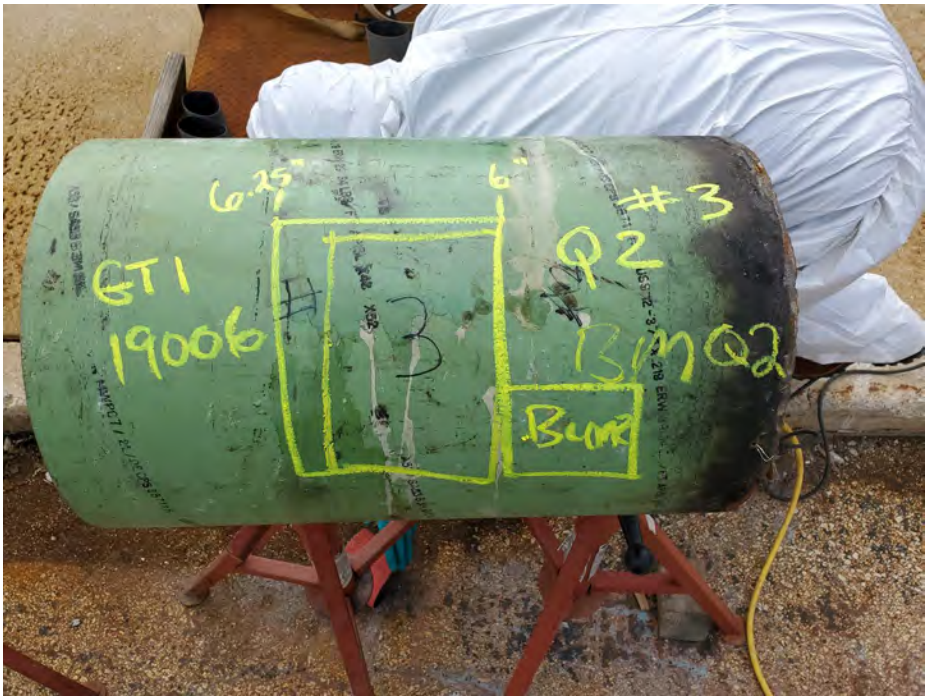

Figure 1: Test locations and overview of Sample 003.

Figure 2: Test locations and overview of Sample 004.

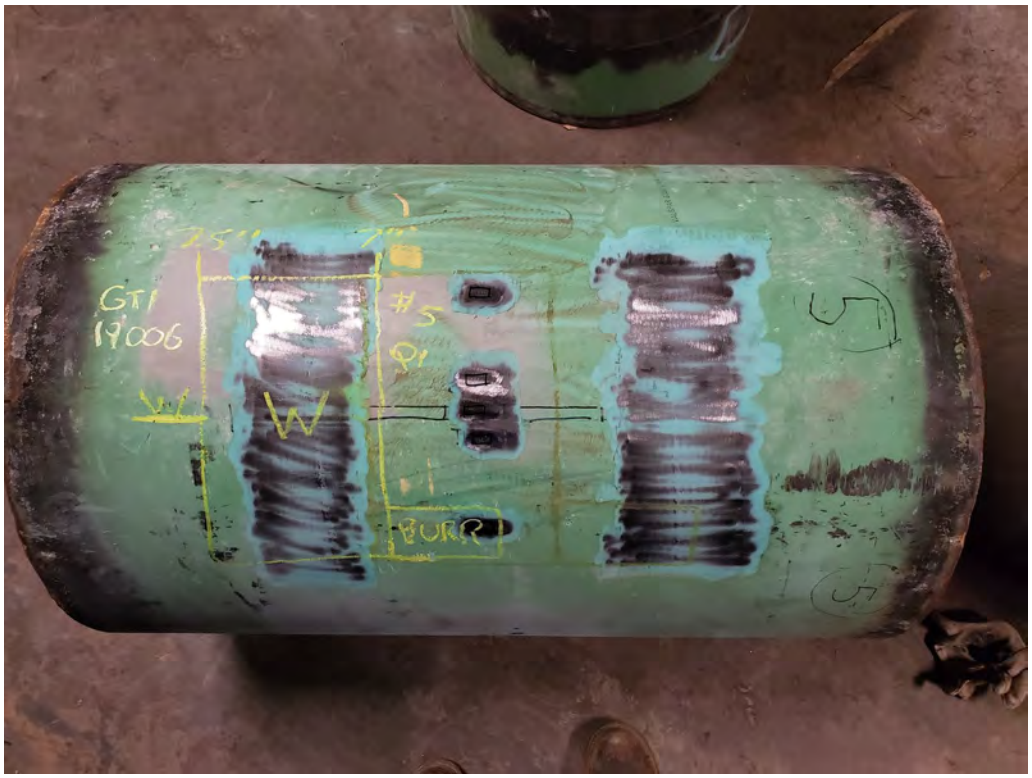

Figure 3: Test locations and overview of Sample 005.

Figure 4: Test locations and overview of Sample 006.

Figure 5: Test locations and overview of Sample 012.

Figure 6: Test locations and overview of Sample 013.

Figure 7: Test locations and overview of Sample 018.

Figure 8: Test locations and overview of Sample 019.

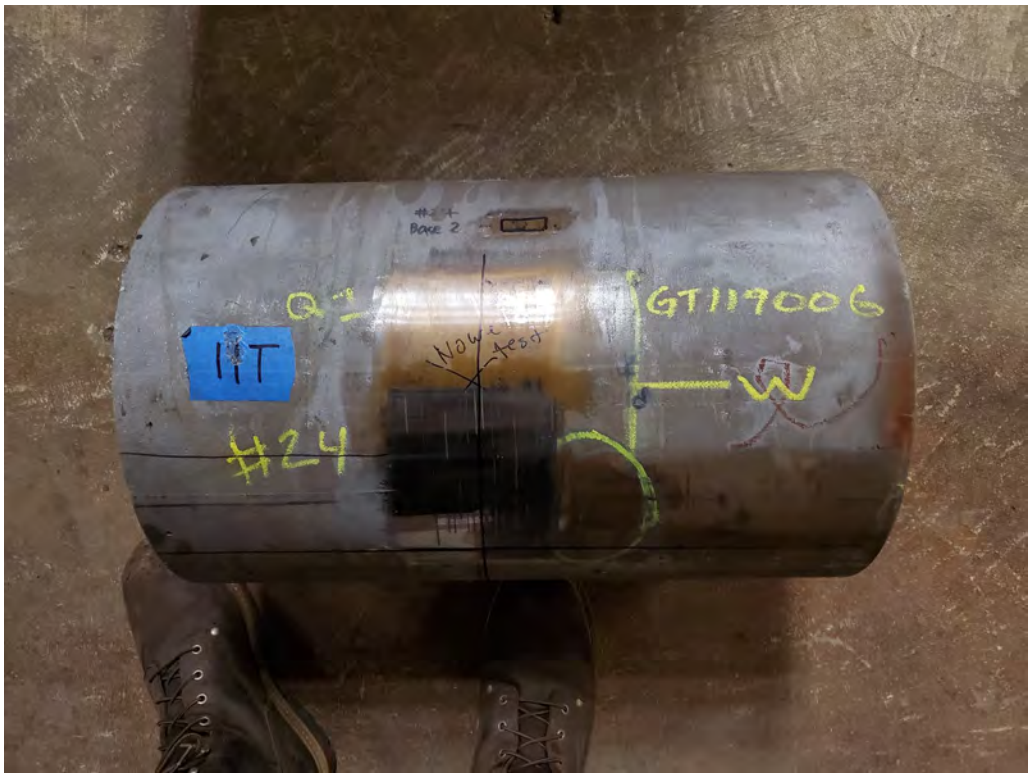

Figure 9: Test locations and overview of Sample 024.

Figure 10: Test locations and overview of Sample 025.

Figure 11: Test locations and overview of Sample 026.

Figure 12: Test locations and overview of Sample 027.

Figure 13: Test locations and overview of Sample 028.

Figure 14: Test locations and overview of Sample 029.

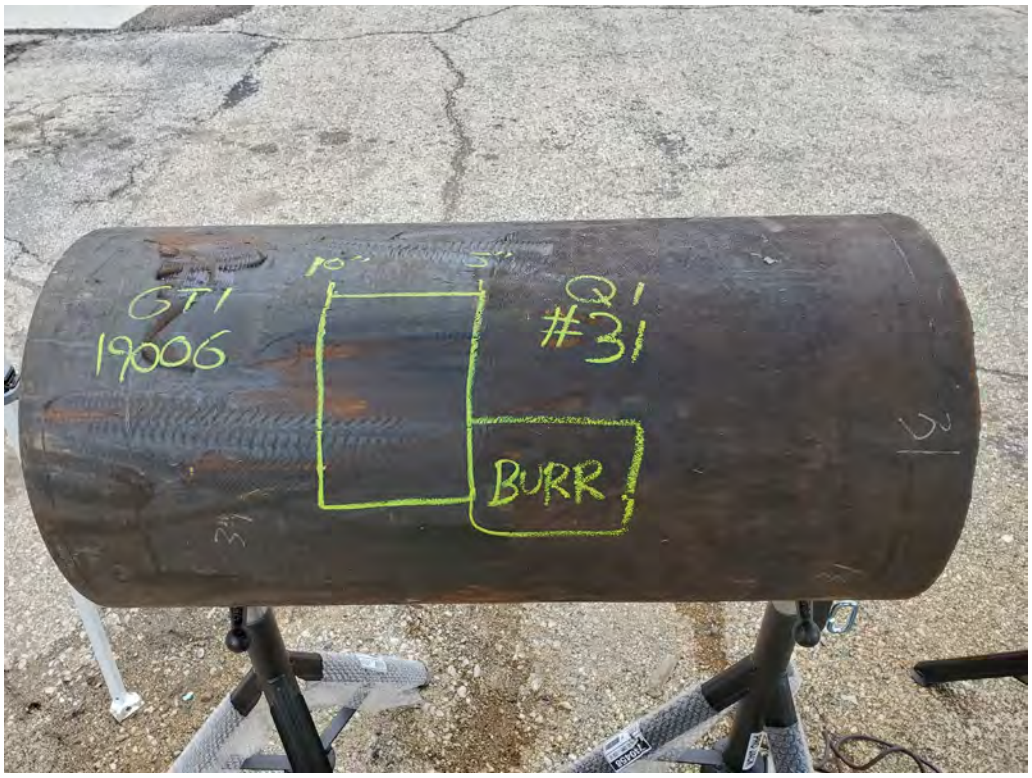

Figure 15: Test locations and overview of Sample 031.

Figure 16: Test locations and overview of Sample 032.

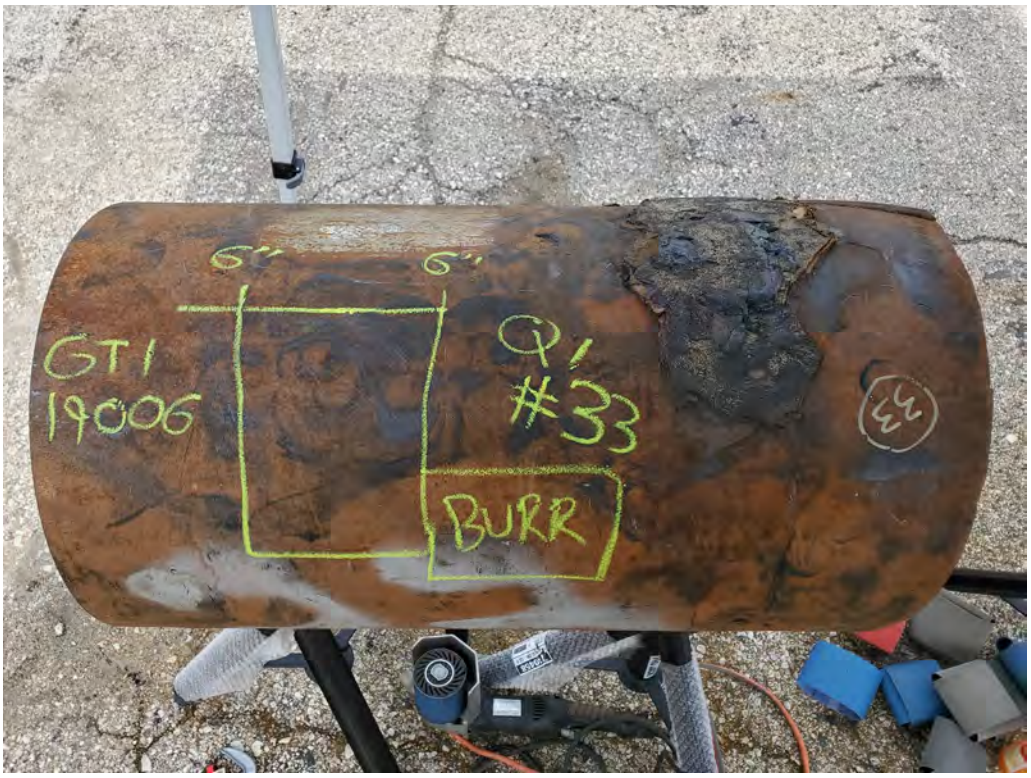

Figure 17: Test locations and overview of Sample 033.

Figure 18: Test locations and overview of Sample 034.

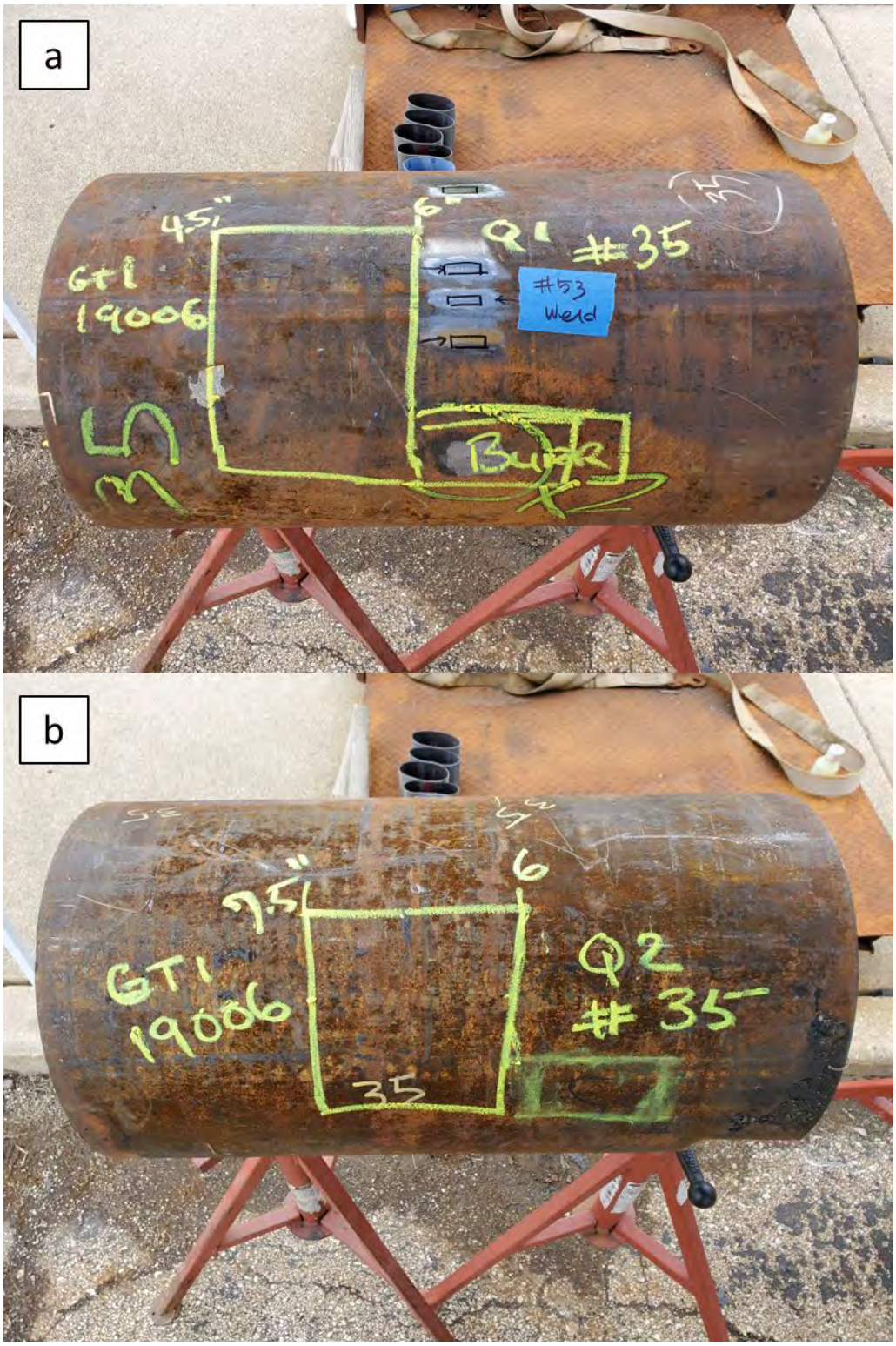

Figure 19: (a) Test location Q1 on ERW seam and overview of Sample 035; (b) Test location Q2 and overview of Sample 035.

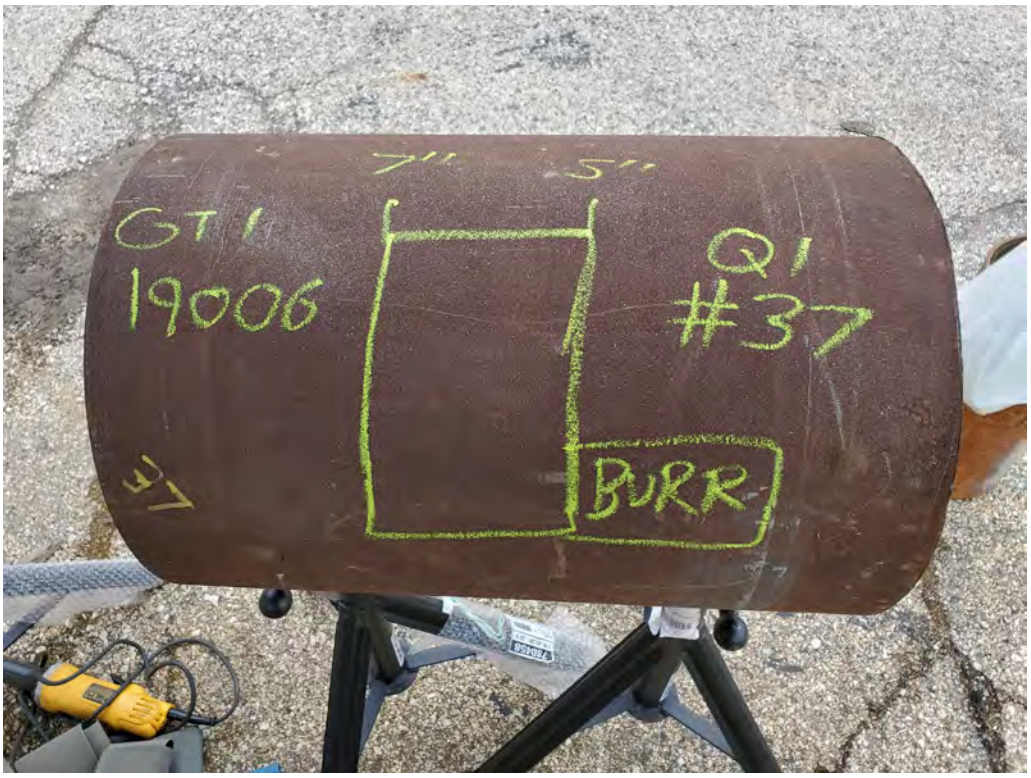

Figure 20: Test locations and overview of Sample 037.

Figure 21: Test locations and overview of Sample 040.

Figure 22: Test locations and overview of Sample 042.

Figure 23: Test locations and overview of Sample 043.

Figure 24: Test locations and overview of Sample 044.

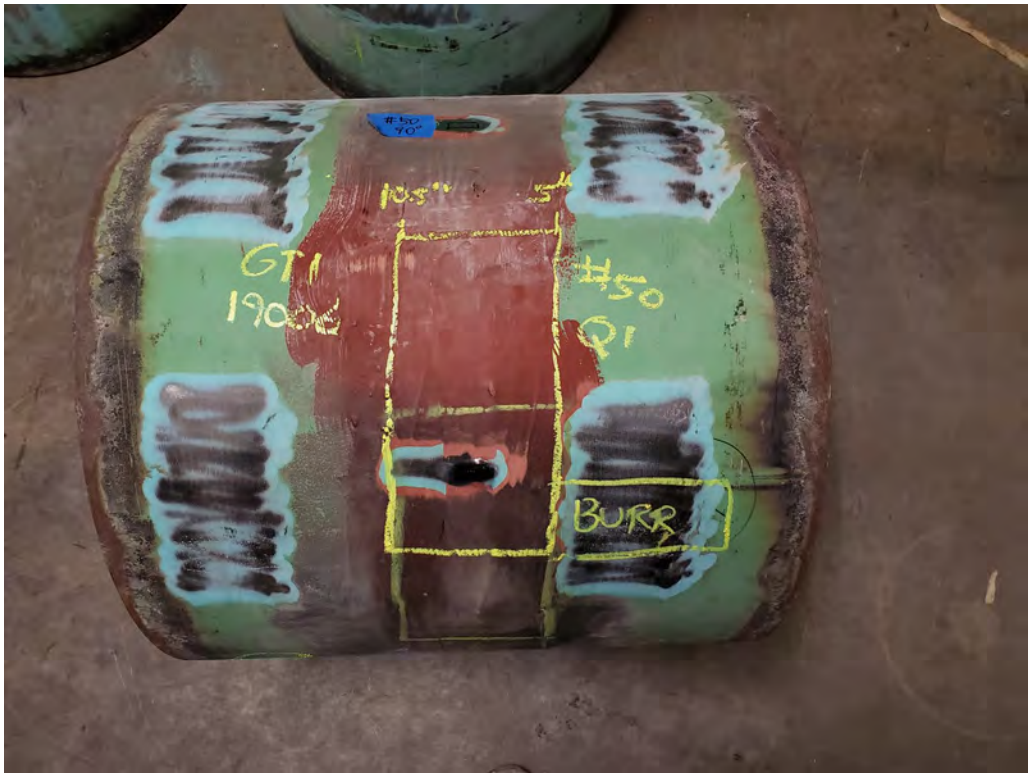

Figure 25: Test locations and overview of Sample 050.

Figure 26: Test locations and overview of Sample 107.

Figure 27: Test locations and overview of Sample 108.

Figure 28: Test locations and overview of Sample 109.

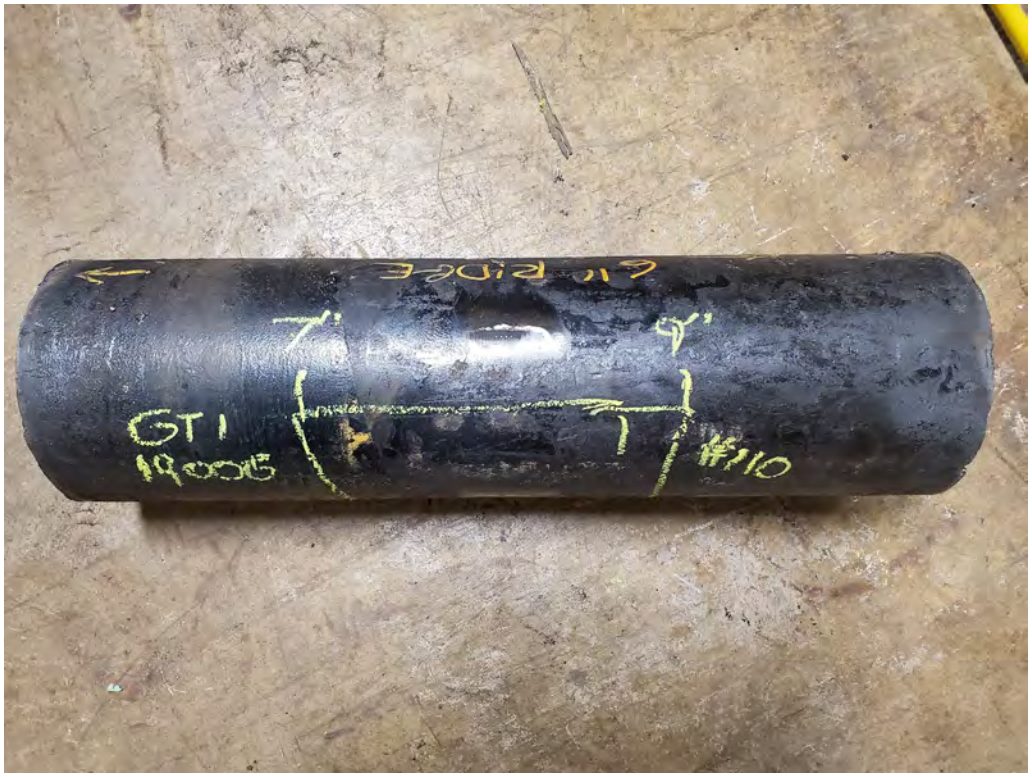

Figure 29: Test locations and overview of Sample 110.

Figure 30: Test locations and overview of Sample 111.

Figure 31: Test locations and overview of Sample 112.

Figure 32: Test locations and overview of Sample 113.

Figure 33: Test locations and overview of Sample 114.

Figure 34: Test locations and overview of Sample 115.

Figure 35: (a) Test location Q1 on ERW seam and overview of Sample 116; (b) Test location Q2 and overview of Sample 116.

Figure 36: Test locations and overview of Sample 117.

Figure 37: Test locations and overview of Sample 118.

Figure 38: Test locations and overview of Sample 119.

Figure 39: Test locations and overview of Sample 121.

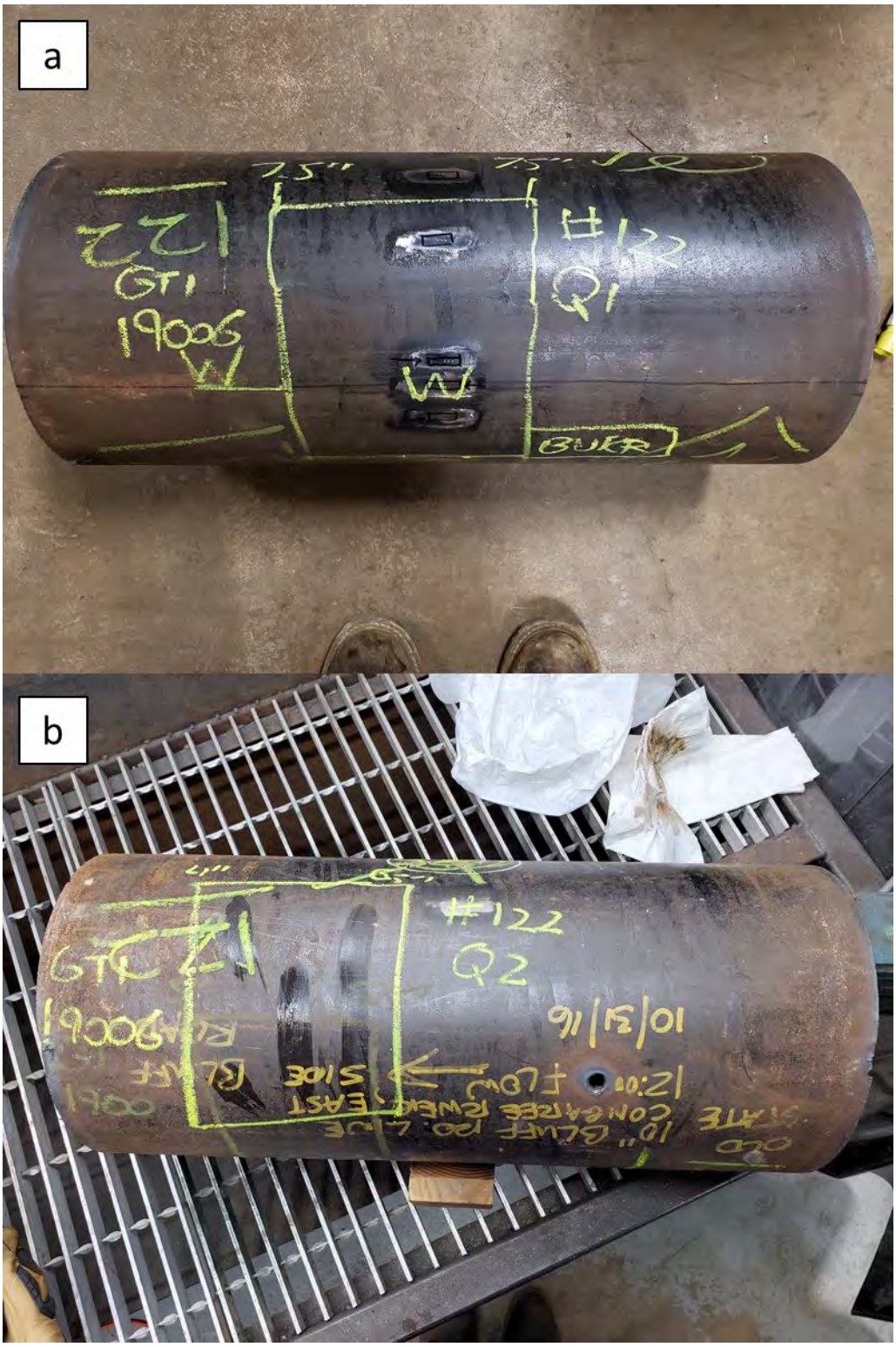

Figure 40: (a) Test location Q1 on ERW seam and overview of Sample 122; (b) Test location Q2 and overview of Sample 122.

Figure 41: Test locations and overview of Sample 123.

Figure 42: Test locations and overview of Sample 124.

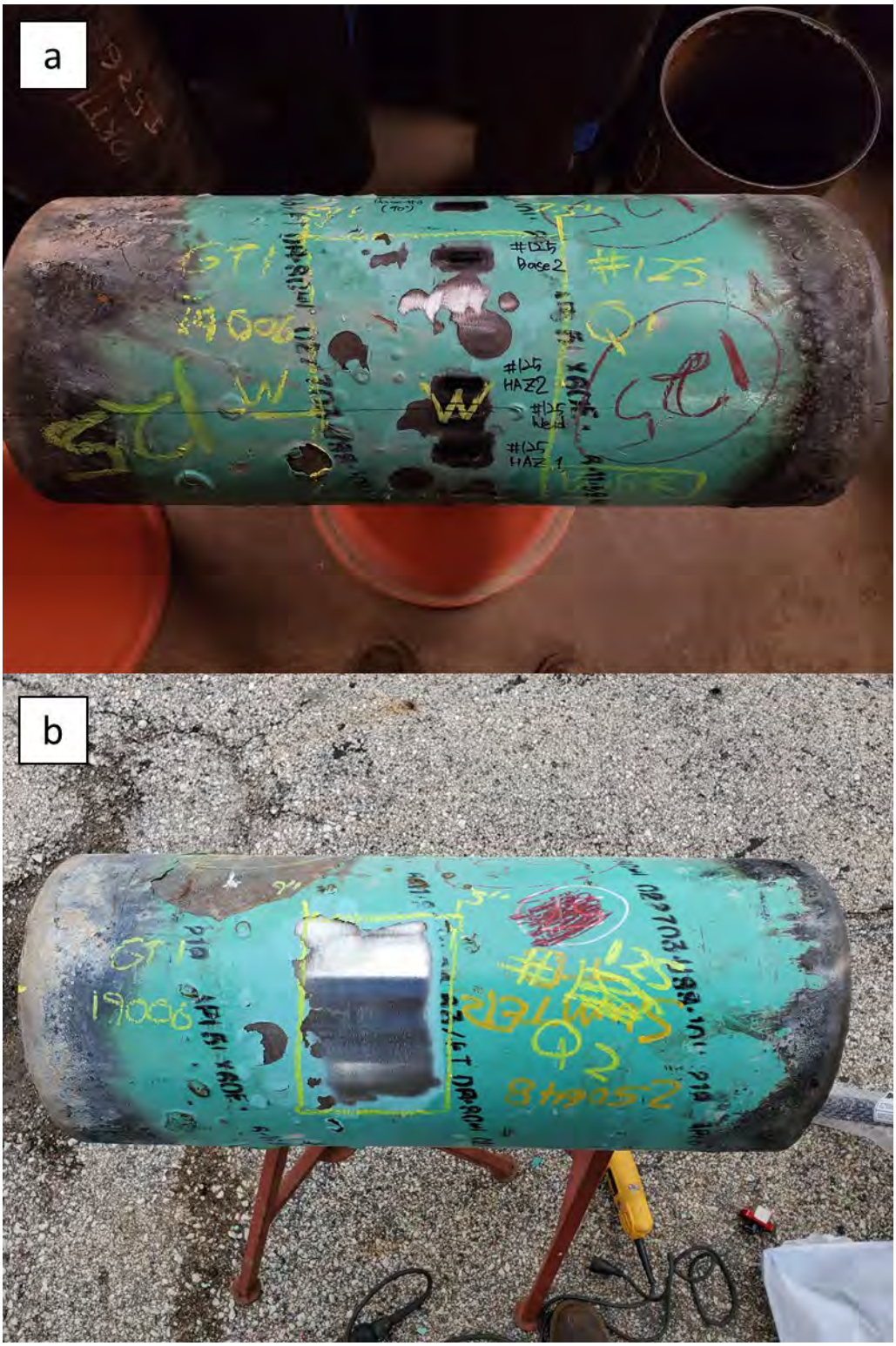

Figure 43: (a) Test location Q1 on ERW seam and overview of Sample 125; (b) Test location Q2 and overview of Sample 125.

Figure 44: Test locations and overview of Sample 126.

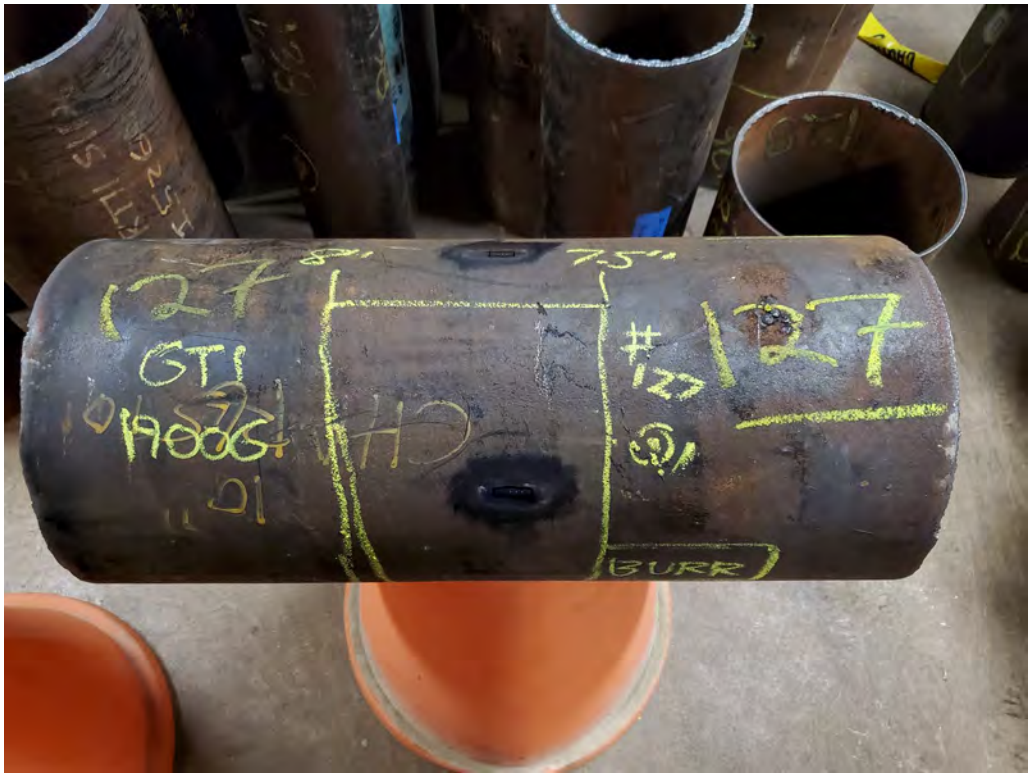

Figure 45: Test locations and overview of Sample 127.

Figure 46: Test locations and overview of Sample 130.

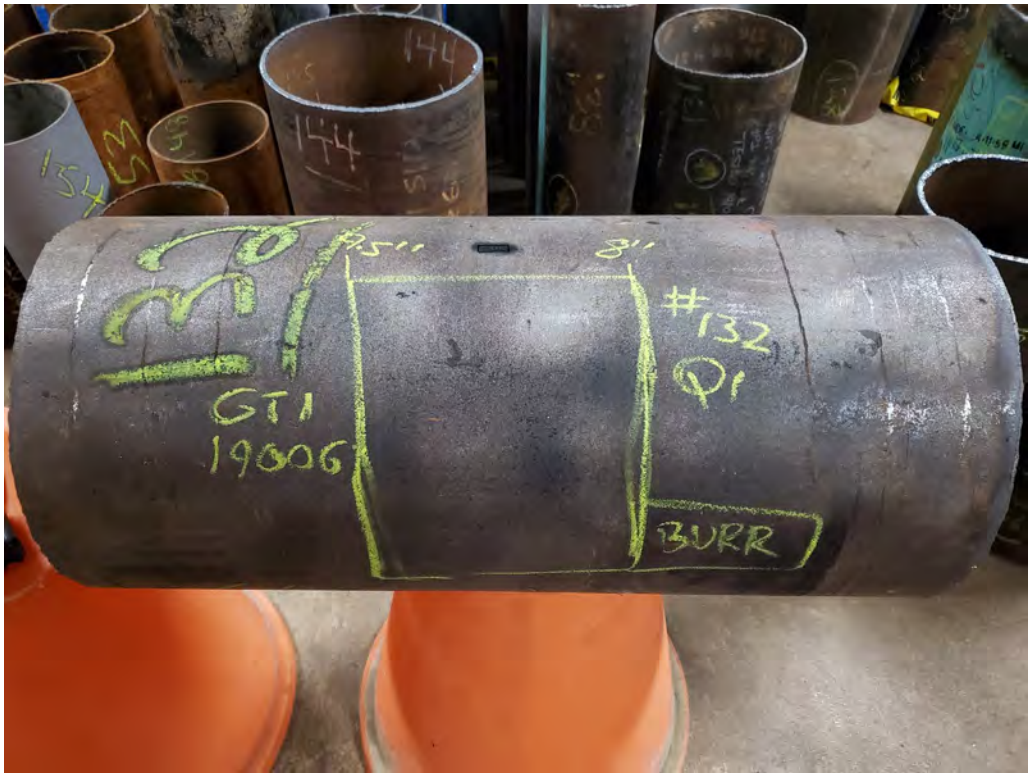

Figure 47: Test locations and overview of Sample 132.

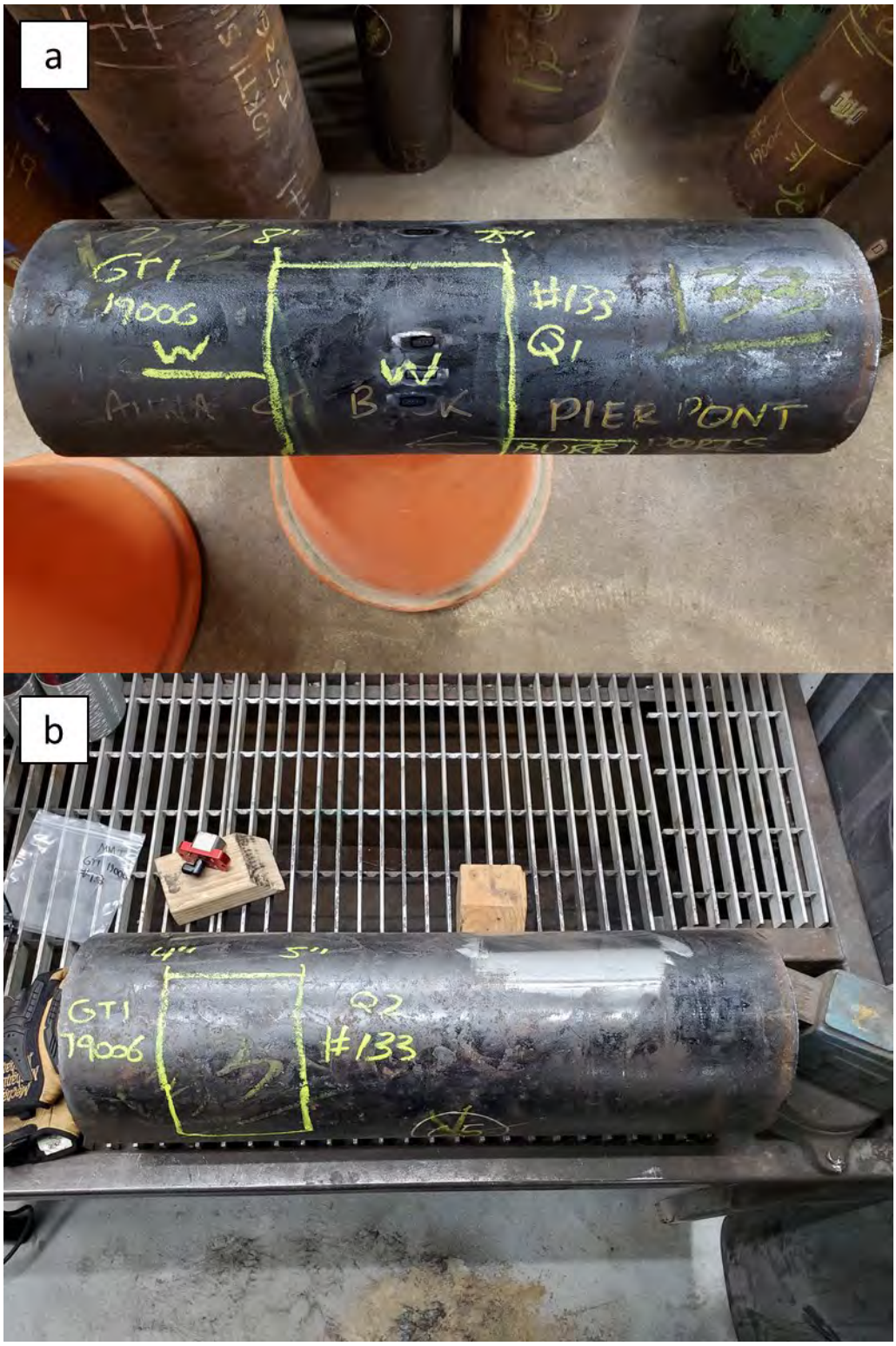

Figure 48: (a) Test location Q1 on ERW seam and overview of Sample 133; (b) Test location Q2 and overview of Sample 133.

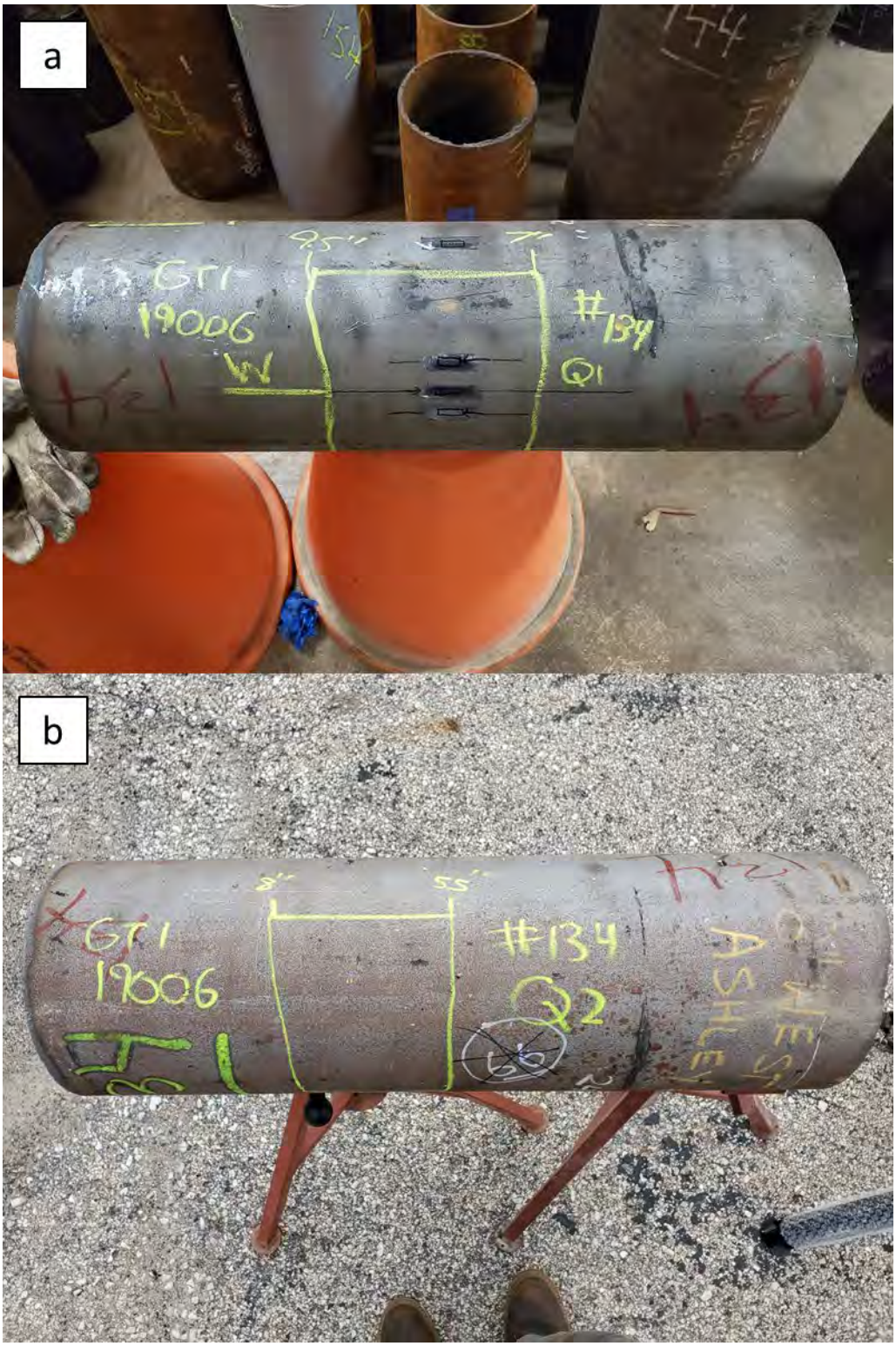

Figure 49: (a) Test location Q1 on ERW seam and overview of Sample 134; (b) Test location Q2 and overview of Sample 134.

Figure 50: Test locations and overview of Sample 136.

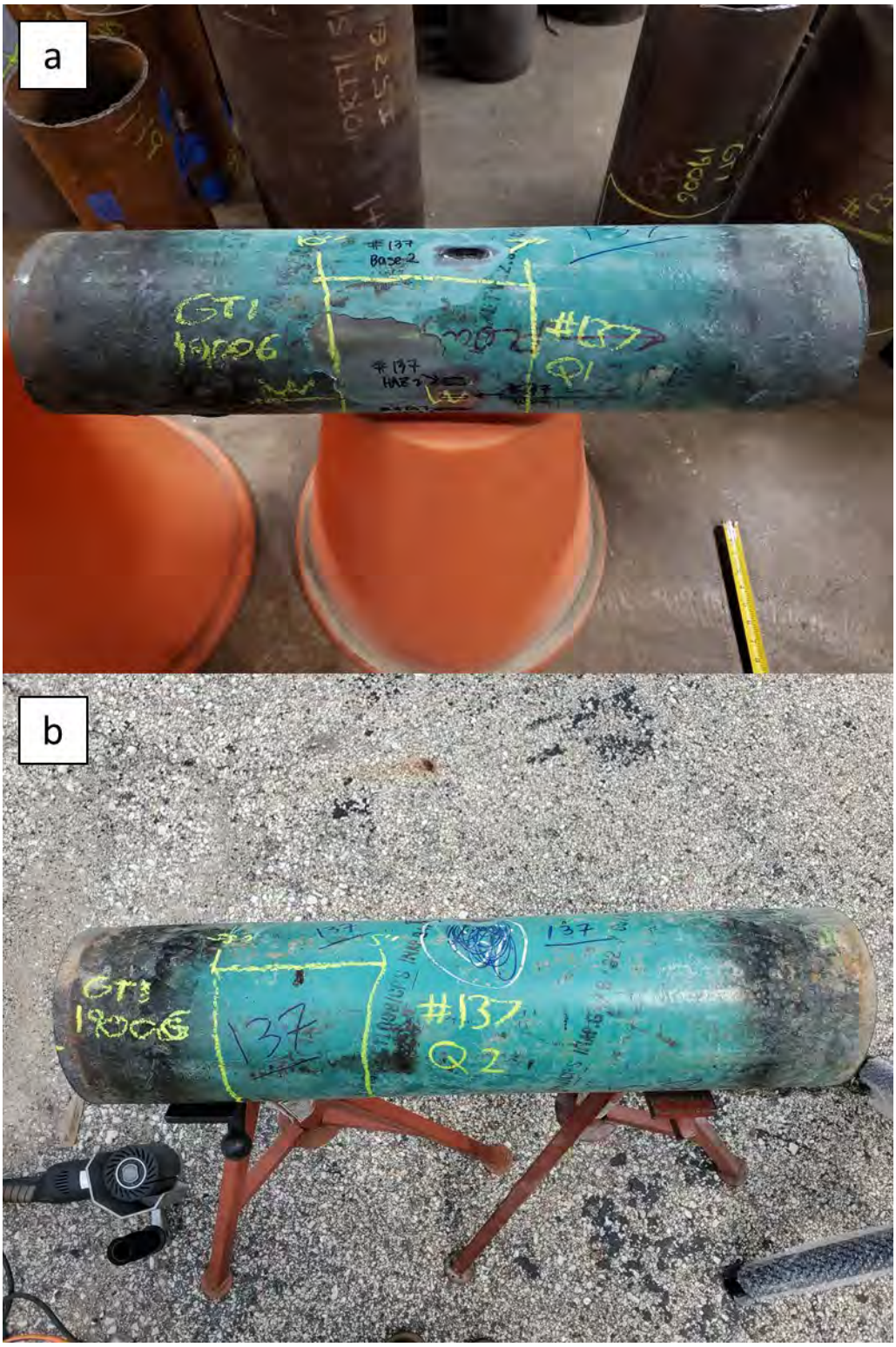

Figure 51: (a) Test location Q1 on ERW seam and overview of Sample 137; (b) Test location Q2 and overview of Sample 137.

Figure 52: Test locations and overview of Sample 138.

Figure 53: Test locations and overview of Sample 139.

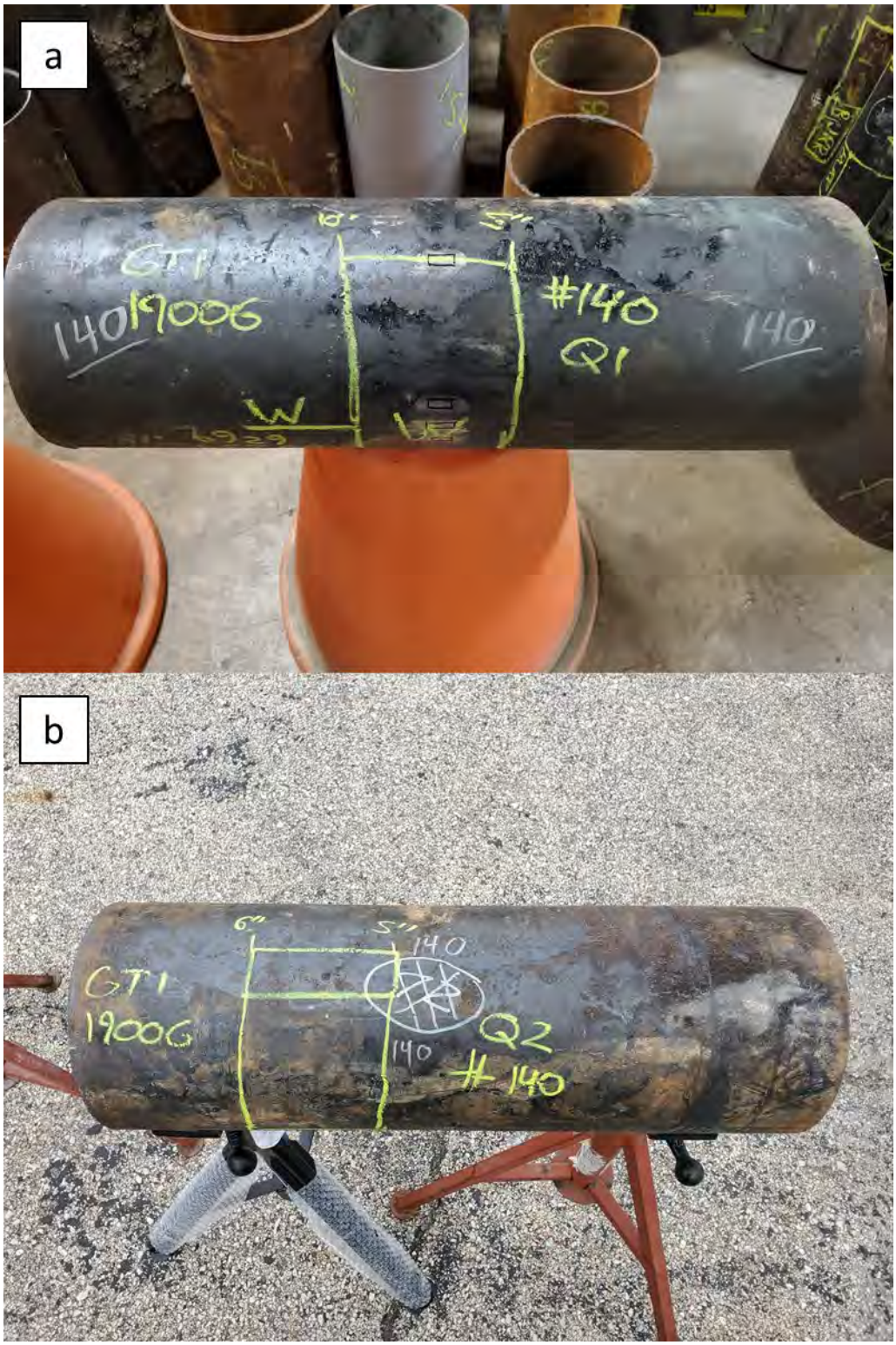

Figure 54: (a) Test location Q1 on ERW seam and overview of Sample 140; (b) Test location Q2 and overview of Sample 140.

Figure 55: (a) Test location Q1 on ERW seam and overview of Sample 141; (b) Test location Q2 and overview of Sample 141.

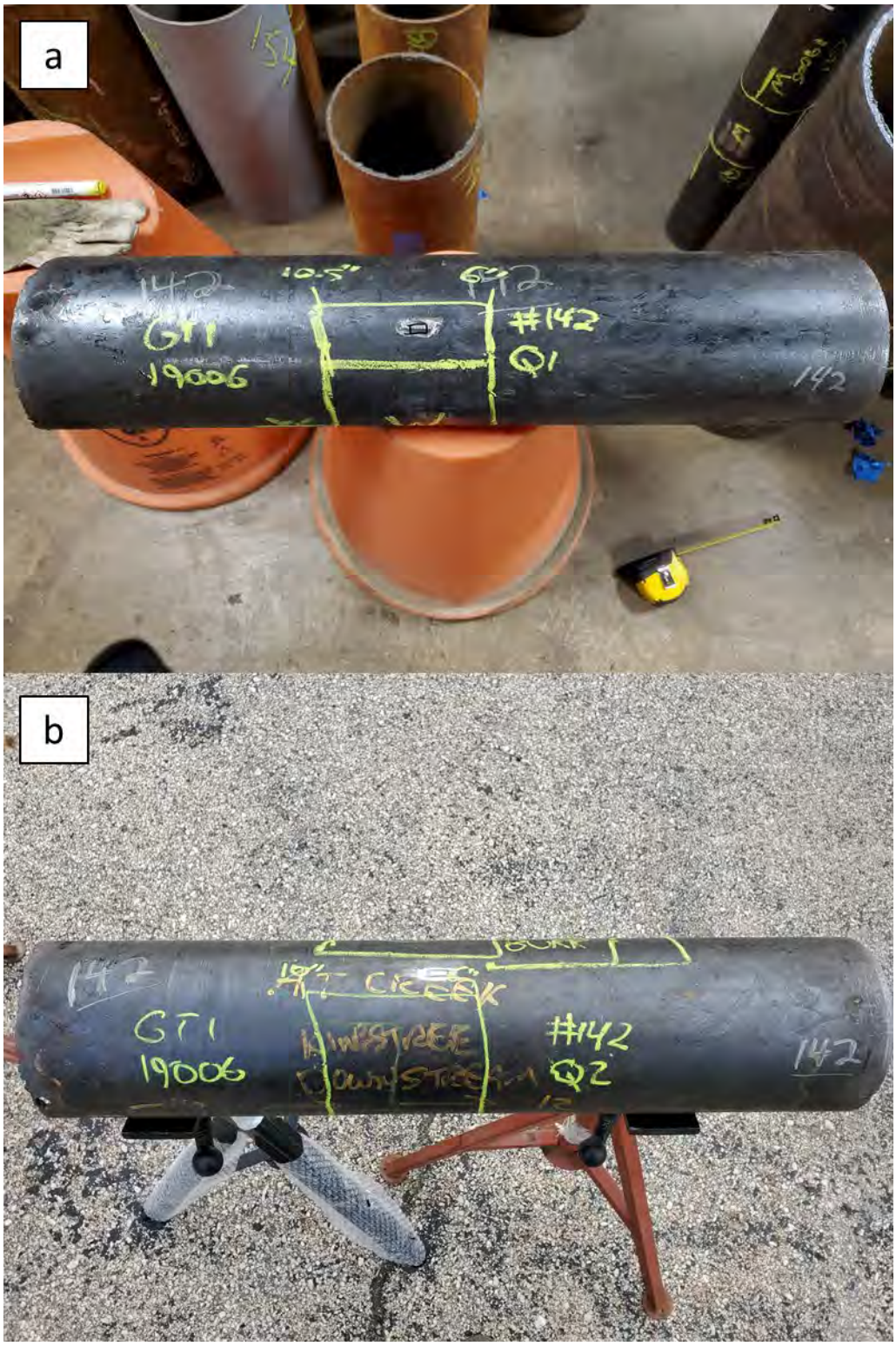

Figure 56: (a) Test location Q1 on ERW seam and overview of Sample 142; (b) Test location Q2 and overview of Sample 142.

Figure 57: (a) Test location Q1 on ERW seam and overview of Sample 143; (b) Test location Q2 and overview of Sample 143.

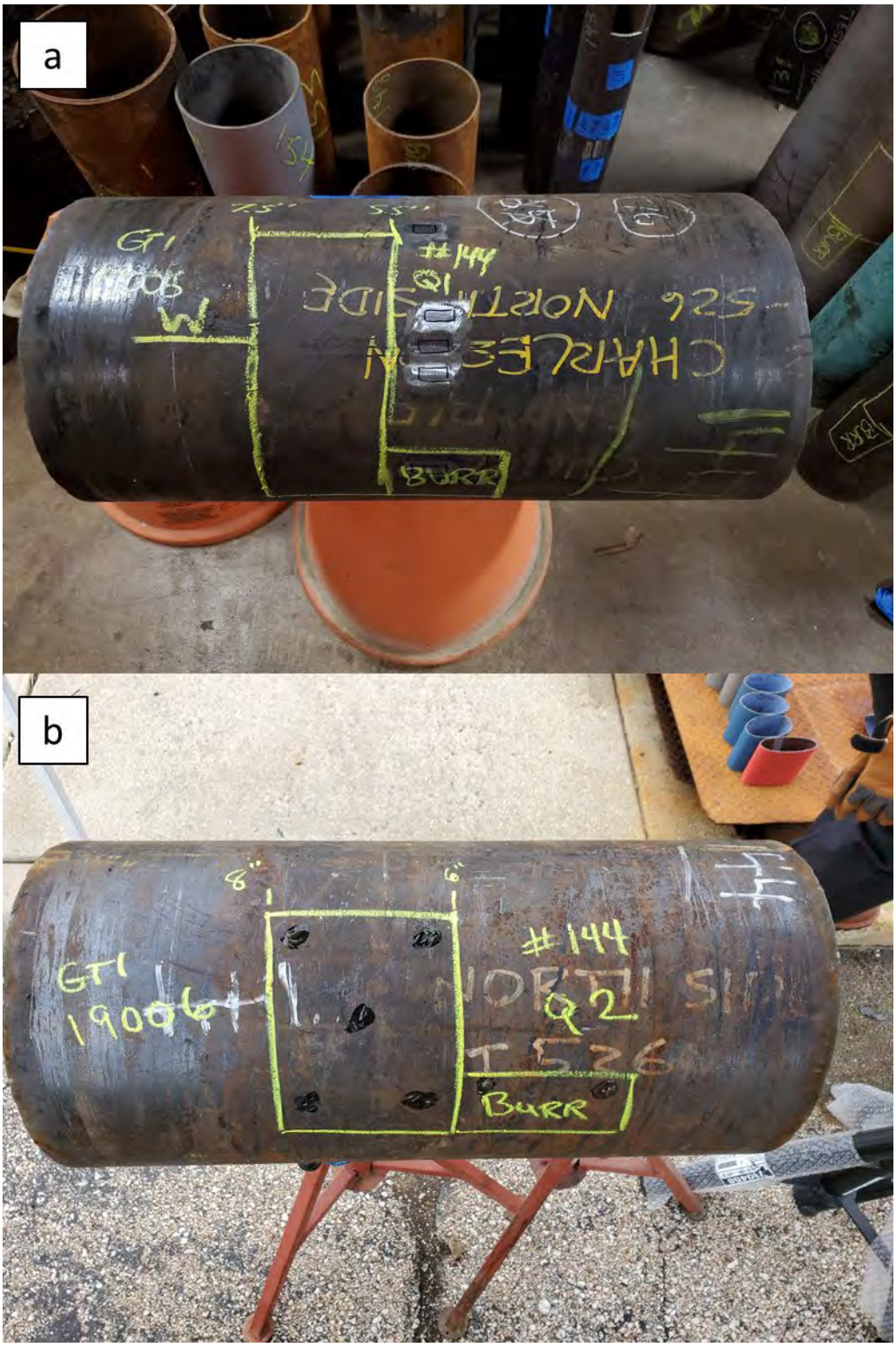

Figure 58: (a) Test location Q1 on ERW seam and overview of Sample 144; (b) Test location Q2 and overview of Sample 144.

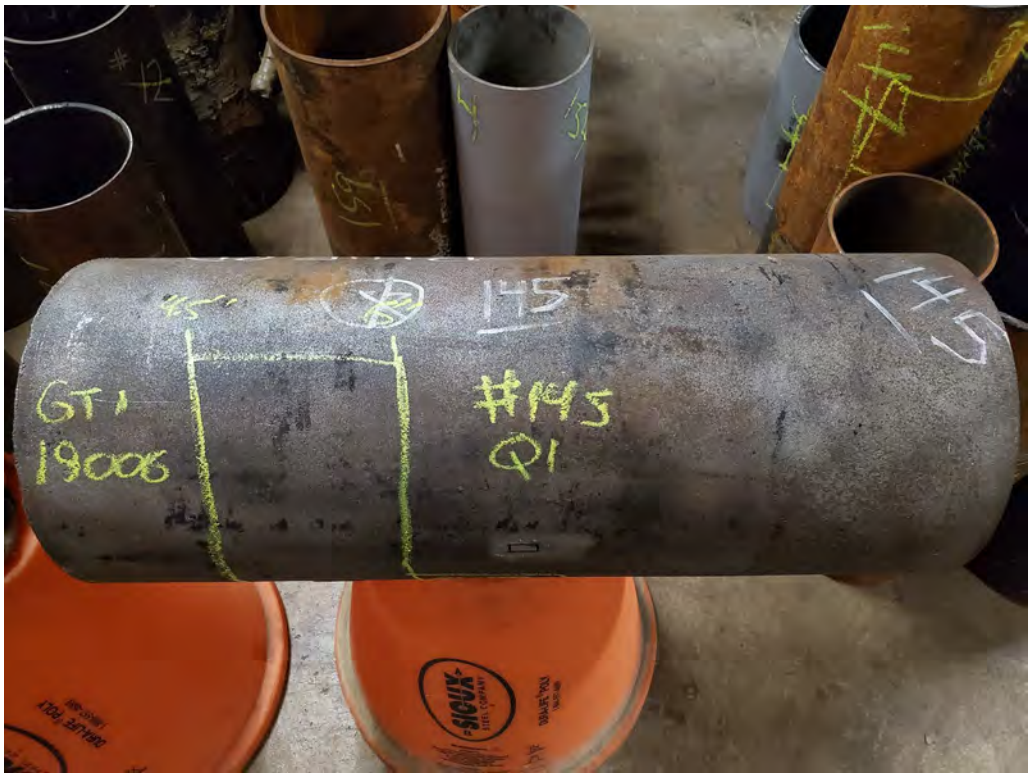

Figure 59: Test locations and overview of Sample 145.

Figure 60: Test locations and overview of Sample 146.

Figure 61: Test locations and overview of Sample 147.

Figure 62: Test locations and overview of Sample 148.

Figure 63: Test locations and overview of Sample 149.

Figure 64: Test locations and overview of Sample 150.

Figure 65: Test locations and overview of Sample 151.

Figure 66: Test locations and overview of Sample 155.

Figure 67: Test locations and overview of Sample 165.

Figure 68: Test locations and overview of Sample 167.

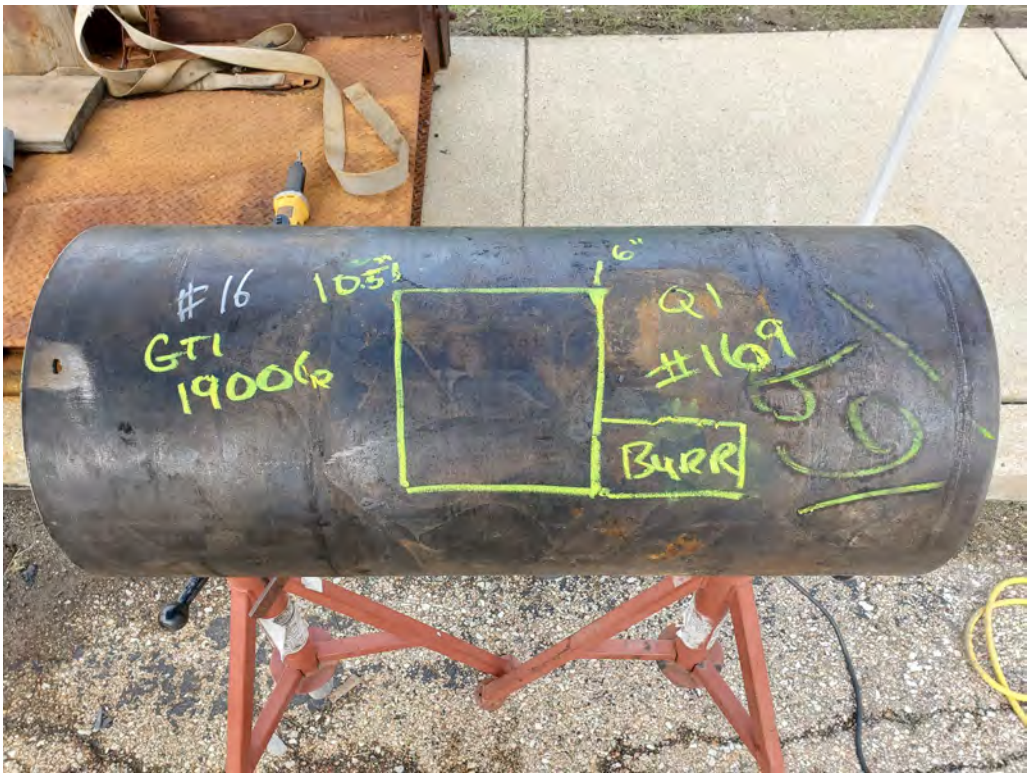

Figure 69: Test locations and overview of Sample 169.

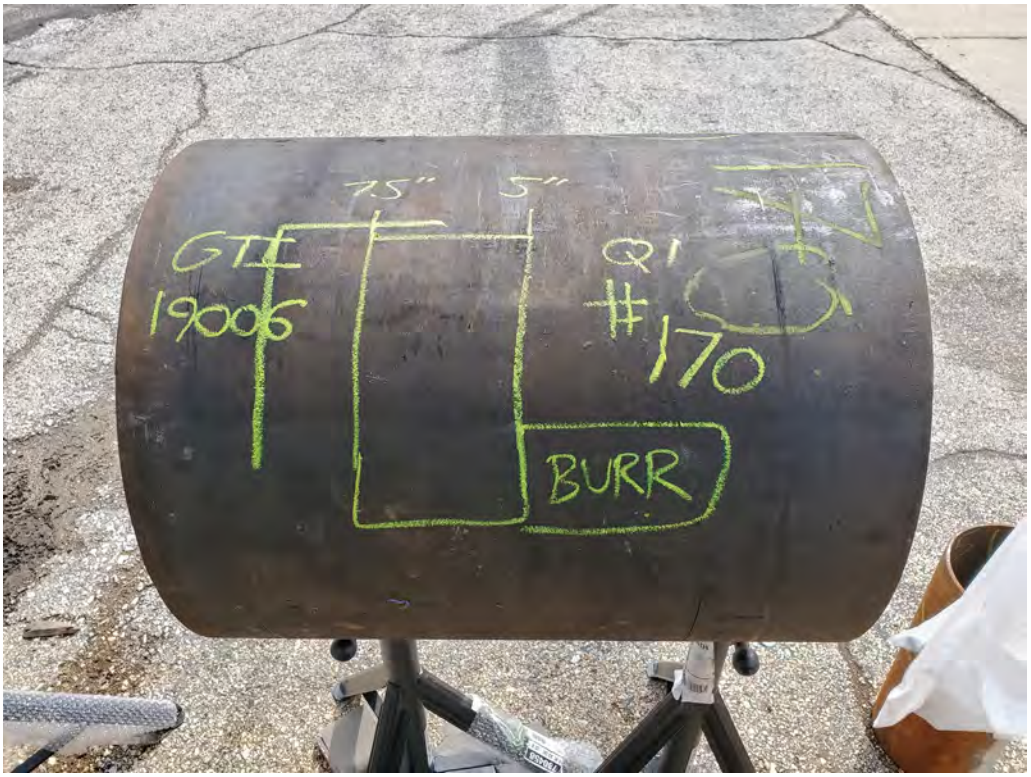

Figure 70: Test locations and overview of Sample 170.

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Customer: Gas Technology Institute

Project ID: MMT Project GTI19006

Subject: **Appendix B: Images of macro-etched weld regions on outer diameter of samples.**

Figure 1: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 003. The boundaries of the etched HAZ are shown in dashed red lines, the bondline is shown by the dashed yellow line, and the edges of the inner hourglass HAZ surrounding the bondline is shown by the dashed green lines. The normalized HAZ width (measured width / wall thickness) is approximately 0.75 in / 0.26 in = 287%. The bondline is located approximately 0.5 inches from the start of the HSD test.

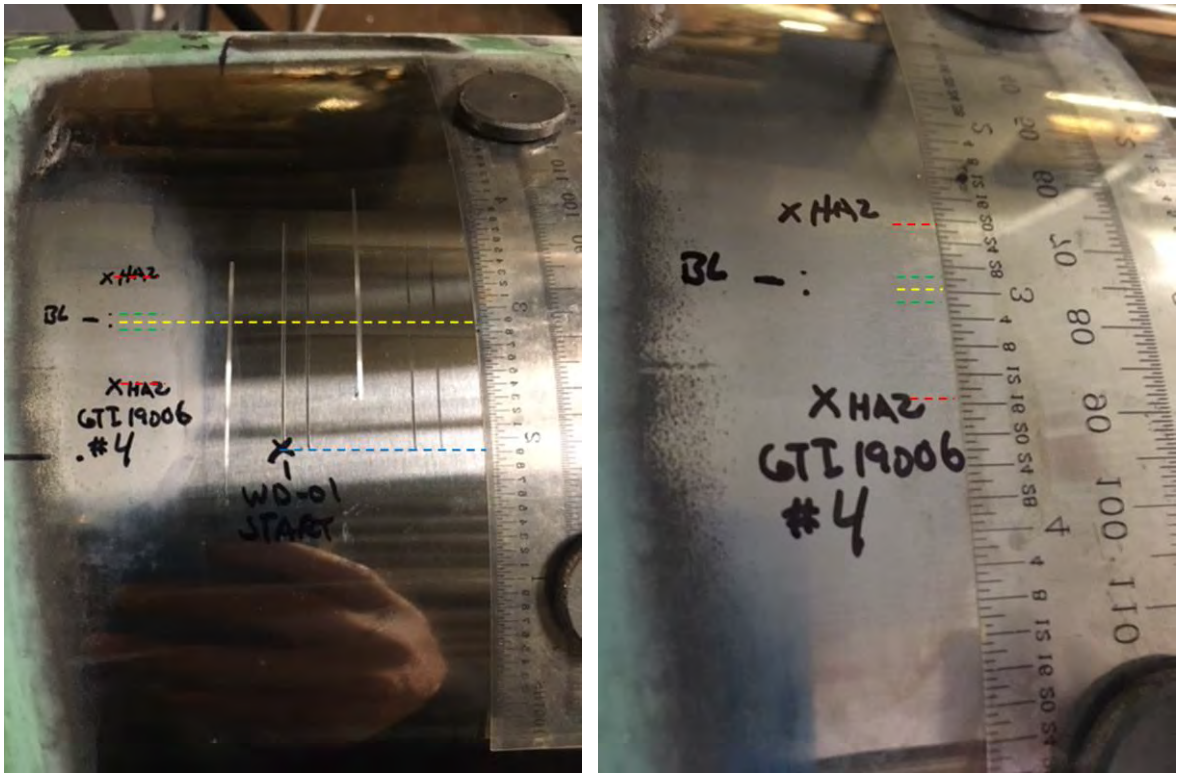

Figure 2: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 004. The boundaries of the etched HAZ are shown in dashed red lines, the bondline is shown by the dashed yellow line, and the edges of the inner hourglass HAZ surrounding the bondline is shown by the dashed green lines. The normalized HAZ width (measured width / wall thickness) is approximately 0.875 in / 0.224 in = 391%. The bondline is located approximately 0.95 inches from the start of the HSD test.

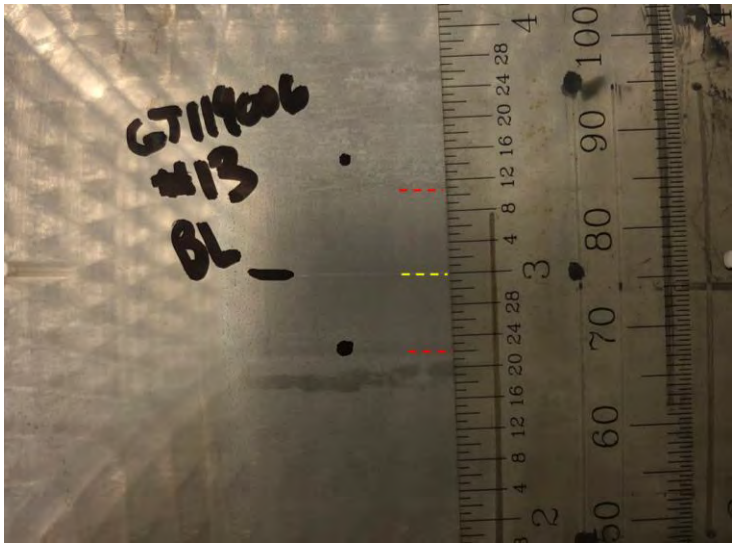

Figure 3: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 013. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.625 in / 0.222 in = 282%.

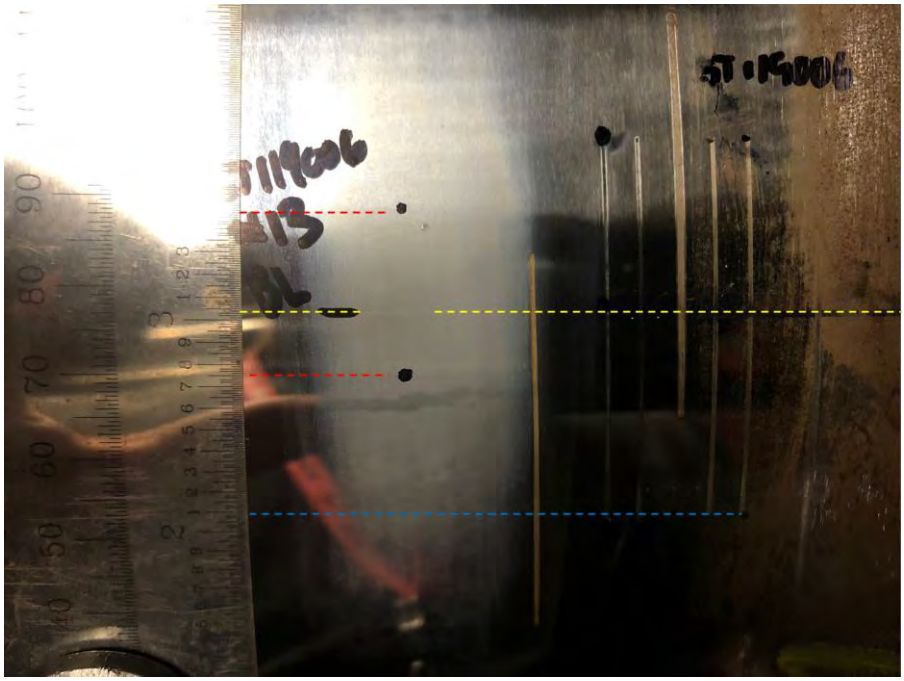

Figure 4: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 013. The bondline is located approximately 0.95 inches from the start of the HSD test.

Figure 5: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 035. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.20 in / 0.25 in = 80%.

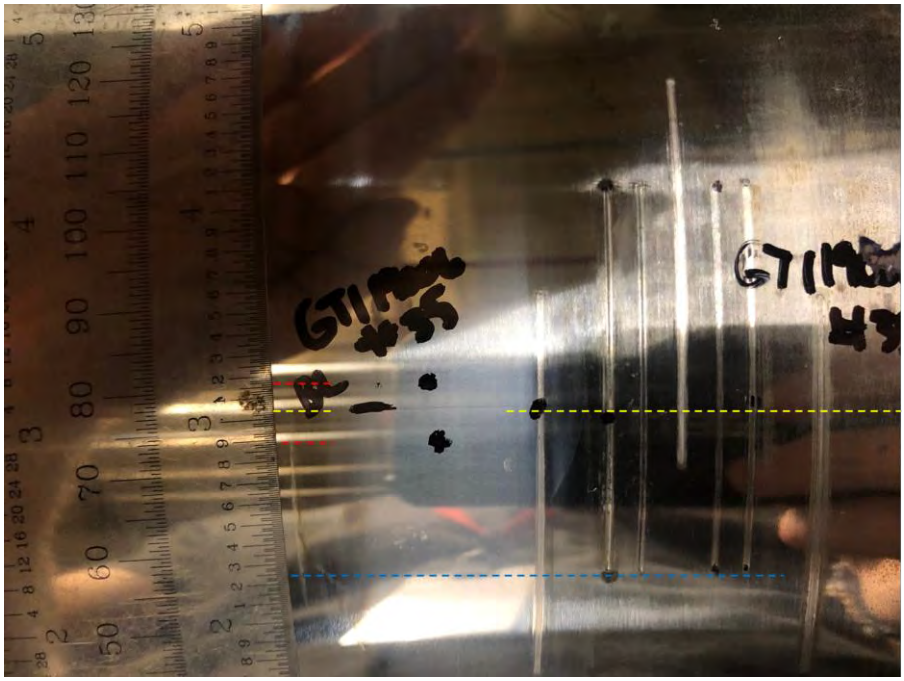

Figure 6: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 035.The bondline is located approximately 0.8 inches from the start of the HSD test.

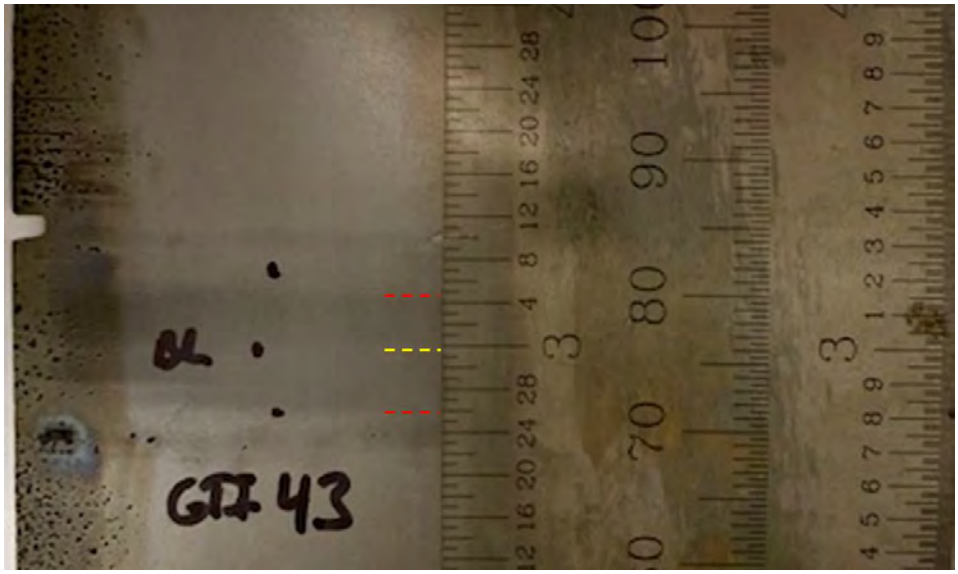

Figure 7: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 043. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.3125 in / 0.25 in = 125%.

Figure 8: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 043. The bondline is located approximately 0.4 inches from the start of the HSD test.

Figure 9: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 107. The bondline is shown by the dashed yellow line. There was no presence of a HAZ due to the quality of the seam etch and image.

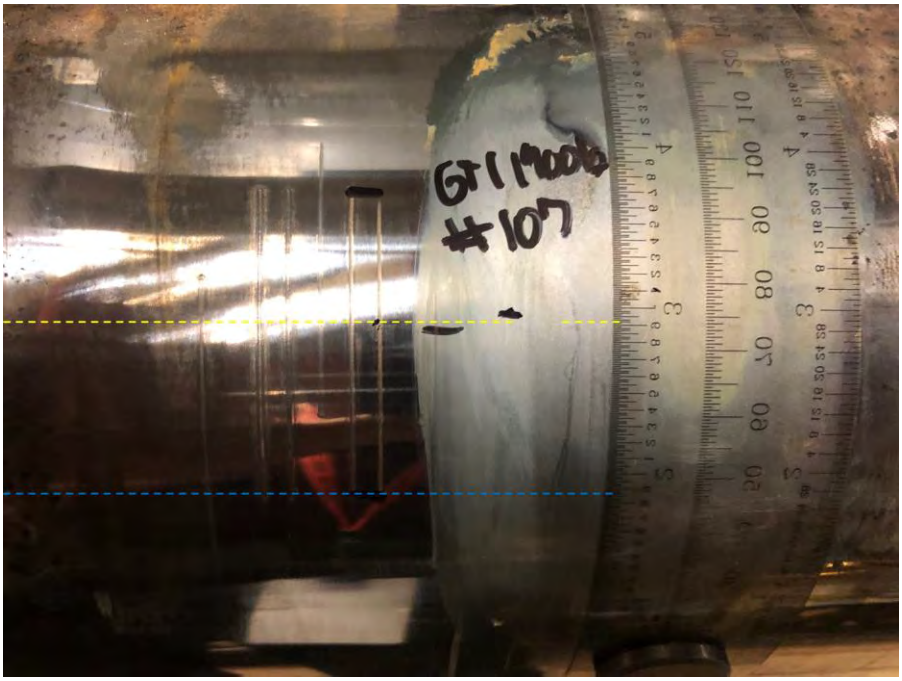

Figure 10: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 107. The bondline is located approximately 1.0 inch from the start of the HSD test.

Figure 11: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 111. The edges of an inner hourglass HAZ surrounding the bondline are shown by the dashed green lines and the bondline is shown by the dashed yellow line. There is no presence of a larger, outer HAZ as a result of a normalization process indicative of HFN-ERW seams.

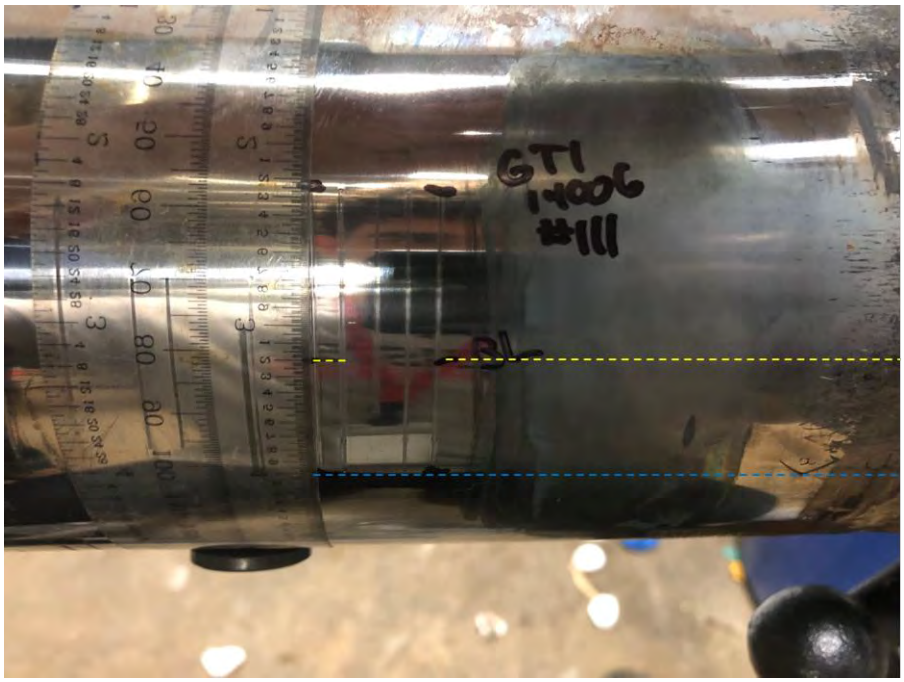

Figure 12: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 111. The bondline is located approximately 0.8 inches from the start of the HSD test.

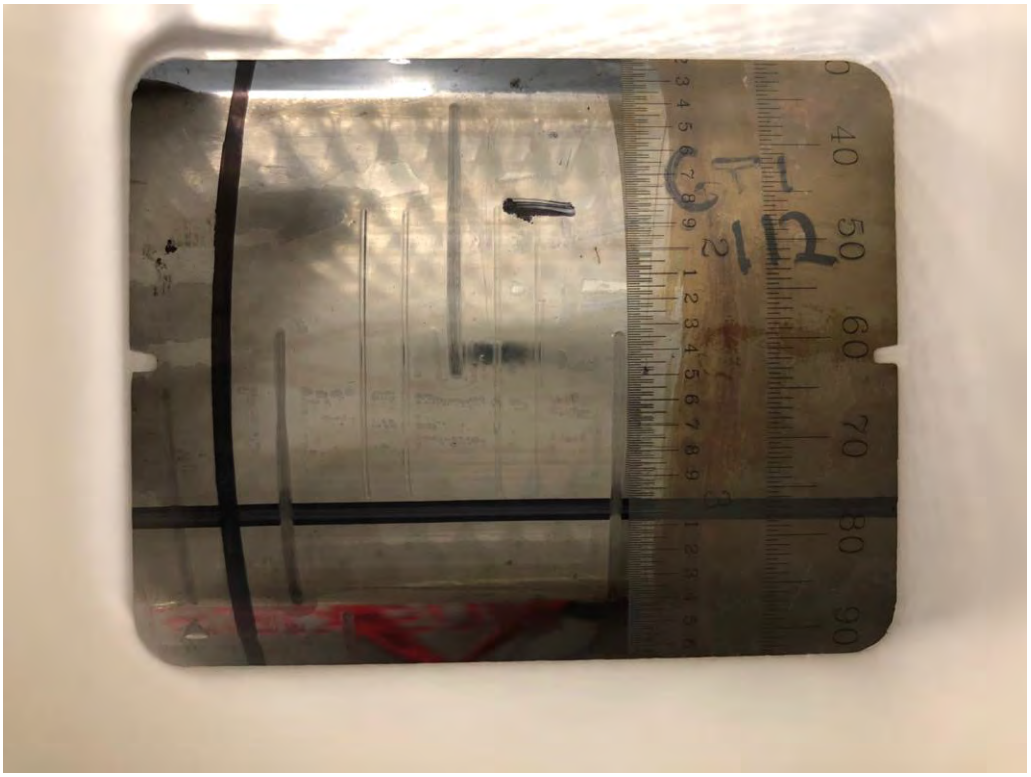

Figure 13: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 112. A HAZ and the bondline were not made visible by the macro-etch procedure. MMT technicians centered the weld test on the seam via visual inspection of the pipe ID and UT thickness mapping.

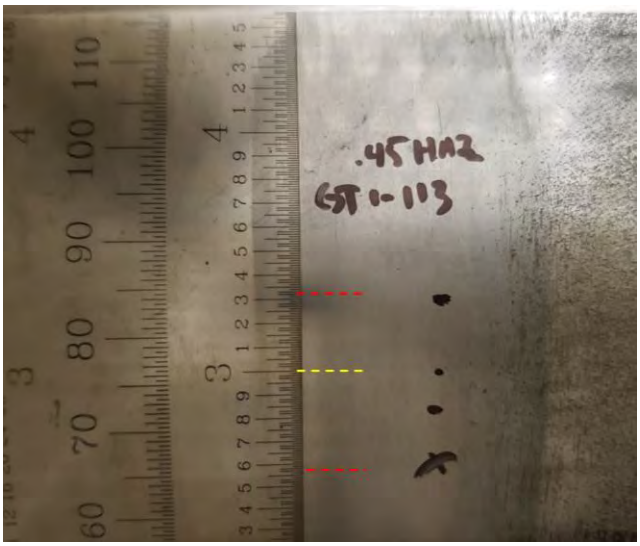

Figure 14: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 113. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.75 in / 0.262 in = 286%.

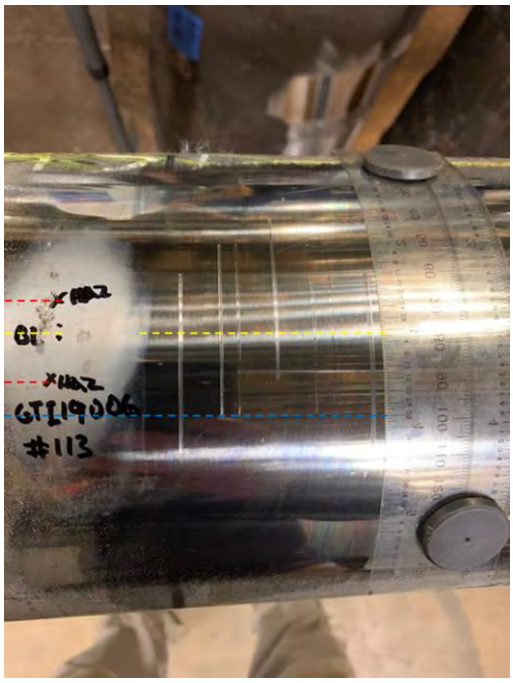

Figure 15: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 113. The bondline is located approximately 0.8 inches from the start of the HSD test.

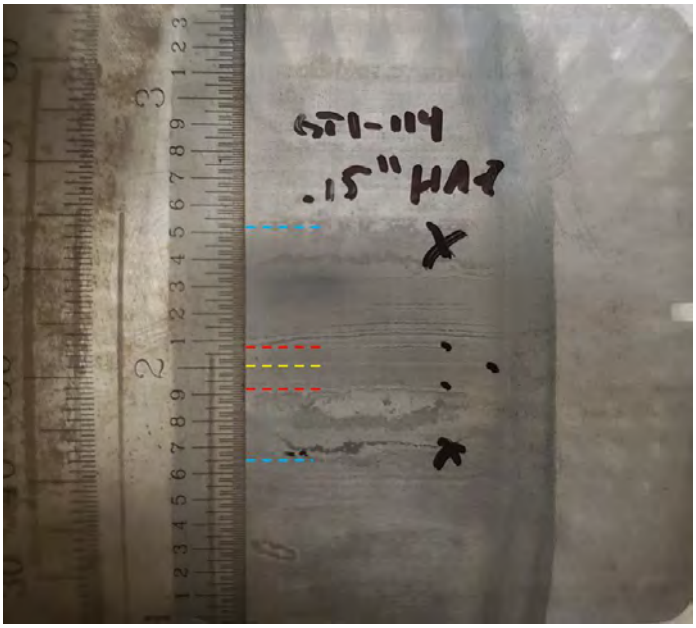

Figure 16: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 114. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.20 in / 0.25 in = 80%.

Figure 17: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 114. The bondline is located approximately 1.3 inches from the start of the HSD test.

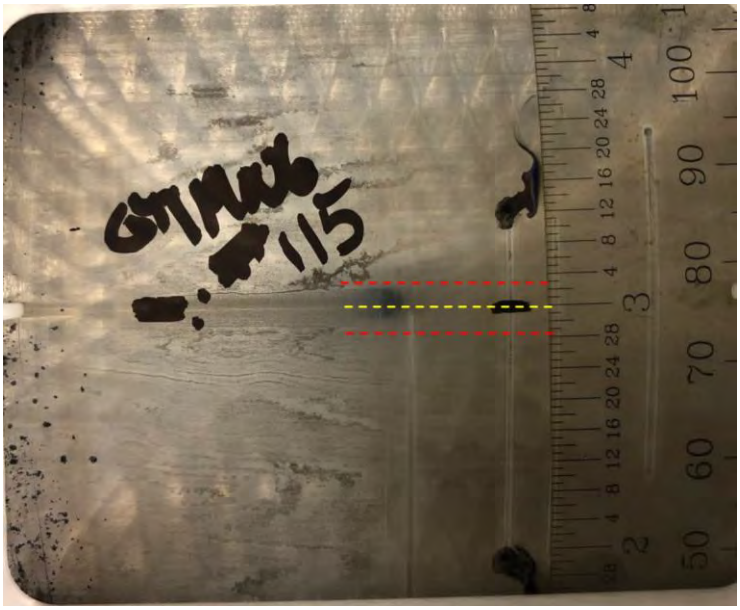

Figure 18: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 115. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.2031 in / 0.26 in = 78%.

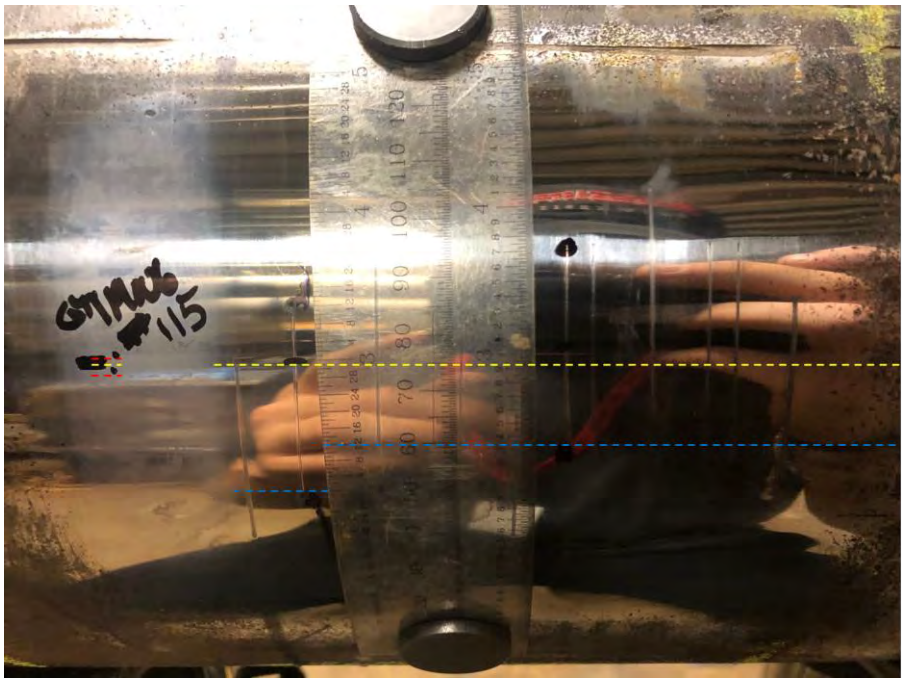

Figure 19: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 115. The bondline is located approximately 0.6 inches from the start of the HSD test.

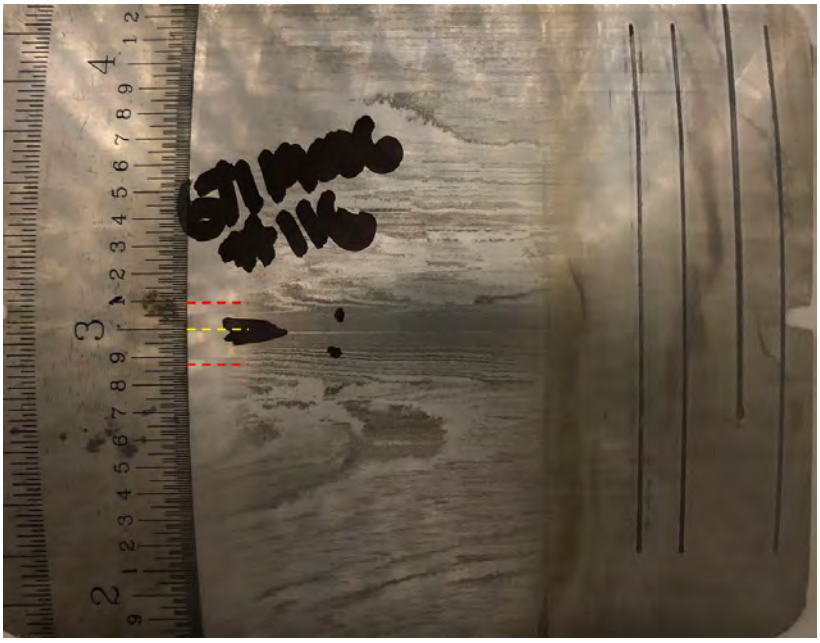

Figure 20: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 116. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.23 in / 0.25 in = 92%.

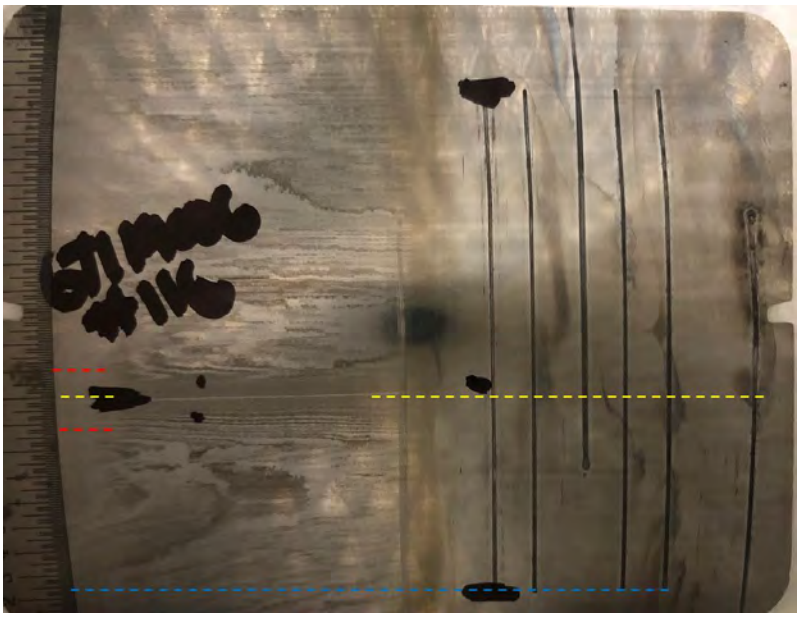

Figure 21: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 116. The bondline is located approximately 0.75 inches from the start of the HSD test.

Figure 22: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 119. The edges of an inner hourglass HAZ surrounding the bondline are shown by the dashed green lines and the bondline is shown by the dashed yellow line. There is no presence of a larger, outer HAZ as a result of a normalization process indicative of HFN-ERW seams.

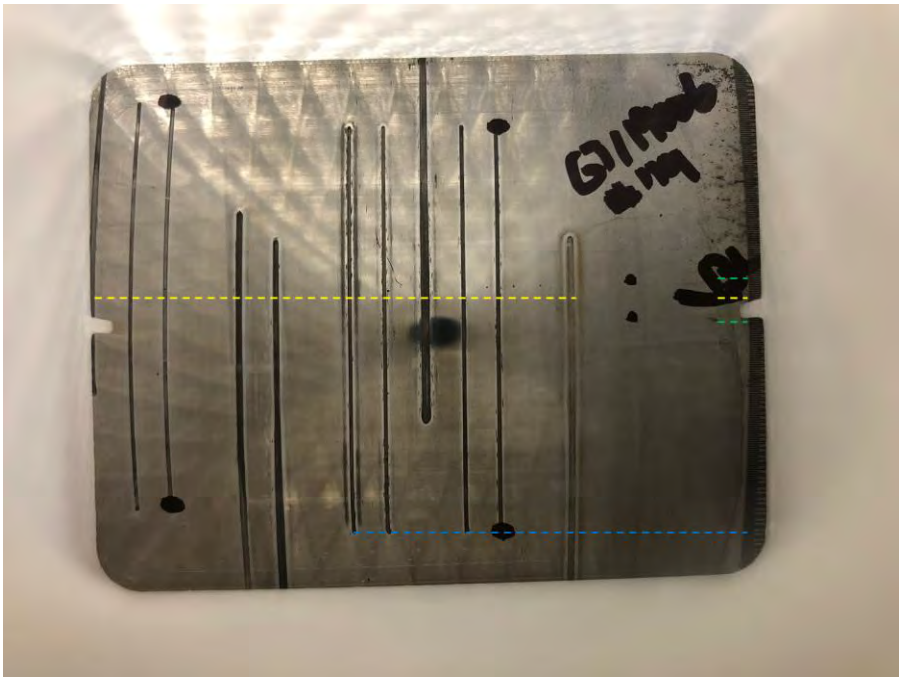

Figure 23: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 119. The bondline is located approximately 1.1 inches from the start of the HSD test.

Figure 24: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 122. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.90 in / 0.25 in = 357%.

Figure 25: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 122. The bondline is located approximately 1.25 inches from the start of the HSD test.

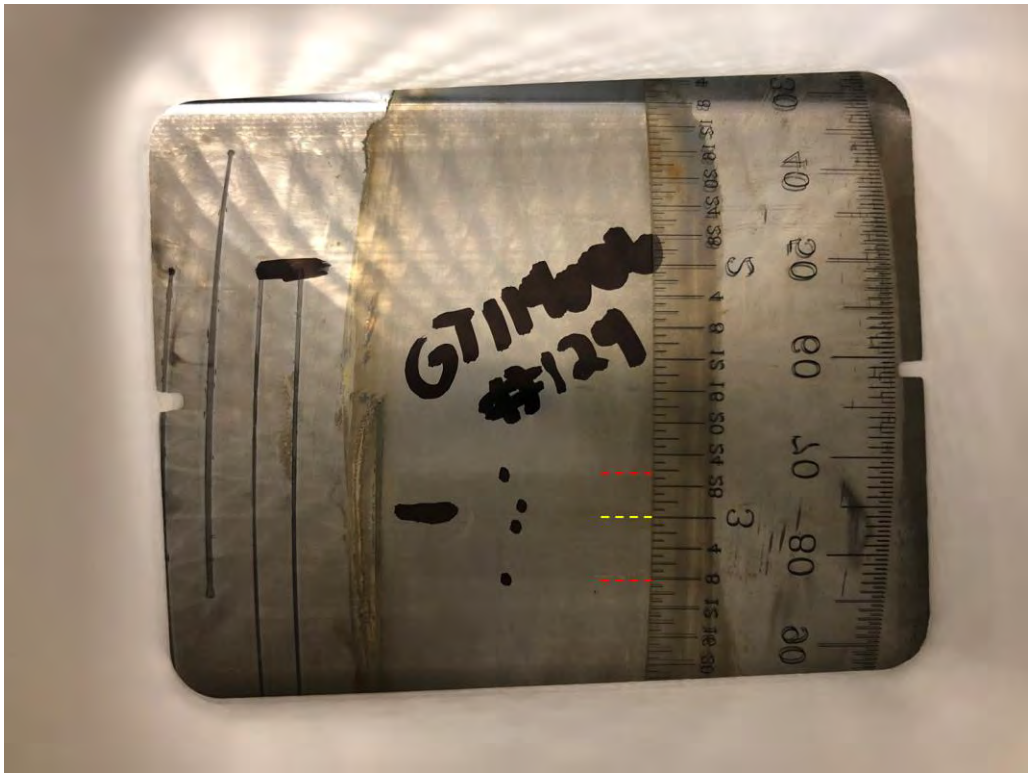

Figure 26: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 124. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.4375 in / 0.156 in = 280%.

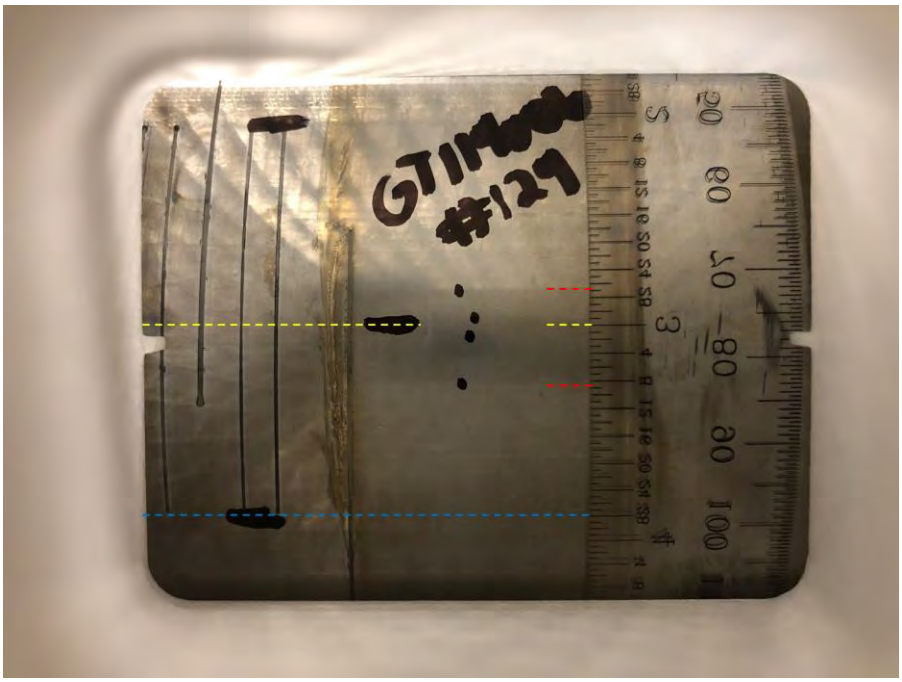

Figure 27: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 124. The bondline is located approximately 0.875 inches from the start of the HSD test.

Figure 28: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 125. The bondline is shown by the dashed yellow line. There was no presence of a HAZ as a result of a complete normalization process indicative of HFN-ERW seams.

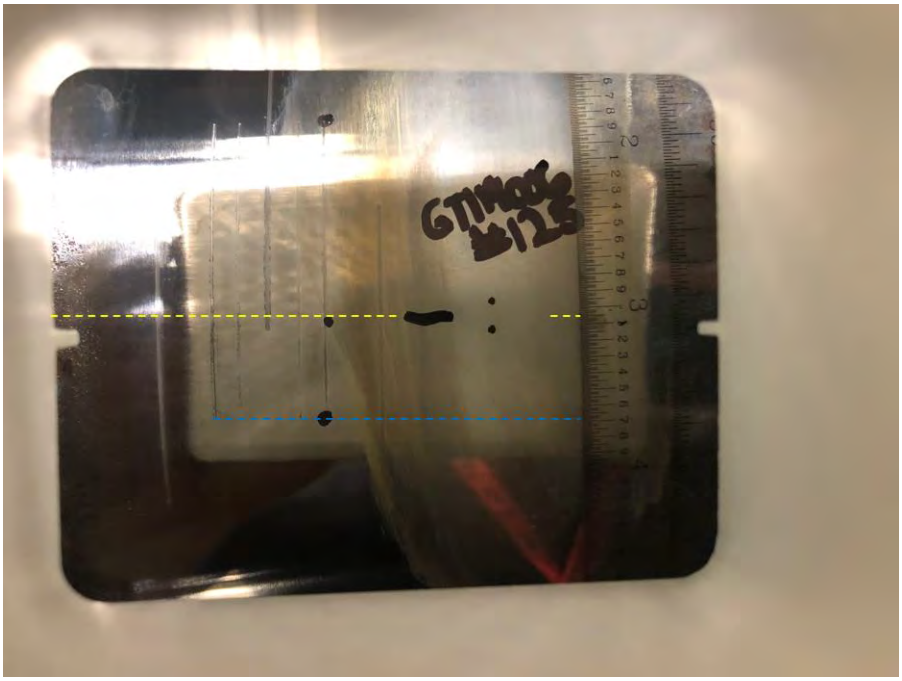

Figure 29: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 125. The bondline is located approximately 0.6 inches from the start of the HSD test.

Figure 30: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 130. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.25 in / 0.20 in = 125%.

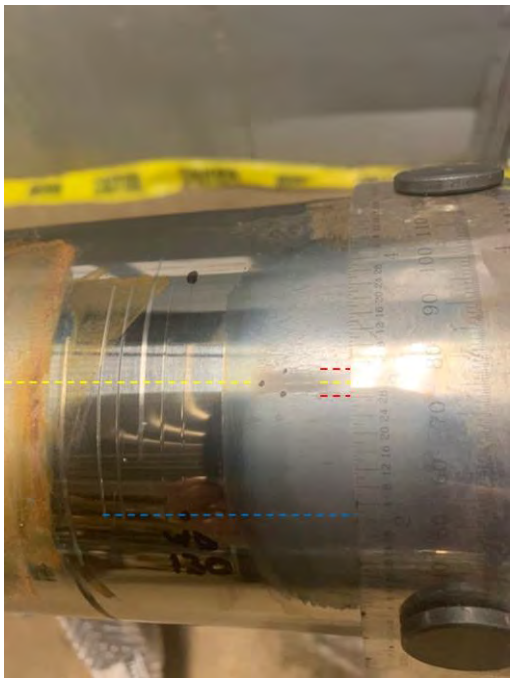

Figure 31: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 130. The bondline is located approximately 1.0 inch from the start of the HSD test.

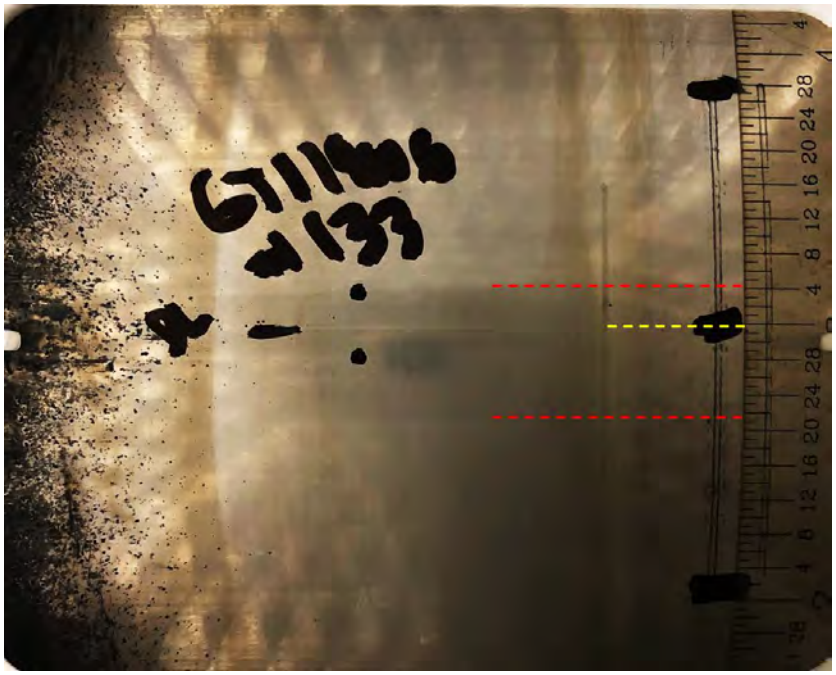

Figure 32: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 133. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.4375 in / 0.26 in = 168%.

Figure 33: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 133. The bondline is located approximately 0.875 inches from the start of the HSD test.

Figure 34: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 134. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.1875 in / 0.26 in = 72%. The bondline is located approximately 0.6875 inches from the start of the HSD test.

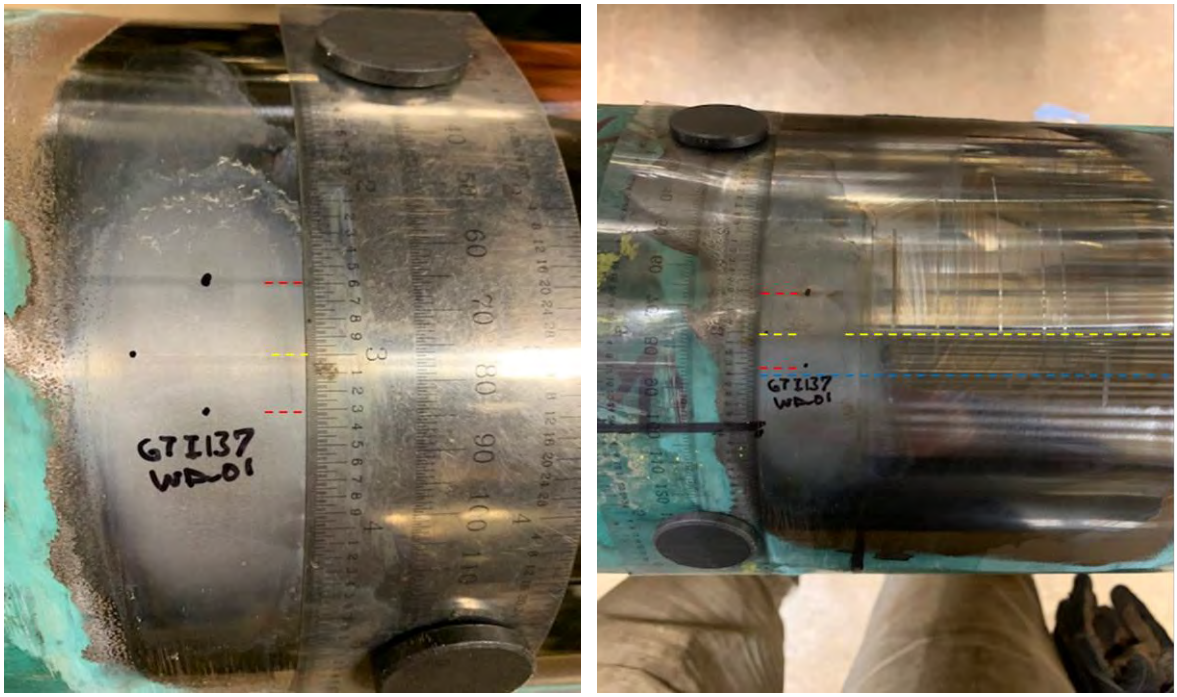

Figure 35: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 137. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.70 in / 0.188 in = 372%. The bondline is located approximately 0.5 inches from the start of the HSD test.

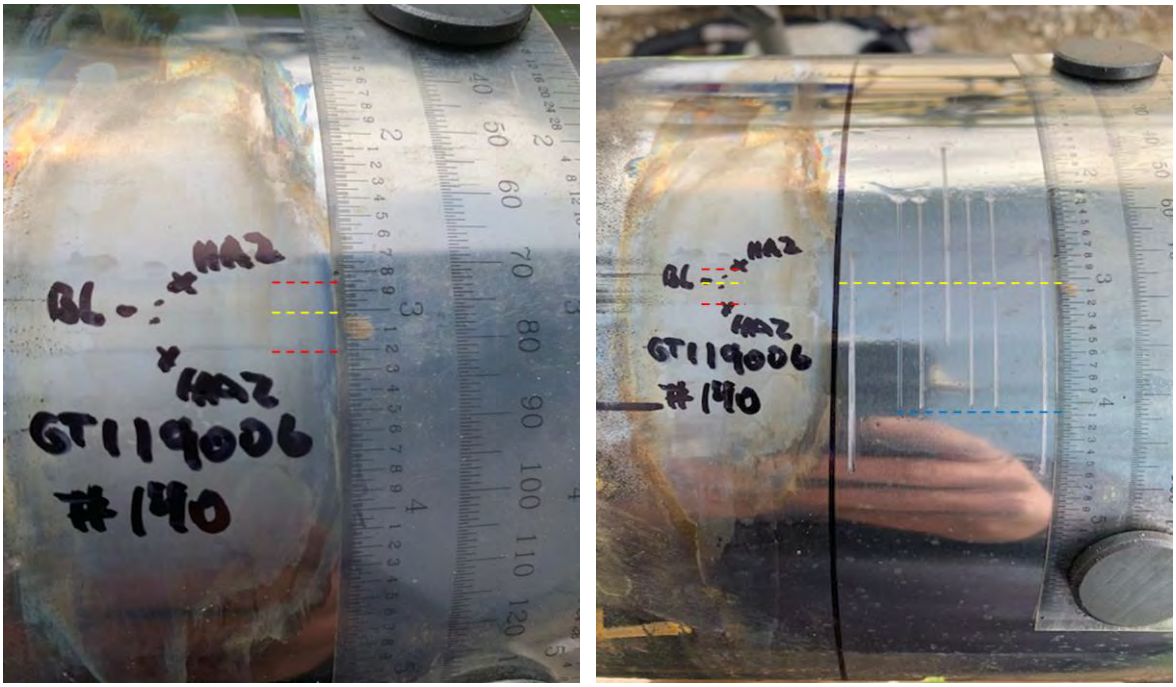

Figure 36: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 140. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.30 in / 0.184 in = 163%. The bondline is located approximately 1.0 inch from the start of the HSD test.

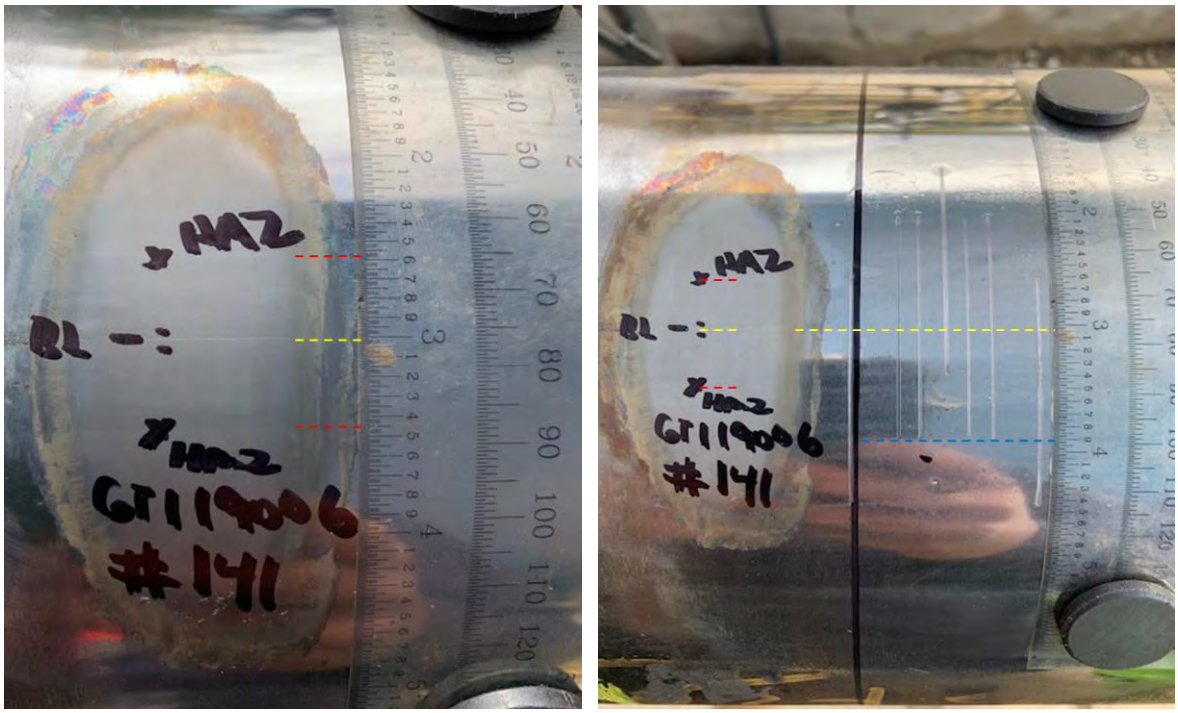

Figure 37: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 141. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.90 in / 0.187 in = 481%. The bondline is located approximately 0.85 inches from the start of the HSD test.

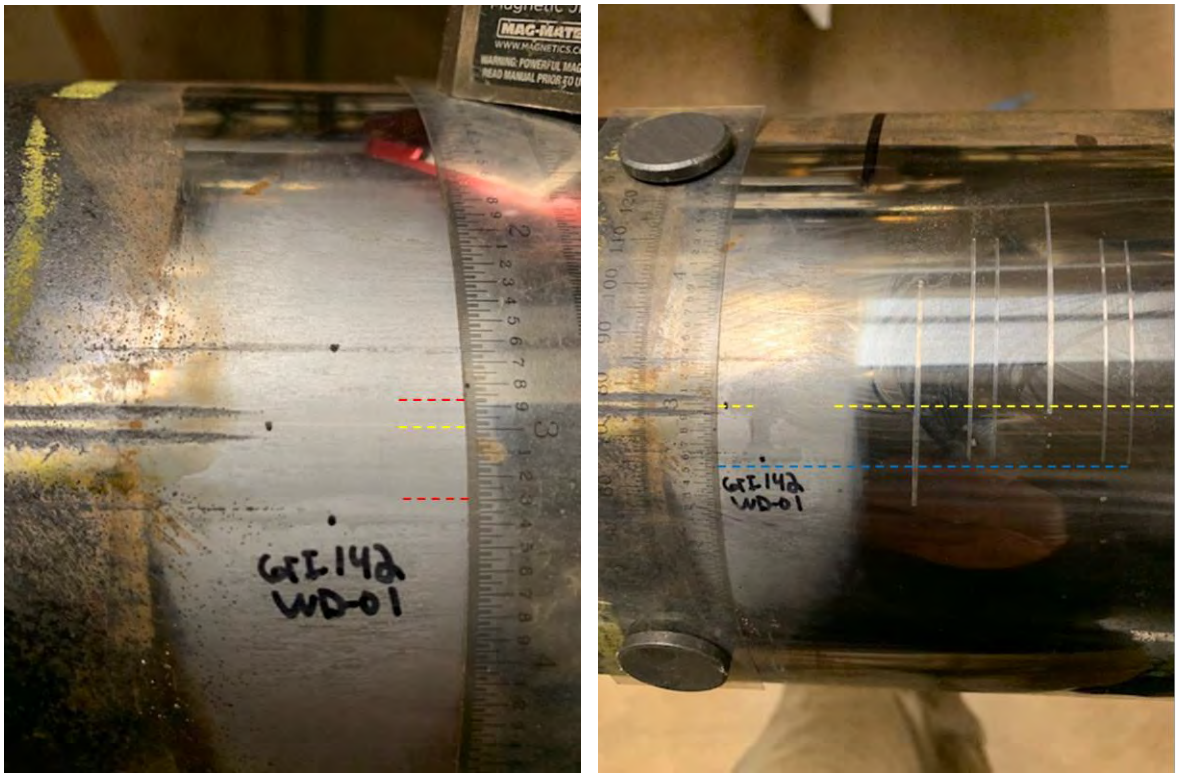

Figure 38: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 142. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.40 in / 0.20 in = 200%. The bondline is located approximately 0.5 inches from the start of the HSD test.

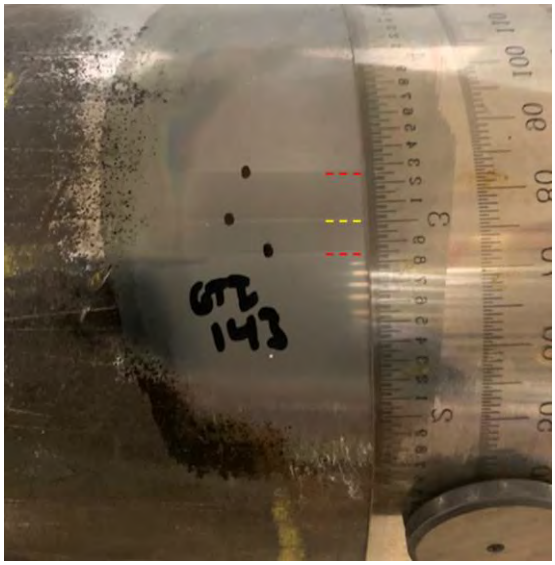

Figure 39: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 143. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.40 in / 0.188 in = 213%.

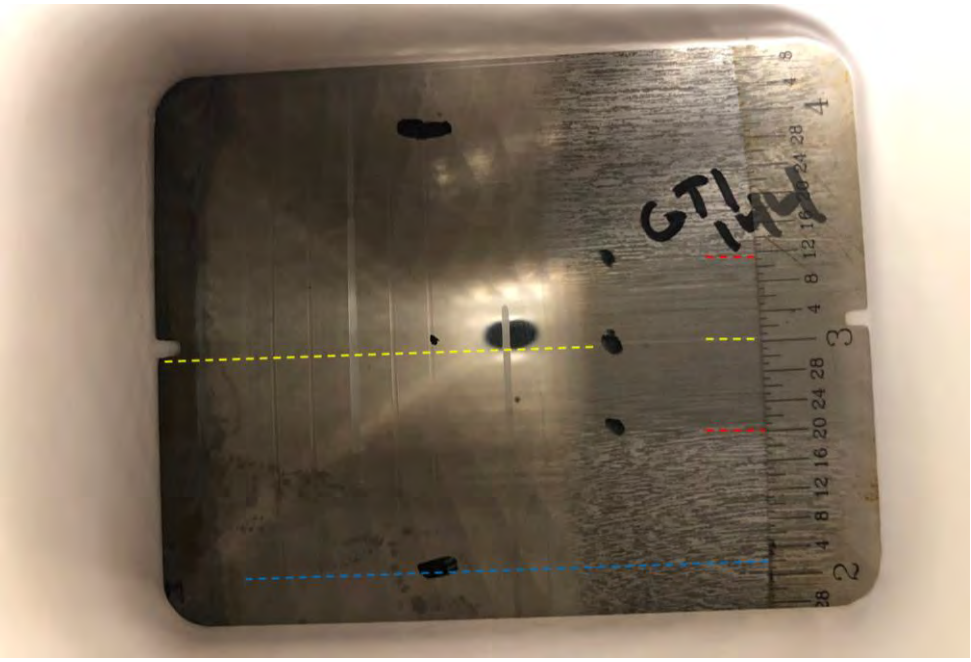

Figure 40: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 144. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately 0.75 in / 0.287 in = 261%.

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ByMMT.com

Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

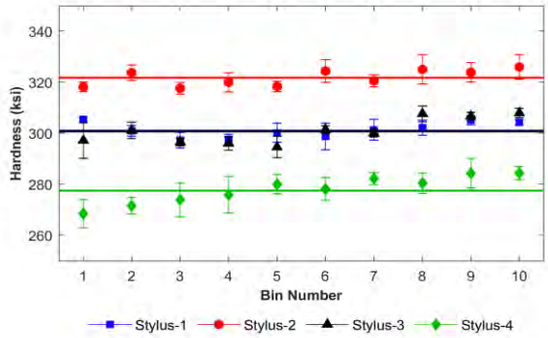
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523122923	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:29	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	3-Q2	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	3-Q2_BM-01_7001-EB7001_190523122923			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.80002	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Ver. 2.2

	HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	300.9	3.89	39
Stylus-2	321.6	4.33	40
Stylus-3	300.6	5.52	43
Stylus-4	277.4	6.80	45

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.10	1.06	0.010	0.008	0.03	0.02	0.07	0.03	0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005	5.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

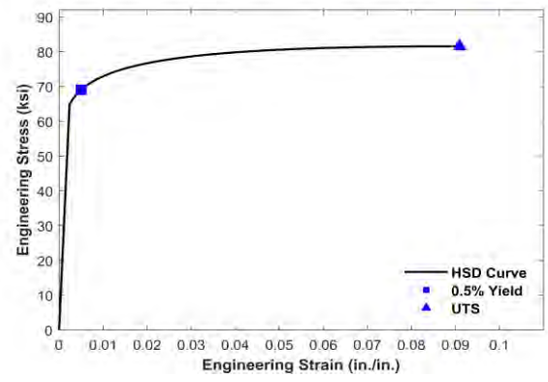
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	69.0	67.6	69.2	70.4
UTS (ksi)	81.5	81.3	81.2	82.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522130524	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:05	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	3-Q2	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials		
Test Name	3-Q2_BM-01_7003-EB7003_190522130524			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

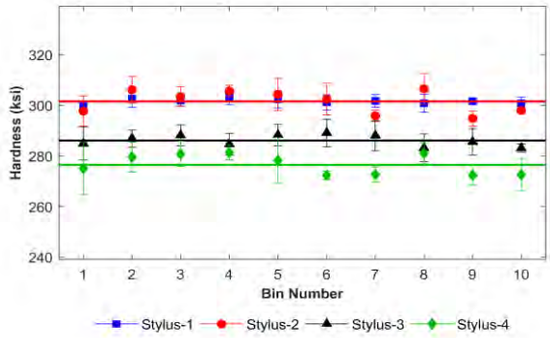
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	301.6	2.60	47
Stylus-2	301.6	5.98	51
Stylus-3	286.1	4.83	46
Stylus-4	276.5	6.64	50

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.06	0.010	0.008	0.03	0.02	0.07	0.03	0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

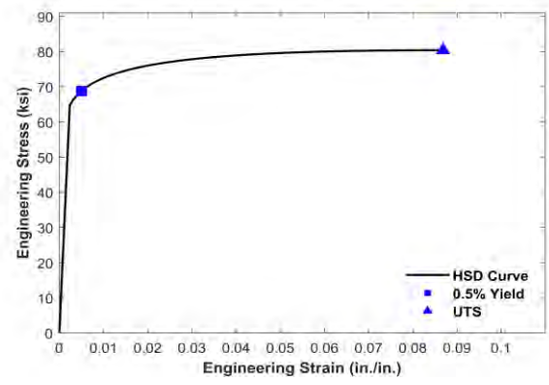
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	68.8	69.2	68.7	68.5
UTS (ksi)	80.4	80.5	80.5	80.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523125325	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:53	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	3-Q2	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	3-Q2_BM-02_7001-EB7001_190523125325			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

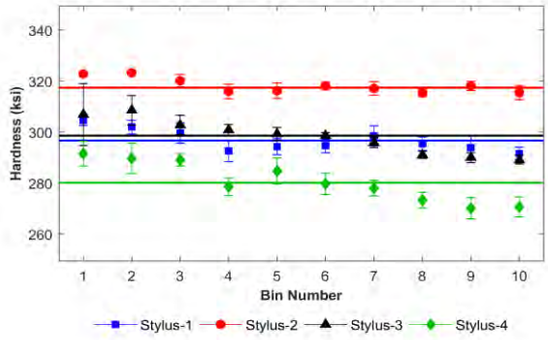
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	296.7	5.07	55
Stylus-2	317.4	2.94	44
Stylus-3	298.6	7.77	58
Stylus-4	280.2	8.32	58

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.06	0.010	0.008	0.03	0.02	0.07	0.03	0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

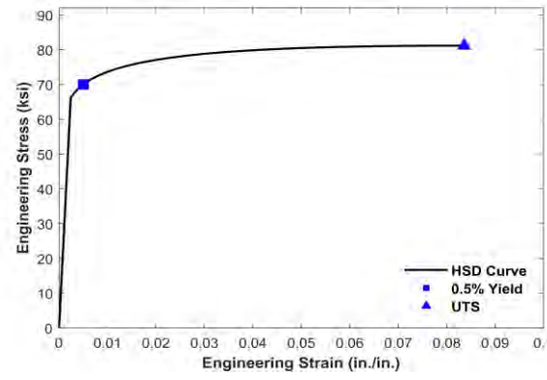
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	70.0	71.7	70.5	67.7
UTS (ksi)	81.2	82.2	81.1	80.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531120821	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	4-Q1	Pipe Size	12 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	4-Q1_BM-01_5002-EB5002_190531120821			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

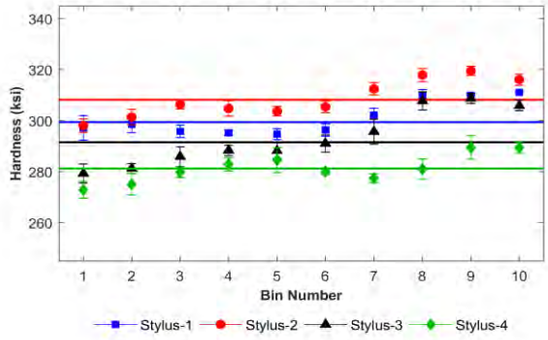
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	299.3	6.05	57
Stylus-2	308.2	7.39	64
Stylus-3	291.5	10.23	61
Stylus-4	281.2	6.01	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.07	0.010	0.008	0.03	0.02	0.07	0.03	< 0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

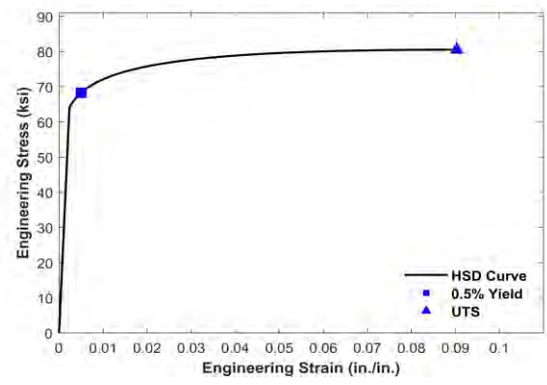
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	68.3	66.9	68.4	69.9
UTS (ksi)	80.5	79.6	80.1	82.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529142708	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:27	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	4-Q1	Pipe Size	12 OD x 0.22 WT (in)	Operator Initials	JN	
Test Name	4-Q1_BM-01_7001-EB7001_190529142708			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.80002	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

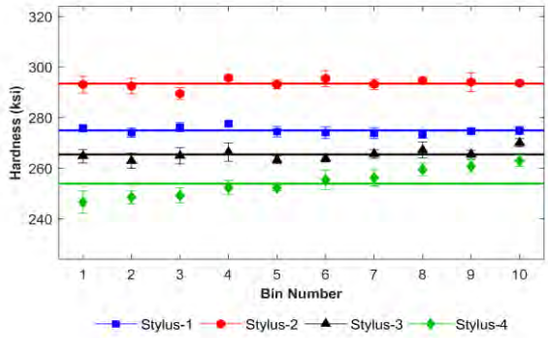
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	274.9	2.02	50
Stylus-2	293.5	2.85	53
Stylus-3	265.4	3.08	52
Stylus-4	253.9	5.92	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.07	0.010	0.008	0.03	0.02	0.07	0.03	< 0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

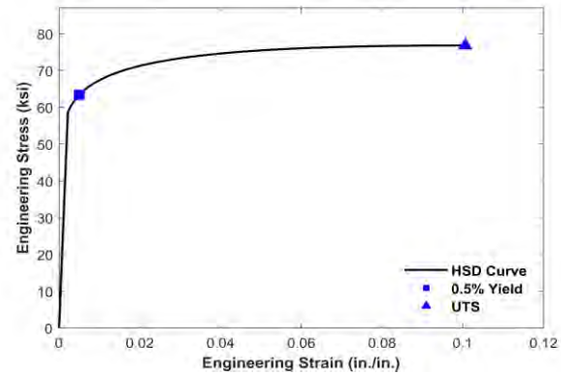
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	63.4	61.9	63.1	64.9
UTS (ksi)	76.8	76.5	76.9	77.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521100831	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	4-Q2	Pipe Size	12 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	4-Q2_BM-02_7001-EB7001_190521100831			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

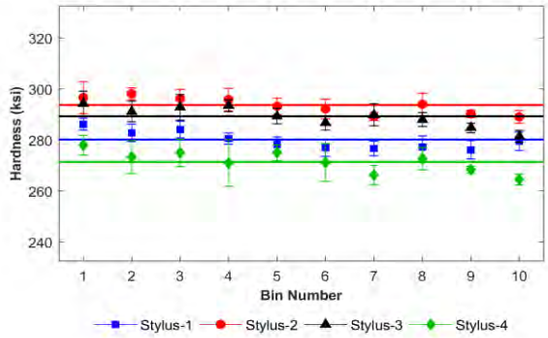
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	280.2	4.50	52
Stylus-2	293.8	4.61	53
Stylus-3	289.3	4.94	54
Stylus-4	271.4	6.23	51

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.07	0.010	0.008	0.03	0.02	0.07	0.03	< 0.01	0.02	0.21	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

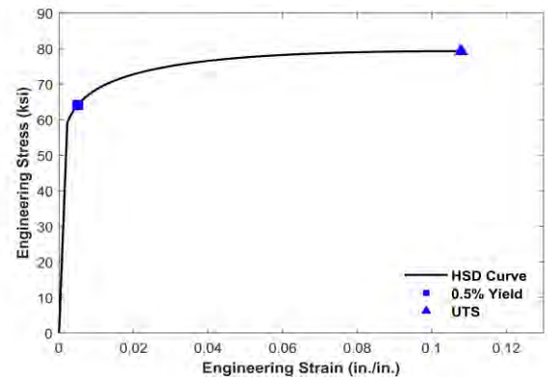
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.1	64.6	64.5	63.3
UTS (ksi)	79.2	79.8	79.3	78.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190524105236	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:52	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	5-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JJ	
Test Name	5-Q1_BM-01_7001-EB7001_190524105236			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

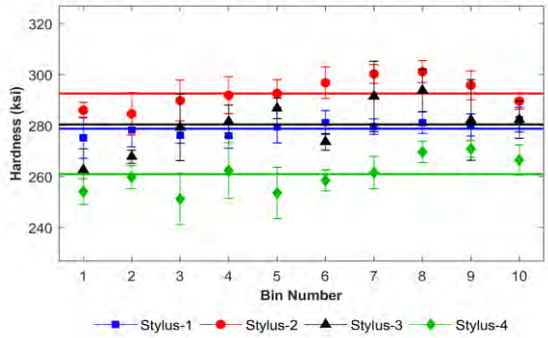
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	278.8	5.29	51
Stylus-2	292.5	7.62	54
Stylus-3	280.5	12.39	55
Stylus-4	261.0	8.97	47

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.62	0.009	< 0.005	0.02	0.01	0.01	0.06	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

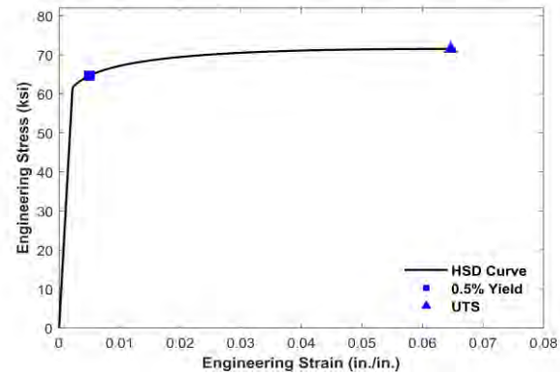
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.6	63.1	63.7	60.2
UTS (ksi)	71.5	70.7	71.4	72.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190524112228	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	5-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JJ	
Test Name	5-Q1_BM-02_7001-EB7001_190524112228			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

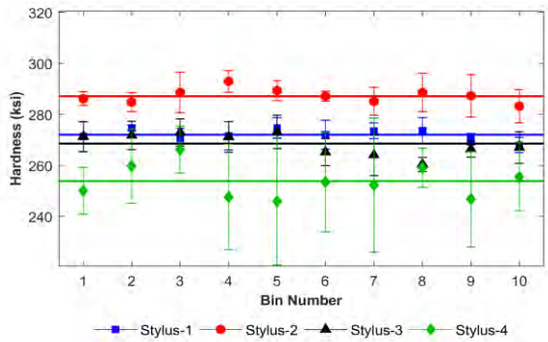
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	272.1	4.30	51
Stylus-2	287.1	5.71	50
Stylus-3	268.6	6.63	54
Stylus-4	253.7	16.74	49

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.62	0.009	< 0.005	0.02	0.01	0.01	0.06	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

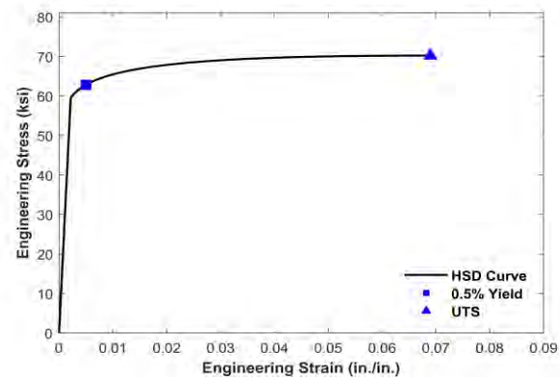
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.8	64.3	61.0	62.9
UTS (ksi)	70.2	70.5	70.3	70.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190524120114	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:01	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	5-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JJ	
Test Name	5-Q1_BM-03_7001-EB7001_190524120114			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

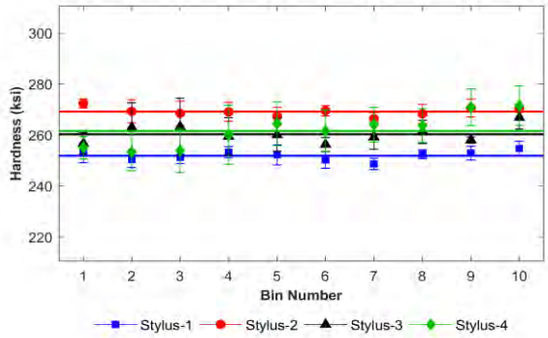
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	251.8	3.11	50
Stylus-2	269.1	3.43	50
Stylus-3	260.2	6.37	43
Stylus-4	261.5	9.51	55

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.62	0.009	< 0.005	0.02	0.01	0.01	0.06	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

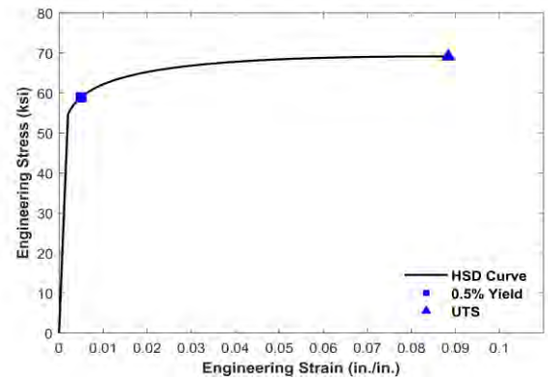
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.9	57.2	59.2	60.2
UTS (ksi)	69.1	68.3	69.3	70.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

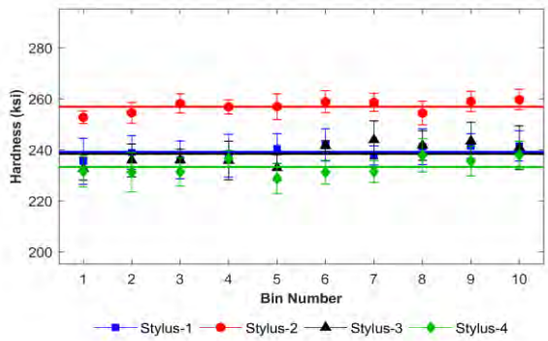
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530114931	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:49	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	6-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JN	
Test Name	6-Q1_BM-01_7001-EB7001_190530114931			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Ver. 2.2

	HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	239.2	6.59	58
Stylus-2	256.9	4.17	51
Stylus-3	238.4	7.08	56
Stylus-4	233.2	6.04	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.07	0.63	0.010	< 0.005	0.02	0.01	0.01	0.05	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005	9.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

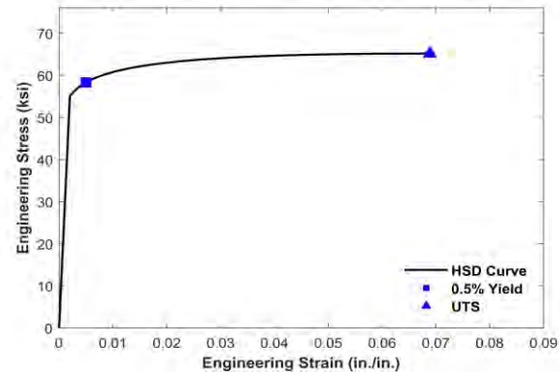
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.3	57.9	57.9	59.0
UTS (ksi)	65.2	64.8	65.1	65.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523180341	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	6-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JN	
Test Name	6-Q1_BM-01_7003-EB7003_190523180341			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

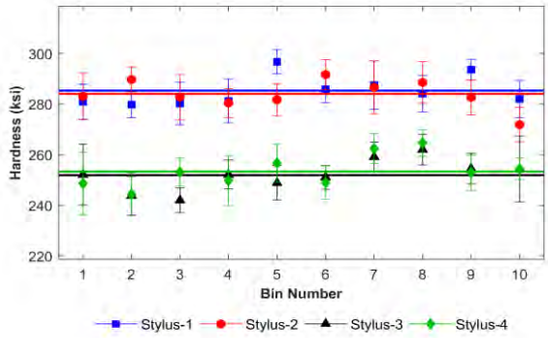
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	285.3	8.54	55
Stylus-2	284.0	8.55	52
Stylus-3	251.9	9.22	51
Stylus-4	253.4	9.02	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.63	0.010	< 0.005	0.02	0.01	0.01	0.05	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

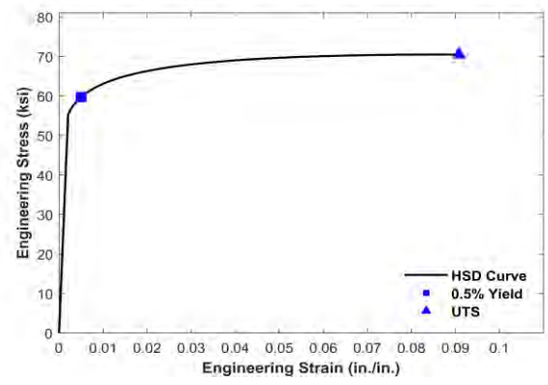
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	59.7	58.5	59.4	60.9
UTS (ksi)	70.5	70.0	70.7	70.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523185038	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:50	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	6-Q1	Pipe Size	24 OD x 0.38 WT (in)	Operator Initials	JN	
Test Name	6-Q1_BM-03_7003-EB7003_190523185038			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

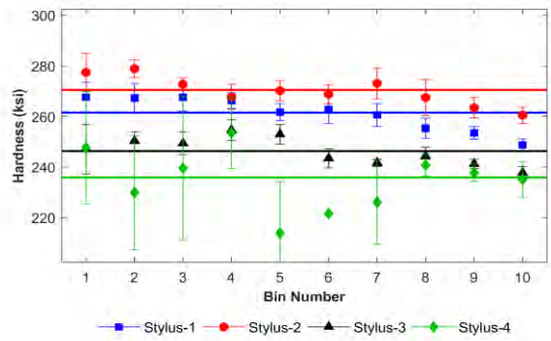
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	261.4	7.26	57
Stylus-2	270.4	6.73	51
Stylus-3	246.2	6.56	58
Stylus-4	235.9	18.78	49

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.63	0.010	< 0.005	0.02	0.01	0.01	0.05	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

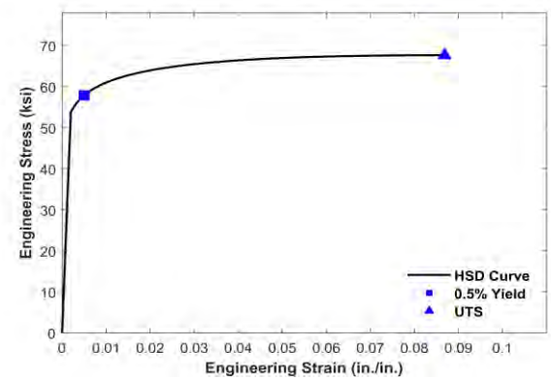
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	57.9	58.5	56.0	58.6
UTS (ksi)	67.7	68.5	68.1	66.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190424173445	REV --
Test Location	Gas Technology Institute			Test Date	4/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:34	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	12-Q1	Pipe Size	12 OD x 0.40 WT (in)	Operator Initials	RP	
Test Name	12-Q1_BM-01_5001-EB5001_190424173445			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

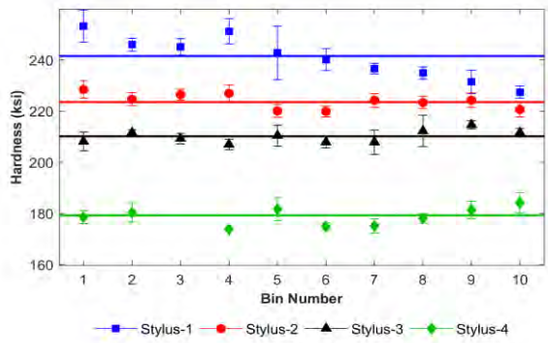
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	241.6	9.30	64
Stylus-2	223.6	3.63	53
Stylus-3	210.2	3.76	58
Stylus-4	179.3	4.27	50

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.54	0.008	0.029	0.03	< 0.01	< 0.01	0.03	0.01	0.02	0.16	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

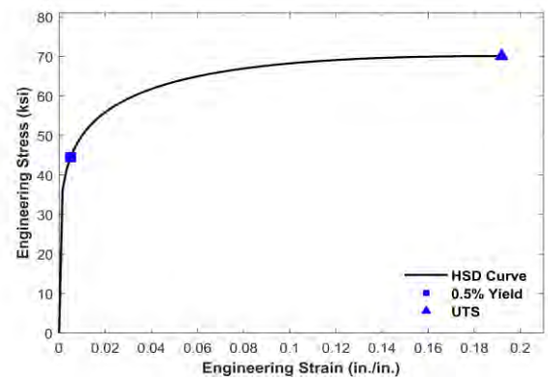
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	44.5	43.1	44.1	45.8
UTS (ksi)	70.1	72.4	70.9	68.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425122050	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	12-Q1	Pipe Size	12 OD x 0.40 WT (in)	Operator Initials	JJ	
Test Name	12-Q1_BM-02_7001-EB7001_190425122050			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

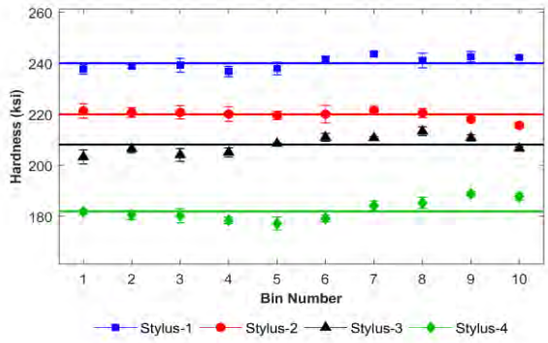
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	240.1	2.82	37
Stylus-2	220.0	2.53	37
Stylus-3	208.2	3.51	39
Stylus-4	182.0	4.01	38

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.54	0.008	0.029	0.03	< 0.01	< 0.01	0.03	0.01	0.02	0.16	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

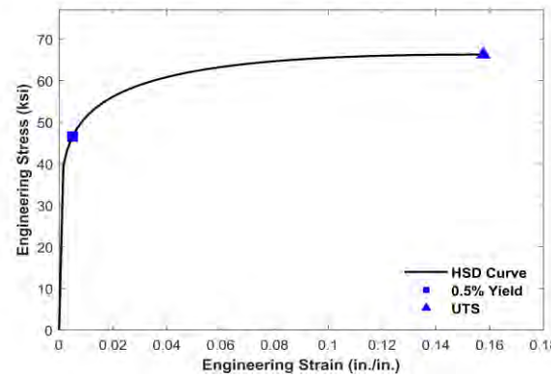
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.5	46.1	45.6	48.0
UTS (ksi)	66.3	66.0	66.4	66.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529133441	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:34	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	13-Q1	Pipe Size	16 OD x 0.22 WT (in)	Operator Initials	JN	
Test Name	13-Q1_BM-02_7001-EB7001_190529133441			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

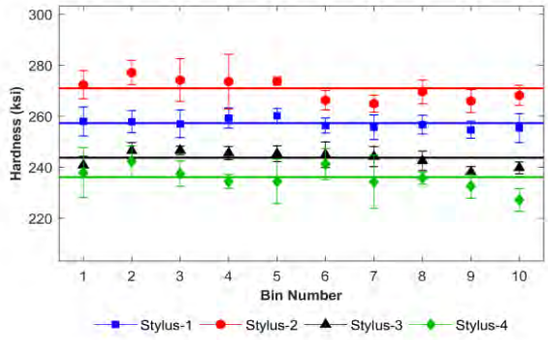
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.2	4.26	51
Stylus-2	270.9	6.70	52
Stylus-3	243.7	4.00	52
Stylus-4	236.0	7.36	53

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.92	0.011	0.025	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

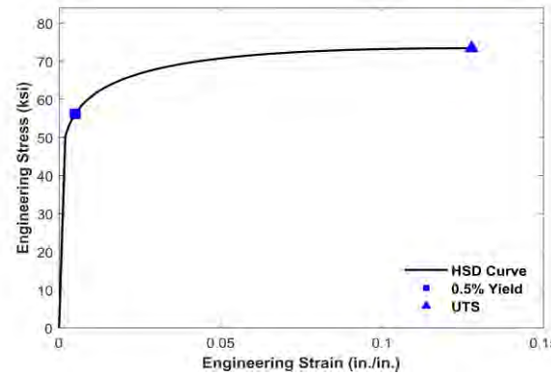
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	56.2	56.7	56.5	55.9
UTS (ksi)	73.4	72.9	73.8	73.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523113112	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:31	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	13-Q2	Pipe Size	16 OD x 0.22 WT (in)	Operator Initials		
Test Name	13-Q2_BM-02_7003-EB7003_190523113112			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

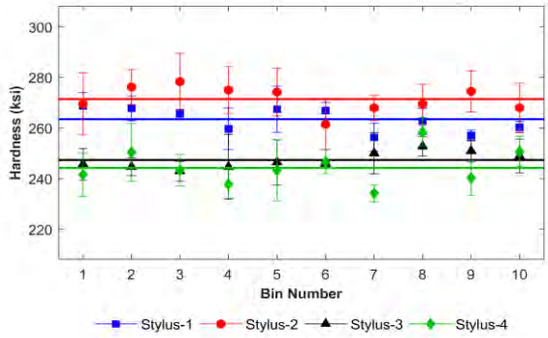
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	263.5	6.38	36
Stylus-2	271.5	9.41	40
Stylus-3	247.4	6.82	37
Stylus-4	244.2	9.20	37

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.92	0.011	0.025	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

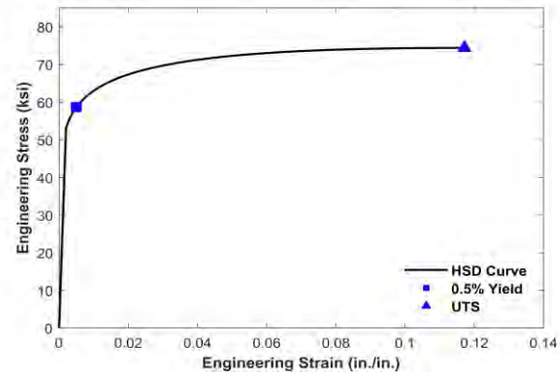
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.6	57.9	58.0	60.0
UTS (ksi)	74.4	74.8	74.3	74.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522190453	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	18-Q1	Pipe Size	20 OD x 0.24 WT (in)	Operator Initials		
Test Name	18-Q1_BM-01_7003-EB7003_190522190453			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

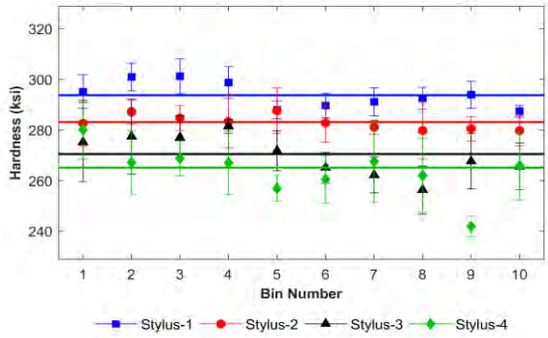
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	293.8	6.84	54
Stylus-2	283.1	6.99	49
Stylus-3	270.5	11.61	50
Stylus-4	265.2	13.46	51

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.37	0.007	0.018	0.02	0.03	0.03	< 0.01	0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

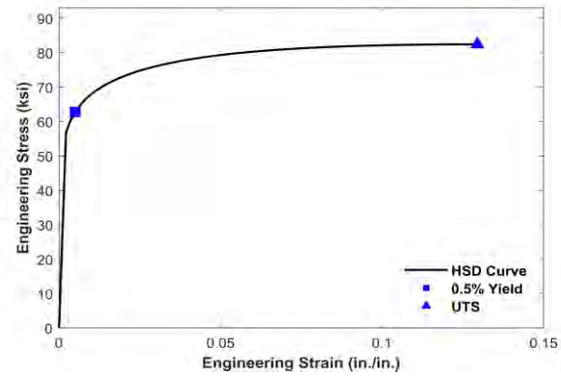
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.8	65.2	63.5	61.7
UTS (ksi)	82.4	82.0	83.2	81.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529175402	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	18-Q1	Pipe Size	20 OD x 0.24 WT (in)	Operator Initials	JN	
Test Name	18-Q1_BM-02_7001-EB7001_190529175402			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

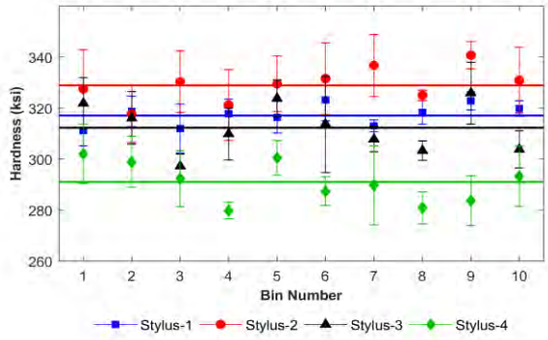
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	317.0	6.88	52
Stylus-2	328.9	12.76	52
Stylus-3	312.3	12.96	56
Stylus-4	290.9	11.56	46

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.37	0.007	0.018	0.02	0.03	0.03	< 0.01	0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

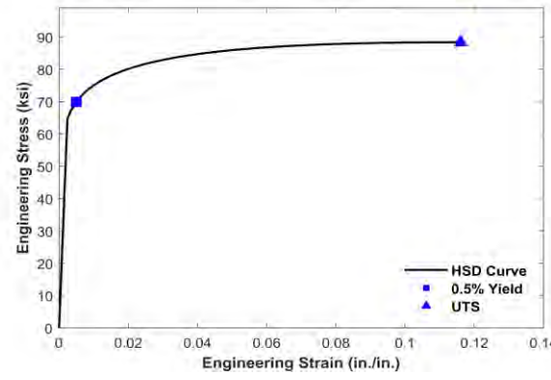
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	69.9	65.1	70.0	68.2
UTS (ksi)	88.4	88.3	88.5	88.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522152433	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:24	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	19-Q1	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	19-Q1_BM-01_7001-EB7001_190522152433			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

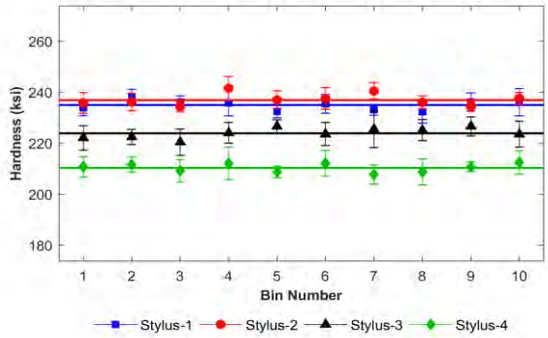
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	235.0	3.85	51
Stylus-2	236.9	3.50	44
Stylus-3	223.9	4.55	52
Stylus-4	210.3	4.10	49

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.012	0.029	0.03	< 0.01	0.11	< 0.01	< 0.01	0.04	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

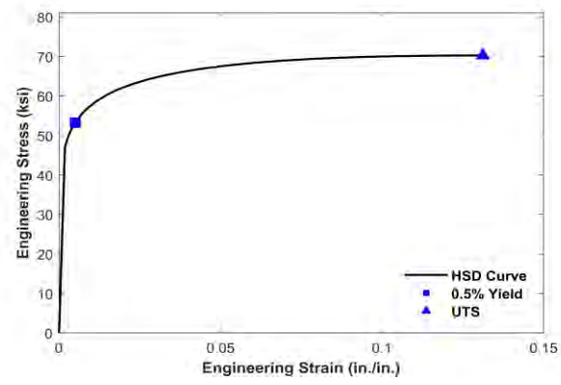
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.2	53.0	53.5	53.2
UTS (ksi)	70.2	70.2	70.2	70.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522184237	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:42	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	19-Q1	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials		
Test Name	19-Q1_BM-01_7003-EB7003_190522184237			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

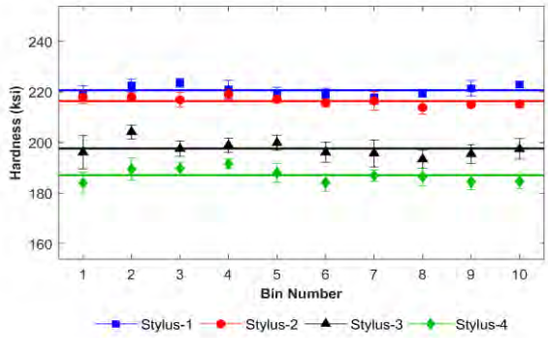
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	220.7	2.98	47
Stylus-2	216.4	2.55	47
Stylus-3	197.6	4.65	50
Stylus-4	187.1	3.83	46

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.012	0.029	0.03	< 0.01	0.11	< 0.01	< 0.01	0.04	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

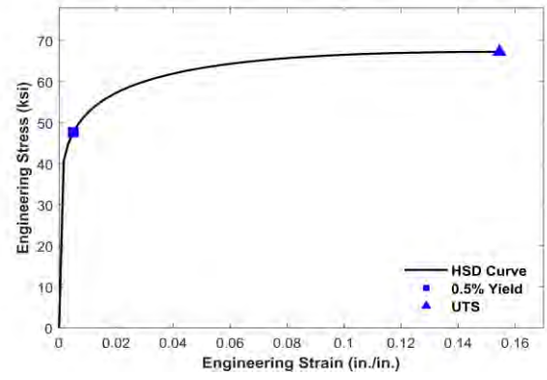
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.7	48.0	48.0	47.1
UTS (ksi)	67.3	67.5	67.2	67.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529190333	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	19-Q1	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials	JN	
Test Name	19-Q1_BM-02_7001-EB7001_190529190333			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

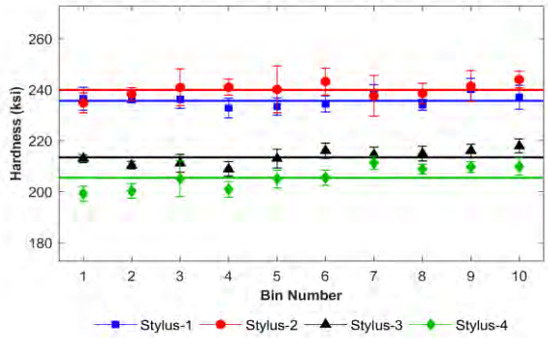
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	235.6	3.72	45
Stylus-2	239.8	5.79	54
Stylus-3	213.4	3.69	55
Stylus-4	205.3	5.25	58

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.012	0.029	0.03	< 0.01	0.11	< 0.01	< 0.01	0.04	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

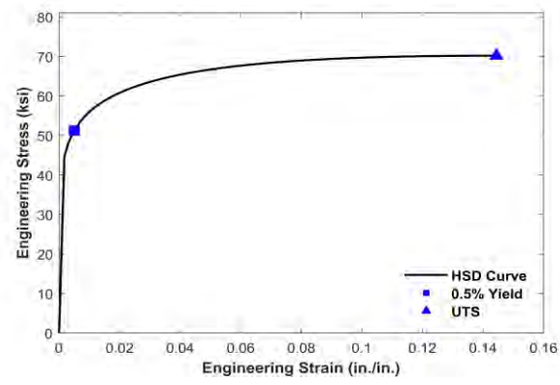
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.2	49.5	50.6	52.1
UTS (ksi)	70.2	70.1	70.1	70.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523111909	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:19	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	24-Q1	Pipe Size	12 OD x 0.46 WT (in)	Operator Initials	JJ	
Test Name	24-Q1_BM-01_7001-EB7001_190523111909			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

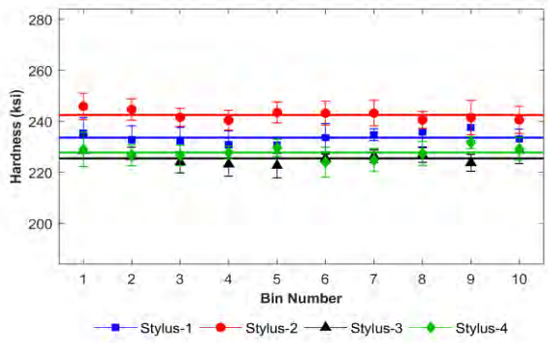
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	233.6	5.03	53
Stylus-2	242.5	4.57	54
Stylus-3	225.4	4.23	50
Stylus-4	227.7	4.59	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	1.02	0.011	0.013	0.03	< 0.01	0.03	0.06	< 0.01	0.01	0.22	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

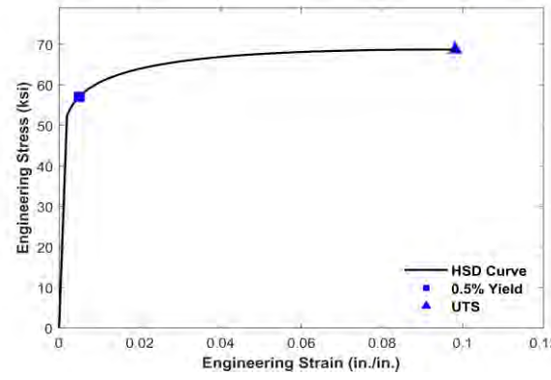
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	57.1	57.0	57.0	57.2
UTS (ksi)	68.7	68.8	68.6	68.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509160937	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:09	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	24-Q2	Pipe Size	12 OD x 0.46 WT (in)	Operator Initials	RP	
Test Name	24-Q2_BM-01_5002-EB5002_190509160937			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

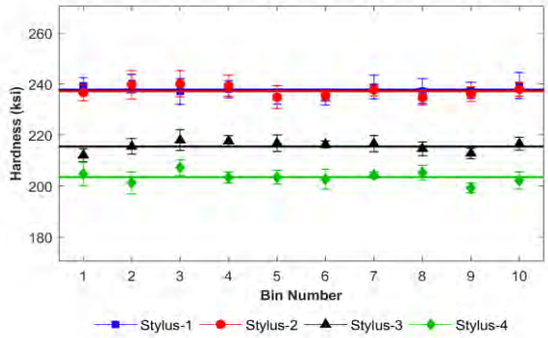
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	237.8	4.06	61
Stylus-2	237.2	3.94	59
Stylus-3	215.6	3.16	58
Stylus-4	203.5	3.61	59

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	1.02	0.011	0.013	0.03	< 0.01	0.03	0.06	< 0.01	0.01	0.22	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

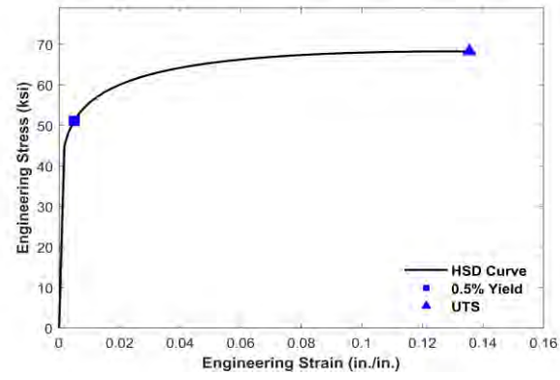
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.1	51.2	51.3	50.9
UTS (ksi)	68.3	68.4	68.2	68.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522163915	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	24-Q2	Pipe Size	12 OD x 0.46 WT (in)	Operator Initials		
Test Name	24-Q2_BM-01_7003-EB7003_190522163915			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.80002	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

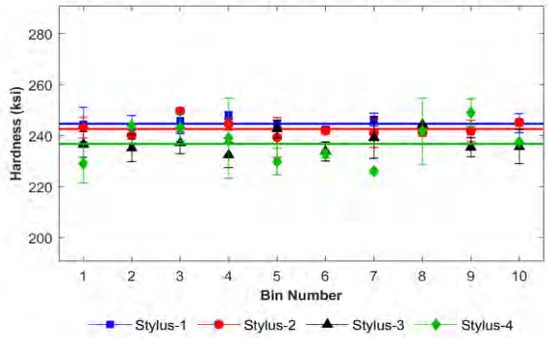
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	244.6	3.56	21
Stylus-2	242.6	3.85	19
Stylus-3	236.8	5.02	20
Stylus-4	236.8	9.21	21

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	1.02	0.011	0.013	0.03	< 0.01	0.03	0.06	< 0.01	0.01	0.22	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

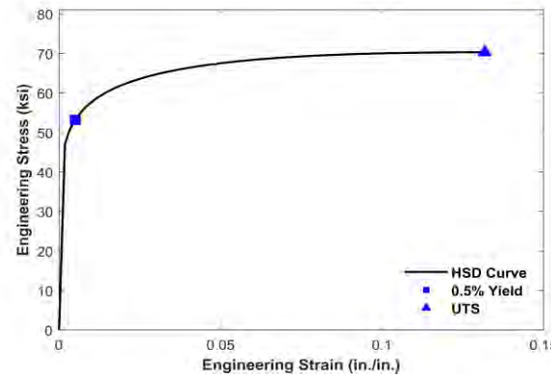
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.2	52.8	52.6	54.2
UTS (ksi)	70.3	70.2	70.1	70.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425124042	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:40	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	25-Q1	Pipe Size	18 OD x 0.33 WT (in)	Operator Initials	RP	
Test Name	25-Q1_BM-01_5001-EB5001_190425124042			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

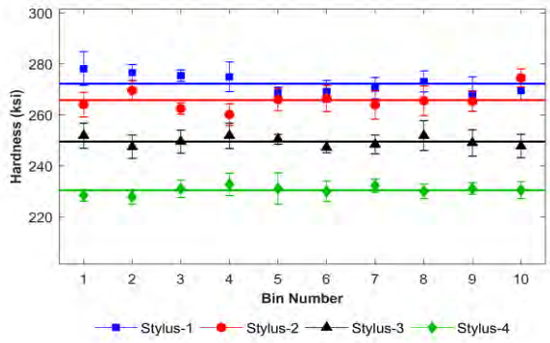
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	272.2	5.33	58
Stylus-2	265.7	5.56	63
Stylus-3	249.5	4.45	59
Stylus-4	230.4	3.47	56

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.85	0.008	0.017	0.03	< 0.01	0.08	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.2

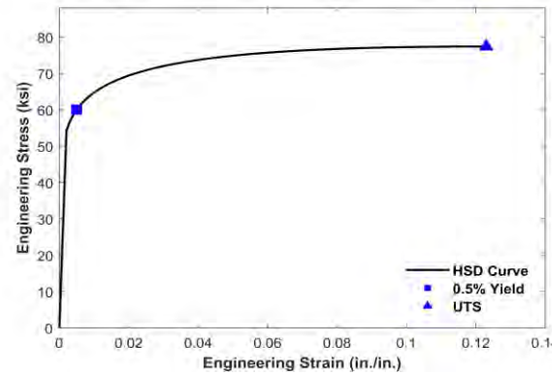
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	60.0	59.0	60.8	60.3
UTS (ksi)	77.4	78.1	76.9	77.3



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522165406	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	25-Q1	Pipe Size	18 OD x 0.33 WT (in)	Operator Initials	JJ	
Test Name	25-Q1_BM-01_7001-EB7001_190522165406			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

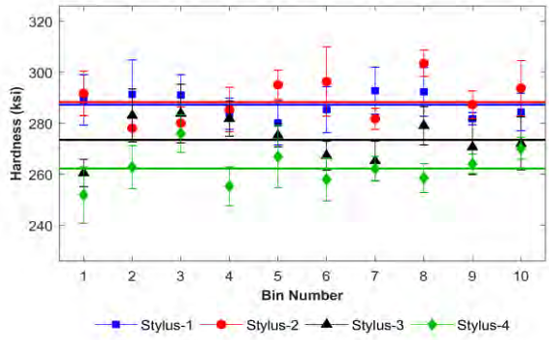
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	287.2	9.32	46
Stylus-2	288.2	10.24	48
Stylus-3	273.5	10.68	50
Stylus-4	262.2	10.38	48

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.85	0.008	0.017	0.03	< 0.01	0.08	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

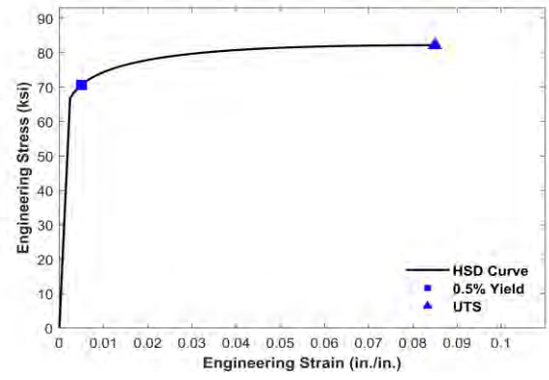
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	70.6	70.5	70.9	70.4
UTS (ksi)	82.2	82.2	82.1	82.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529162259	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	25-Q1	Pipe Size	18 OD x 0.33 WT (in)	Operator Initials	JN	
Test Name	25-Q1_BM-02_7001-EB7001_190529162259			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

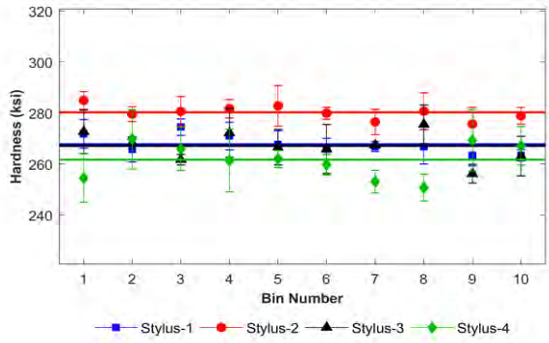
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	267.8	5.46	55
Stylus-2	280.3	5.30	52
Stylus-3	267.1	8.67	48
Stylus-4	261.7	10.30	52

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.85	0.008	0.017	0.03	< 0.01	0.08	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

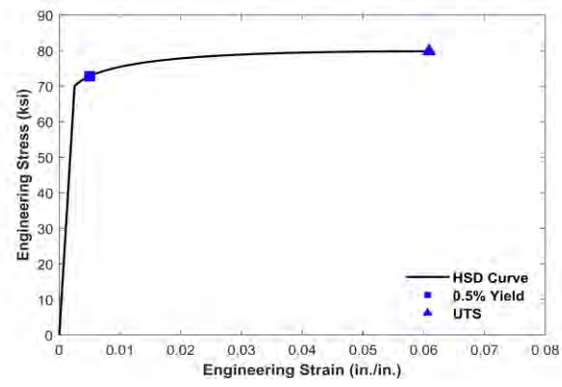
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	72.8	73.1	72.6	72.5
UTS (ksi)	79.8	80.1	79.9	79.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522183130	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:31	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	26-Q1	Pipe Size	18 OD x 0.40 WT (in)	Operator Initials	JJ	
Test Name	26-Q1_BM-01_7001-EB7001_190522183130			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

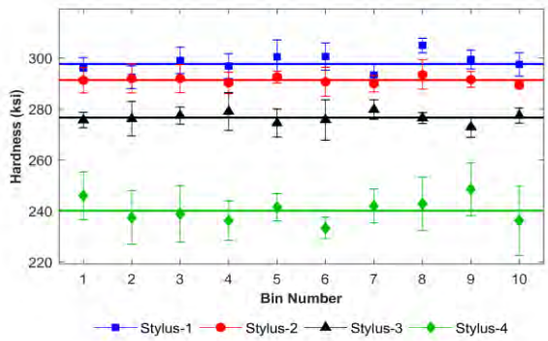
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	297.6	5.44	50
Stylus-2	291.3	4.31	49
Stylus-3	276.6	5.14	49
Stylus-4	240.1	9.50	47

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.15	0.010	0.023	0.04	< 0.01	0.01	0.05	0.02	0.03	0.18	< 0.01	0.06	< 0.0005

Grain Size

mli (µm)
10.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

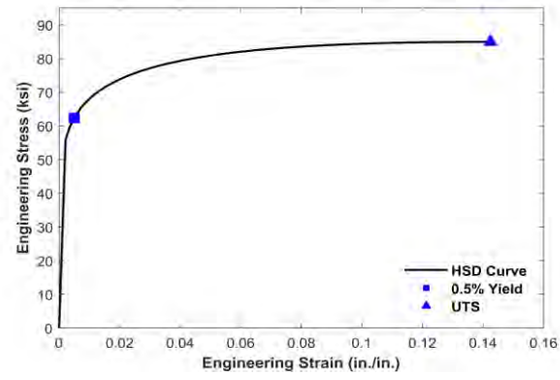
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.3	62.6	61.5	63.0
UTS (ksi)	84.9	84.7	85.2	84.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425120349	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	26-Q1	Pipe Size	18 OD x 0.40 WT (in)	Operator Initials	RP	
Test Name	26-Q1_BM-02_5001-EB5001_190425120349			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

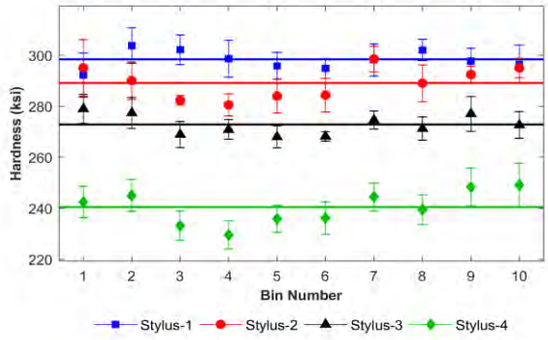
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	298.4	6.55	58
Stylus-2	289.2	8.29	62
Stylus-3	272.9	5.97	58
Stylus-4	240.5	8.35	59

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.15	0.010	0.023	0.04	< 0.01	0.01	0.05	0.02	0.03	0.18	< 0.01	0.06	< 0.0005

Grain Size

mli (µm)
10.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

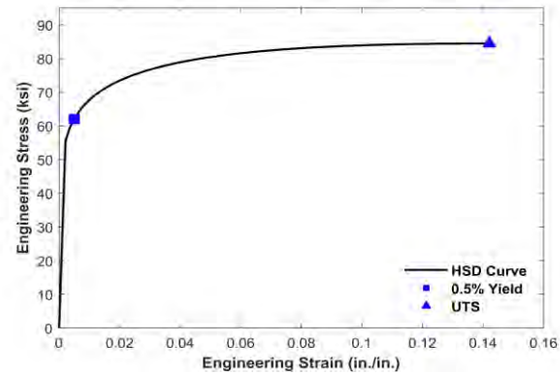
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.0	62.1	60.7	63.4
UTS (ksi)	84.4	84.8	83.8	84.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522155253	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:52	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	27-Q1	Pipe Size	18 OD x 0.44 WT (in)	Operator Initials	JJ	
Test Name	27-Q1_BM-01_7001-EB7001_190522155253			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

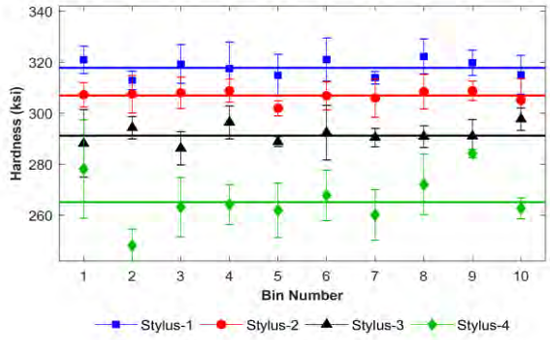
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	317.7	6.97	51
Stylus-2	306.9	5.84	52
Stylus-3	291.2	6.97	48
Stylus-4	265.1	12.46	48

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	1.32	0.010	0.032	0.06	0.01	0.01	< 0.01	0.01	0.04	0.19	< 0.01	0.07	< 0.0005

Grain Size

mli (µm)
10.6

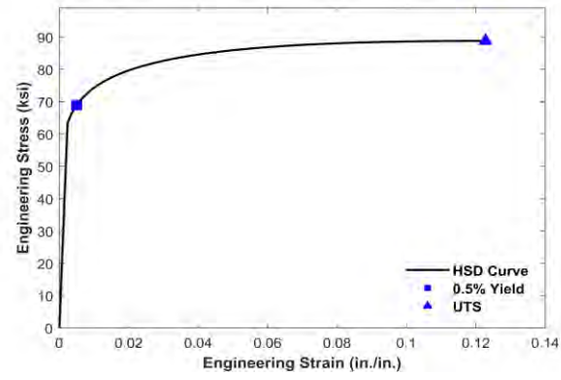
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	68.9	68.1	69.1	69.5
UTS (ksi)	88.8	88.9	88.7	88.8



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522172140	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	27-Q1	Pipe Size	18 OD x 0.44 WT (in)	Operator Initials		
Test Name	27-Q1_BM-01_7003-EB7003_190522172140			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

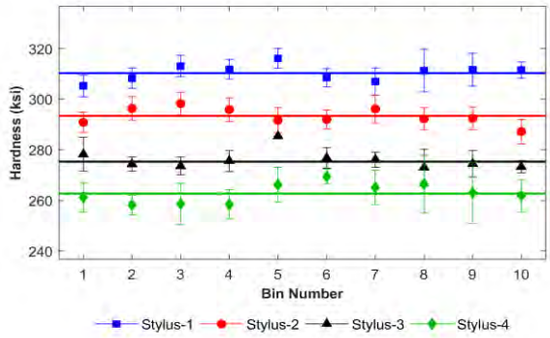
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	310.4	5.37	52
Stylus-2	293.3	5.26	52
Stylus-3	275.3	4.87	45
Stylus-4	262.7	7.69	40

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	1.32	0.010	0.032	0.06	0.01	0.01	< 0.01	0.01	0.04	0.19	< 0.01	0.07	< 0.0005

Grain Size

mli (µm)
10.6

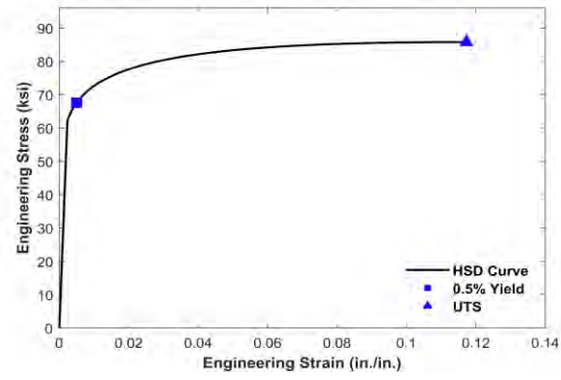
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	67.6	66.8	68.0	67.9
UTS (ksi)	85.7	85.8	86.1	85.4



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522175910	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:59	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	27-Q1	Pipe Size	18 OD x 0.44 WT (in)	Operator Initials		
Test Name	27-Q1_BM-02_7003-EB7003_190522175910			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

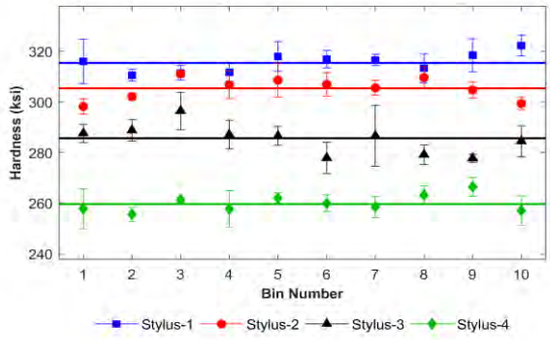
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	315.4	5.49	47
Stylus-2	305.4	5.47	46
Stylus-3	285.7	7.66	45
Stylus-4	259.6	5.26	42

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	1.32	0.010	0.032	0.06	0.01	0.01	< 0.01	0.01	0.04	0.19	< 0.01	0.07	< 0.0005

Grain Size

mli (µm)
10.6

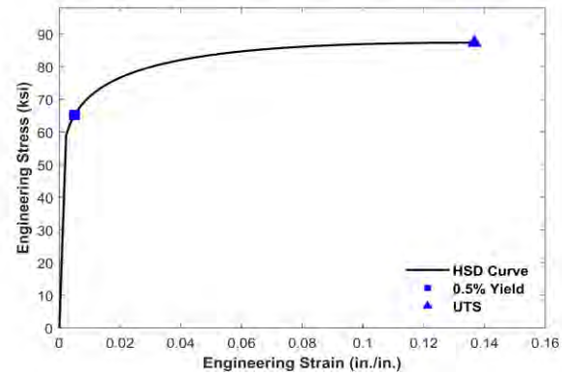
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	65.2	65.3	65.6	64.8
UTS (ksi)	87.4	86.6	87.7	87.5



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523134804	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:48	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	28-Q1	Pipe Size	16 OD x 0.28 WT (in)	Operator Initials	JJ	
Test Name	28-Q1_BM-01_7001-EB7001_190523134804			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

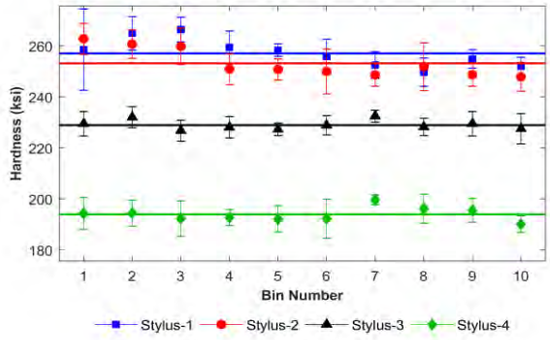
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.1	7.69	51
Stylus-2	253.2	7.88	52
Stylus-3	228.9	4.11	52
Stylus-4	193.9	5.48	57

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.59	0.020	0.014	< 0.01	< 0.01	0.01	0.01	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.2

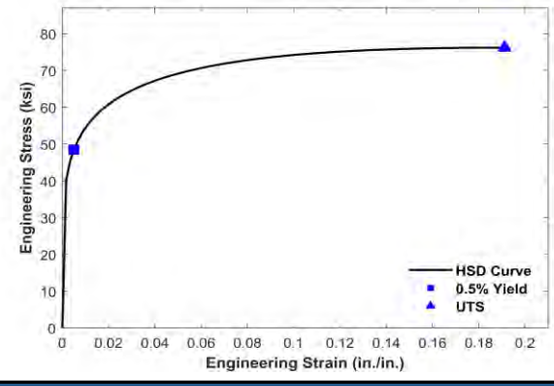
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	48.5	47.5	48.1	49.6
UTS (ksi)	76.2	78.9	75.9	74.6



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523122028	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	28-Q1	Pipe Size	16 OD x 0.28 WT (in)	Operator Initials		
Test Name	28-Q1_BM-01_7003-EB7003_190523122028			Sample Type	Cutout	
Sample Description						

Surface Finish	2000	Grit	LVDT-1 Serial No.	L01-190107
HSD Core Speed	0.117	in/min	LVDT-2 Serial No.	L02-190107
Travel Distance	1.333	in	Stylus-1 Serial No.	103-190412
Profiler Speed	2.8	in/min	Stylus-2 Serial No.	105-XXXXXX
Sampling Rate	1600	Hz	Stylus-3 Serial No.	109-190520
			Stylus-4 Serial No.	118-190520

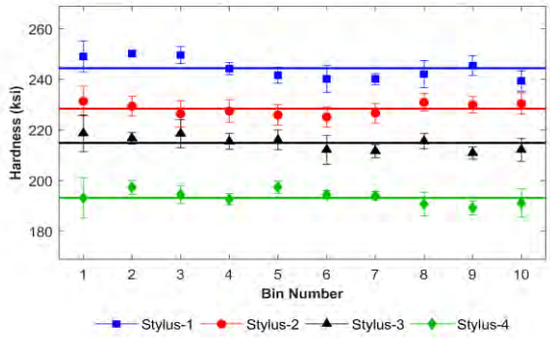
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	244.4	5.44	53
Stylus-2	228.4	4.51	52
Stylus-3	214.9	4.70	53
Stylus-4	193.2	4.14	41

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.59	0.020	0.014	< 0.01	< 0.01	0.01	0.01	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.2

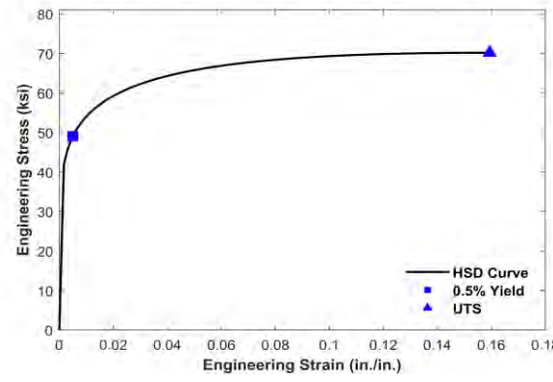
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.0	49.3	49.6	48.5
UTS (ksi)	70.1	71.1	69.5	69.9



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523112457	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:24	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	29-Q1	Pipe Size	16 OD x 0.29 WT (in)	Operator Initials		
Test Name	29-Q1_BM-01_7003-EB7003_190523112457			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

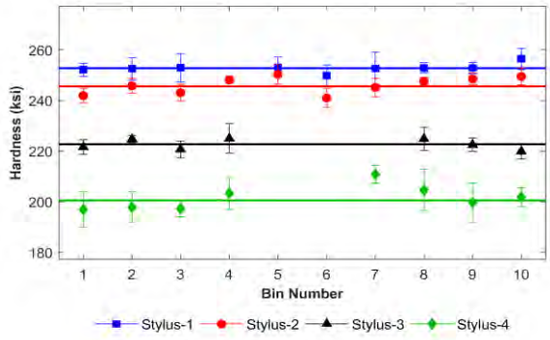
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	252.8	4.15	48
Stylus-2	245.6	4.11	45
Stylus-3	222.7	3.81	38
Stylus-4	200.5	6.71	40

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.53	0.012	0.016	< 0.01	< 0.01	< 0.01	0.02	< 0.01	0.01	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (μm)
11.2

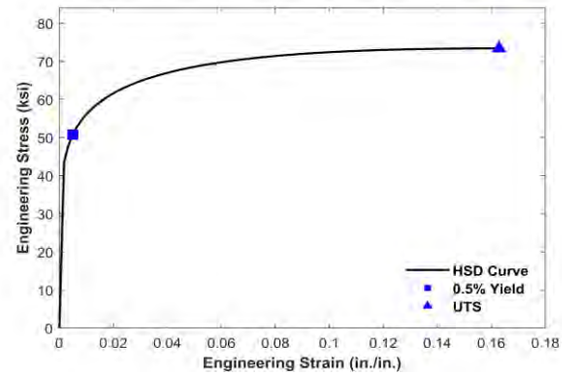
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.8	50.0	51.2	51.3
UTS (ksi)	73.4	73.2	73.2	73.6



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523114522	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:45	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	29-Q1	Pipe Size	16 OD x 0.29 WT (in)	Operator Initials		
Test Name	29-Q1_BM-01_7003-EB7003_190523114522			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

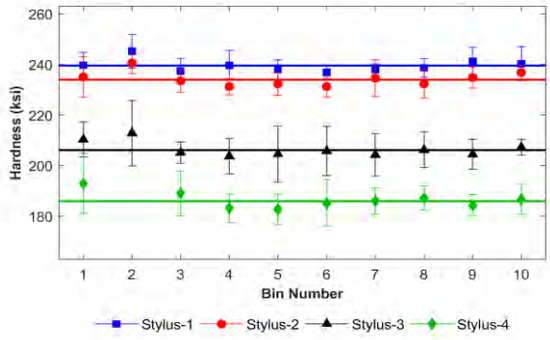
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	239.5	5.15	55
Stylus-2	234.0	5.29	51
Stylus-3	206.1	7.56	52
Stylus-4	185.9	6.80	45

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.53	0.012	0.016	< 0.01	< 0.01	< 0.01	0.02	< 0.01	0.01	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.2

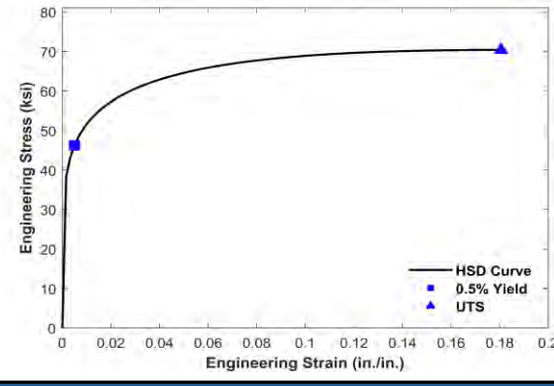
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.2	48.1	45.5	46.2
UTS (ksi)	70.4	70.4	70.1	70.3



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523142244	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	31-Q1	Pipe Size	16 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	31-Q1_BM-01_7001-EB7001_190523142244			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

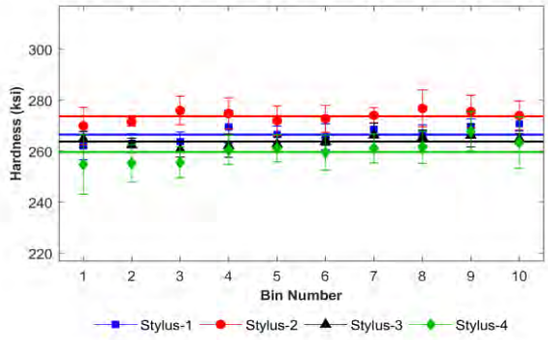
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	266.5	4.84	52
Stylus-2	273.7	5.41	50
Stylus-3	263.8	3.45	45
Stylus-4	259.6	7.56	54

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.98	0.006	0.031	0.05	< 0.01	0.07	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

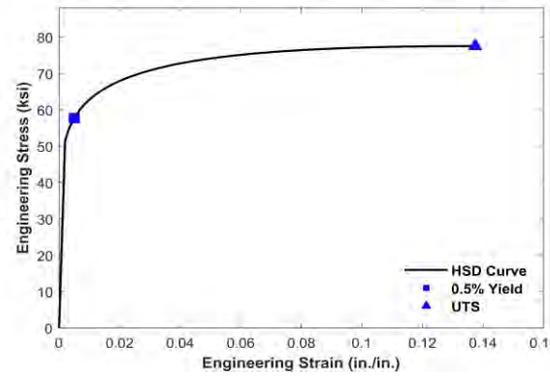
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	57.7	57.0	57.9	58.3
UTS (ksi)	77.5	77.1	77.5	78.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523105445	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	31-Q1	Pipe Size	16 OD x 0.25 WT (in)	Operator Initials		
Test Name	31-Q1_BM-01_7003-EB7003_190523105445			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

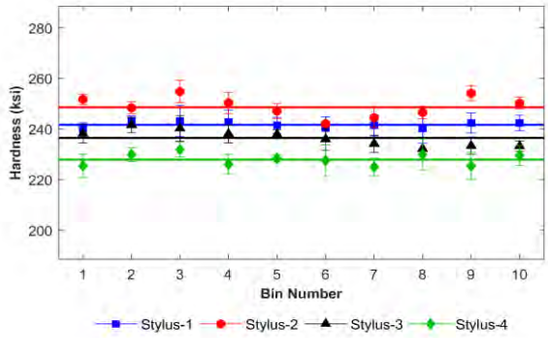
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	241.6	3.78	47
Stylus-2	248.6	4.63	46
Stylus-3	236.5	4.31	47
Stylus-4	227.9	4.56	44

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.98	0.006	0.031	0.05	< 0.01	0.07	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

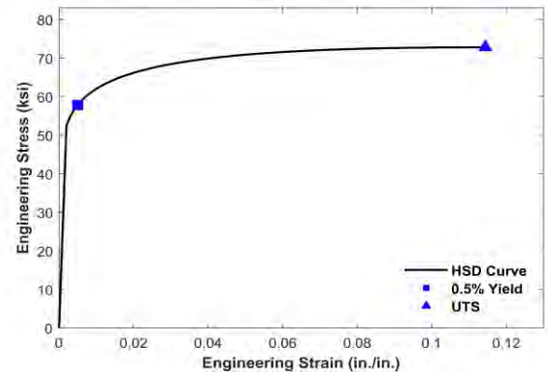
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	57.8	58.4	57.6	57.6
UTS (ksi)	72.8	73.1	72.6	72.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523144010	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:40	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	31-Q1	Pipe Size	16 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	31-Q1_BM-02_7001-EB7001_190523144010			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

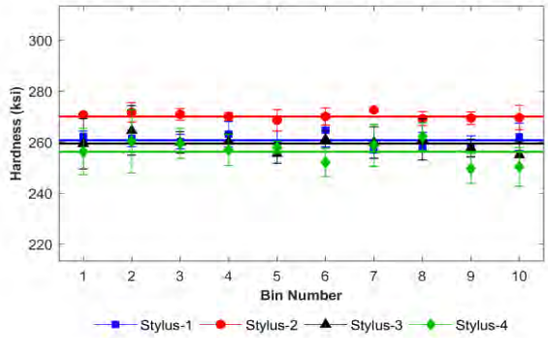
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	260.7	4.65	51
Stylus-2	270.1	3.11	46
Stylus-3	259.5	6.26	55
Stylus-4	256.2	7.53	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.98	0.006	0.031	0.05	< 0.01	0.07	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

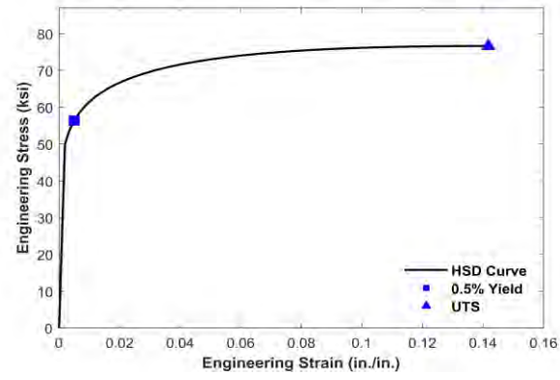
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	56.4	56.9	56.1	56.1
UTS (ksi)	76.6	76.9	76.6	76.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523165856	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	32-Q1	Pipe Size	26 OD x 0.26 WT (in)	Operator Initials	JN	
Test Name	32-Q1_BM-01_7003-EB7003_190523165856			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

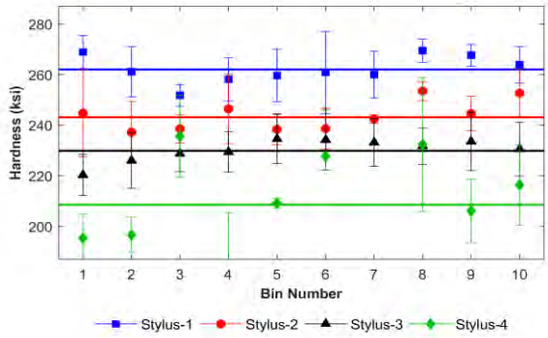
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	262.0	9.46	54
Stylus-2	243.2	10.21	53
Stylus-3	229.8	9.62	50
Stylus-4	208.6	18.55	30

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.010	0.024	0.02	< 0.01	0.05	< 0.01	< 0.01	0.01	0.03	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

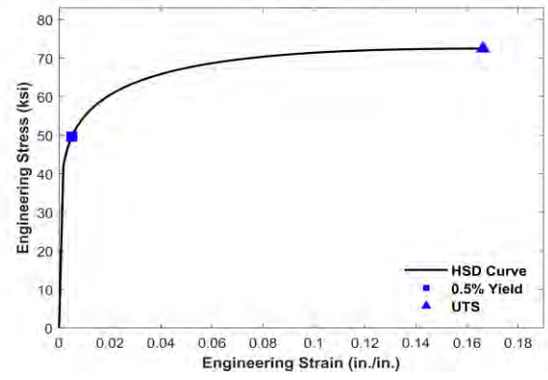
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.6	48.2	50.6	50.9
UTS (ksi)	72.4	72.3	72.0	73.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523191202	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:12	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	32-Q1	Pipe Size	26 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	32-Q1_BM-02_7001-EB7001_190523191202			Sample Type	Cutout	
Sample Description						

Surface Finish	2000	Grit	LVDT-1 Serial No.	L01-190107
HSD Core Speed	0.117	in/min	LVDT-2 Serial No.	L02-190107
Travel Distance	1.333	in	Stylus-1 Serial No.	103-190412
Profiler Speed	2.8	in/min	Stylus-2 Serial No.	105-190412
Sampling Rate	1600	Hz	Stylus-3 Serial No.	109-190520
			Stylus-4 Serial No.	118-190520

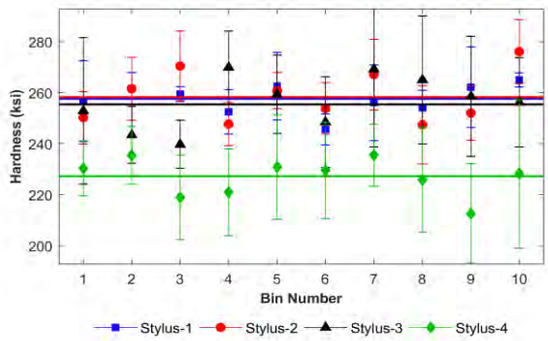
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.5	10.98	54
Stylus-2	258.2	14.15	50
Stylus-3	255.3	20.48	51
Stylus-4	227.2	17.83	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.010	0.024	0.02	< 0.01	0.05	< 0.01	< 0.01	0.01	0.03	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

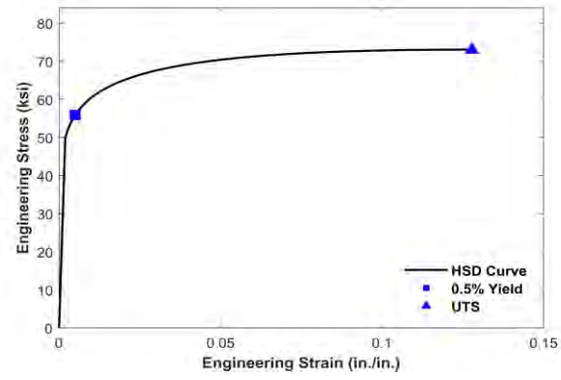
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	55.9	55.4	56.7	55.7
UTS (ksi)	73.0	72.9	72.7	73.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523194040	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:40	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	32-Q1	Pipe Size	26 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	32-Q1_BM-02_7001-EB7001_190523194040			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

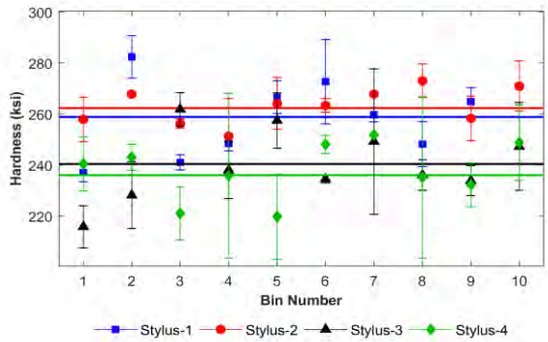
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	258.9	16.15	34
Stylus-2	262.3	9.23	25
Stylus-3	240.4	18.09	33
Stylus-4	236.1	17.65	30

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.80	0.010	0.024	0.02	< 0.01	0.05	< 0.01	< 0.01	0.01	0.03	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

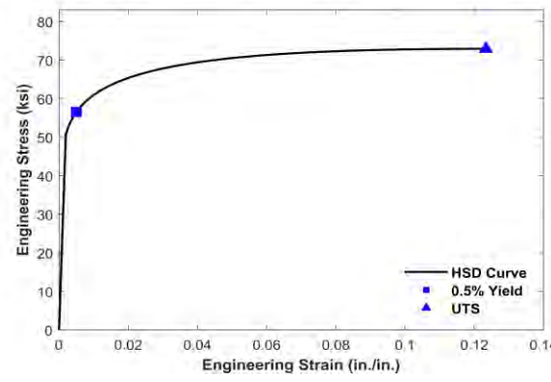
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	56.5	56.4	55.9	57.3
UTS (ksi)	72.9	72.2	73.1	73.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523131921	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:19	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	33-Q1	Pipe Size	16 OD x 0.40 WT (in)	Operator Initials	JJ	
Test Name	33-Q1_BM-01_7001-EB7001_190523131921			Sample Type	Cutout	
Sample Description						

Surface Finish	2000	Grit	LVDT-1 Serial No.	L01-190107
HSD Core Speed	0.117	in/min	LVDT-2 Serial No.	L02-190107
Travel Distance	1.333	in	Stylus-1 Serial No.	103-190412
Profiler Speed	2.8	in/min	Stylus-2 Serial No.	105-190412
Sampling Rate	1600	Hz	Stylus-3 Serial No.	109-190520
			Stylus-4 Serial No.	118-190520

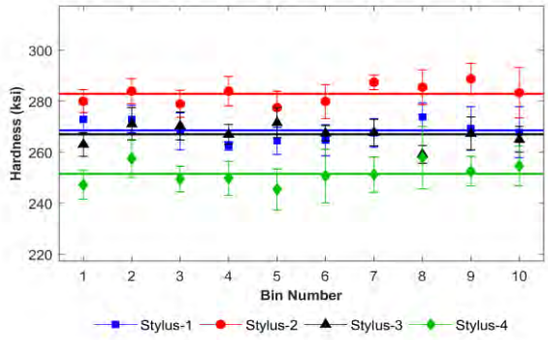
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	268.6	6.94	51
Stylus-2	282.8	6.65	49
Stylus-3	267.0	5.84	54
Stylus-4	251.5	8.17	57

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.52	< 0.005	0.026	0.04	< 0.01	0.20	< 0.01	0.01	0.06	0.08	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
16.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

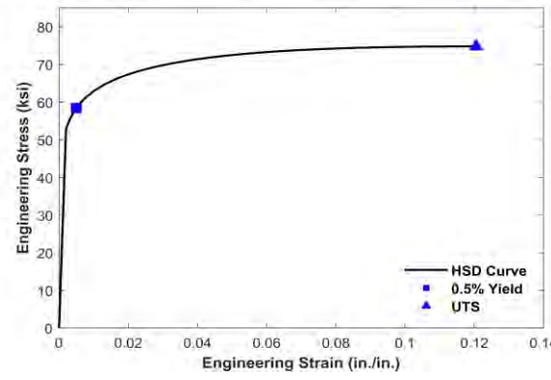
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.4	58.1	58.4	58.8
UTS (ksi)	74.8	74.9	74.4	75.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523124441	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:44	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	33-Q1	Pipe Size	16 OD x 0.40 WT (in)	Operator Initials		
Test Name	33-Q1_BM-02_7003-EB7003_190523124441			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

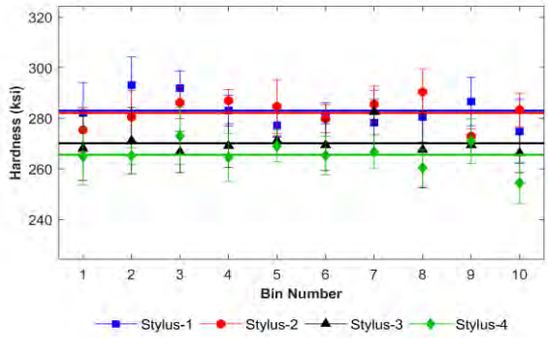
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	283.0	10.15	52
Stylus-2	282.1	8.59	50
Stylus-3	270.1	9.60	51
Stylus-4	265.6	8.94	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.52	< 0.005	0.026	0.04	< 0.01	0.20	< 0.01	0.01	0.06	0.08	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
16.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

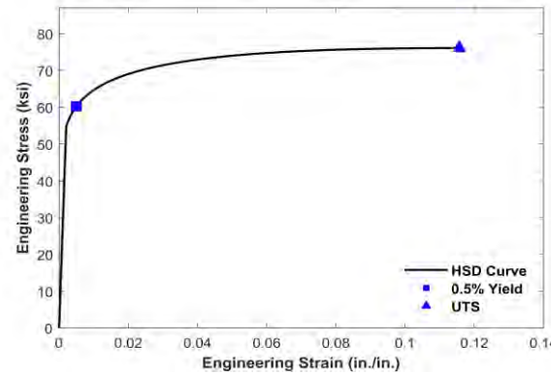
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	60.2	59.8	60.8	60.2
UTS (ksi)	76.1	76.3	76.1	75.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523162340	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:23	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	34-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	34-Q1_BM-01_7001-EB7001_190523162340			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

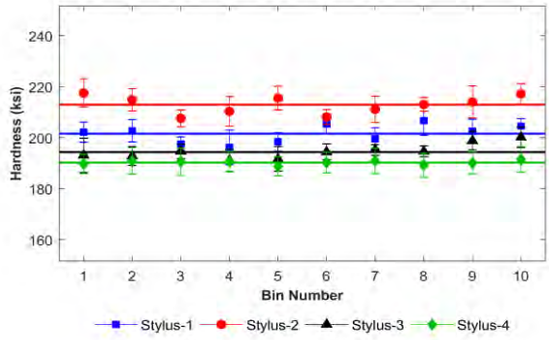
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	201.5	5.18	53
Stylus-2	212.9	5.42	54
Stylus-3	194.4	4.52	54
Stylus-4	190.2	4.22	55

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.08	0.40	0.005	0.015	0.03	< 0.01	0.08	< 0.01	0.01	0.06	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.9

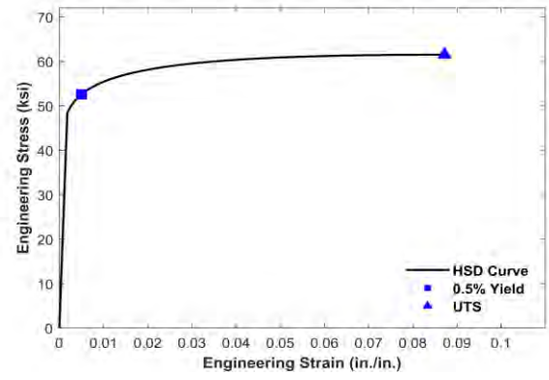
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.5	52.5	52.8	52.3
UTS (ksi)	61.5	61.4	61.1	61.9



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523142513	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:25	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	34-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JN	
Test Name	34-Q1_BM-02_7003-EB7003_190523142513			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

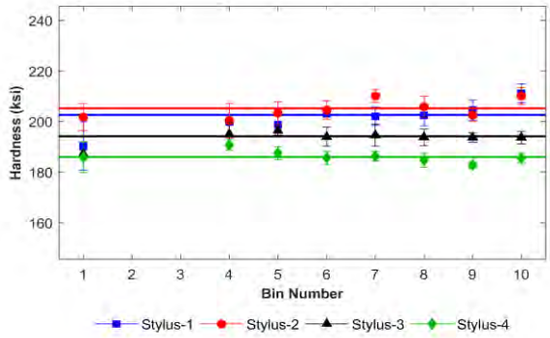
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	202.6	5.98	43
Stylus-2	205.3	5.09	43
Stylus-3	194.1	3.52	42
Stylus-4	186.0	3.06	42

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.08	0.40	0.005	0.015	0.03	< 0.01	0.08	< 0.01	0.01	0.06	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

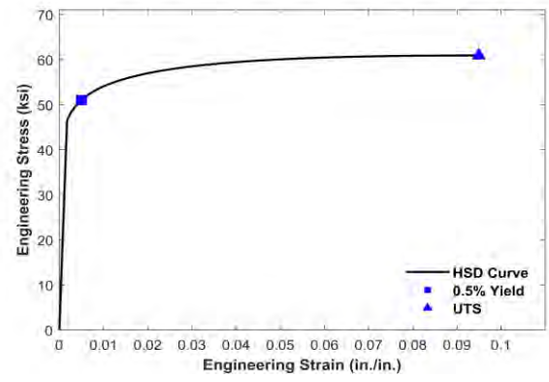
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.0	52.1	51.8	50.1
UTS (ksi)	60.9	58.9	60.8	61.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509124425	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:44	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	35-Q1	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	35-Q1_BM-01_5002-EB5002_190509124425			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

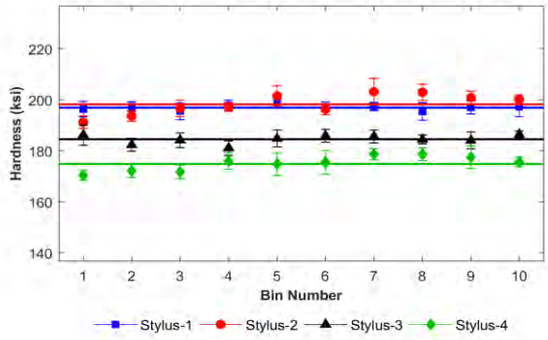
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	197.0	2.72	62
Stylus-2	198.3	4.68	63
Stylus-3	184.5	2.99	59
Stylus-4	174.9	4.05	62

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.40	0.007	0.016	0.03	< 0.01	0.05	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

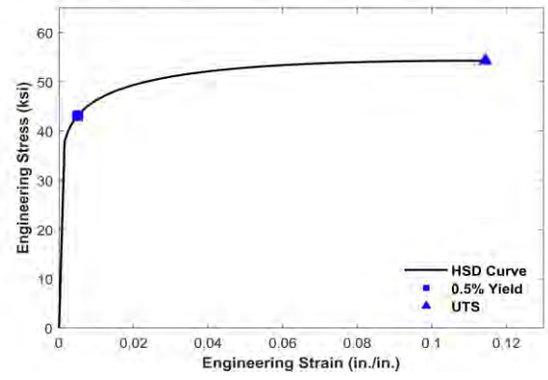
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	43.1	42.4	43.1	43.8
UTS (ksi)	54.3	54.0	54.3	54.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520113954	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	35-Q1	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	35-Q1_BM-01_7001-EB7001_190520113954			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

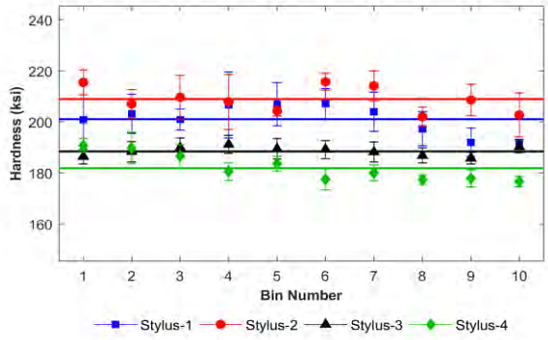
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	201.0	9.52	51
Stylus-2	208.9	7.51	47
Stylus-3	188.4	3.43	44
Stylus-4	181.8	5.94	48

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.40	0.007	0.016	0.03	< 0.01	0.05	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

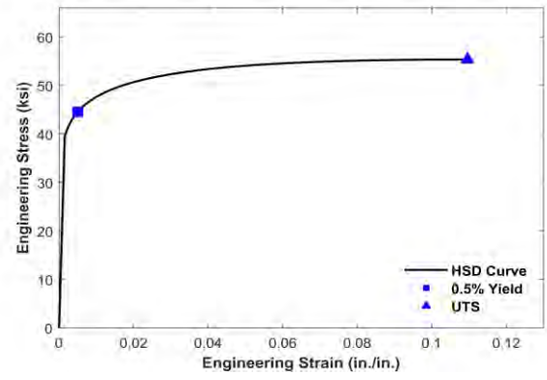
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	44.6	46.0	43.6	44.3
UTS (ksi)	55.4	55.5	56.0	54.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523114834	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:48	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	37-Q1	Pipe Size	12 OD x 0.28 WT (in)	Operator Initials	JJ	
Test Name	37-Q1_BM-01_7001-EB7001_190523114834			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

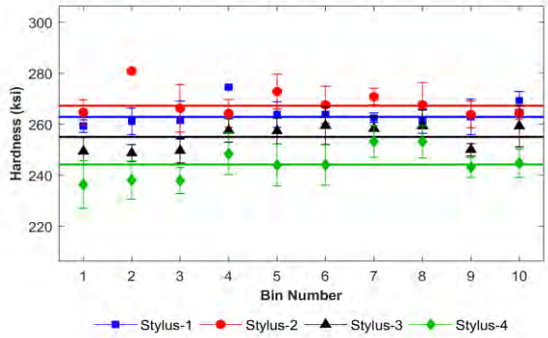
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	262.8	5.46	48
Stylus-2	267.3	6.87	48
Stylus-3	255.0	6.65	52
Stylus-4	244.1	8.59	53

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.44	0.013	0.045	0.02	< 0.01	0.03	< 0.01	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

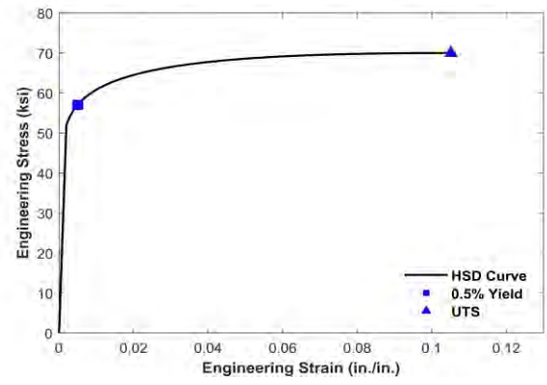
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	57.0	55.4	57.5	58.0
UTS (ksi)	70.0	69.5	70.3	70.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522154057	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:40	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	37-Q1	Pipe Size	12 OD x 0.28 WT (in)	Operator Initials		
Test Name	37-Q1_BM-01_7003-EB7003_190522154057			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

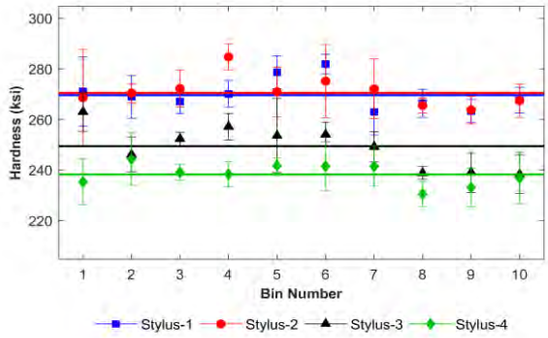
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	269.5	8.72	51
Stylus-2	270.5	9.56	47
Stylus-3	249.3	10.56	52
Stylus-4	238.2	8.00	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.44	0.013	0.045	0.02	< 0.01	0.03	< 0.01	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

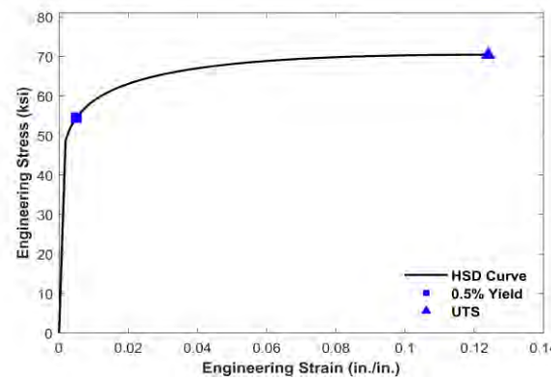
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	54.5	55.1	54.5	53.8
UTS (ksi)	70.4	70.5	71.5	69.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523120624	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:06	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	37-Q1	Pipe Size	12 OD x 0.28 WT (in)	Operator Initials	JJ	
Test Name	37-Q1_BM-02_7001-EB7001_190523120624			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

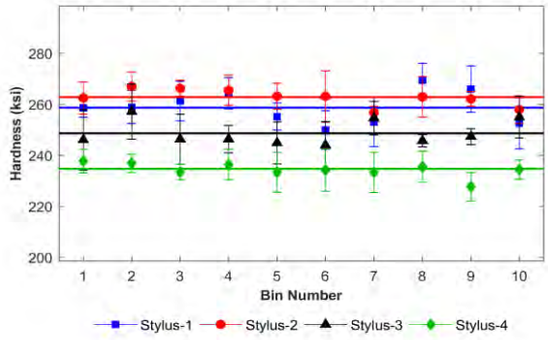
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	258.7	8.71	50
Stylus-2	262.8	6.01	49
Stylus-3	248.6	8.65	51
Stylus-4	234.7	5.86	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.44	0.013	0.045	0.02	< 0.01	0.03	< 0.01	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

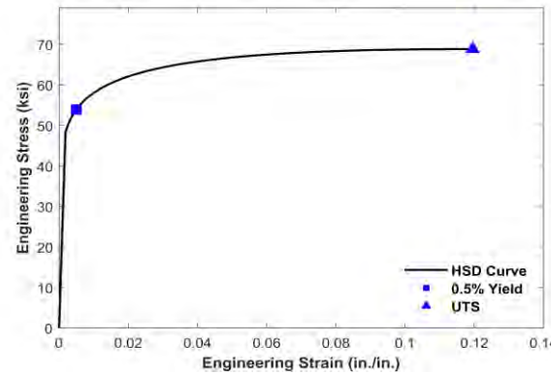
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.9	54.3	53.9	53.4
UTS (ksi)	68.8	69.1	68.6	68.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523182251	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	40-Q1	Pipe Size	30 OD x 0.37 WT (in)	Operator Initials	JJ	
Test Name	40-Q1_BM-01_7001-EB7001_190523182251			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

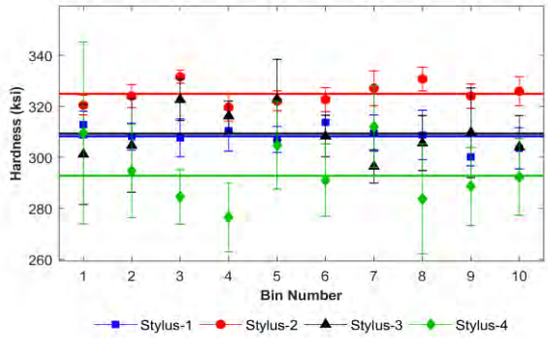
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	308.3	7.13	51
Stylus-2	325.0	5.79	49
Stylus-3	309.3	14.83	52
Stylus-4	292.8	19.83	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.28	0.94	0.019	0.038	0.04	< 0.01	0.15	< 0.01	< 0.01	0.08	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

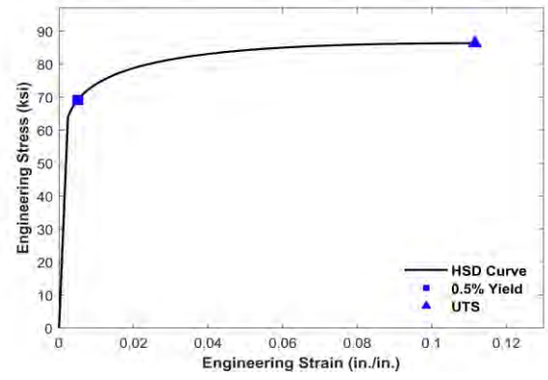
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	69.1	69.4	69.2	68.7
UTS (ksi)	86.3	86.5	86.4	86.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523163018	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:30	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	40-Q1	Pipe Size	30 OD x 0.37 WT (in)	Operator Initials	JN	
Test Name	40-Q1_BM-02_7003-EB7003_190523163018			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

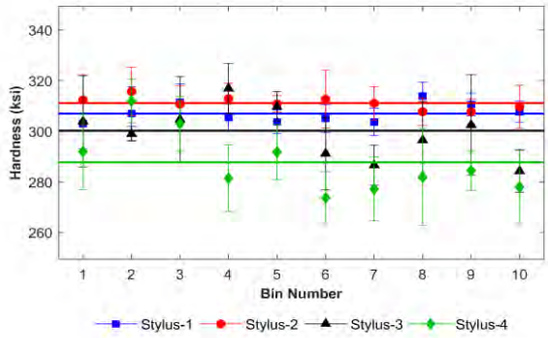
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	307.0	6.79	51
Stylus-2	311.1	6.85	45
Stylus-3	300.2	15.33	53
Stylus-4	287.7	16.31	48

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.28	0.94	0.019	0.038	0.04	< 0.01	0.15	< 0.01	< 0.01	0.08	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

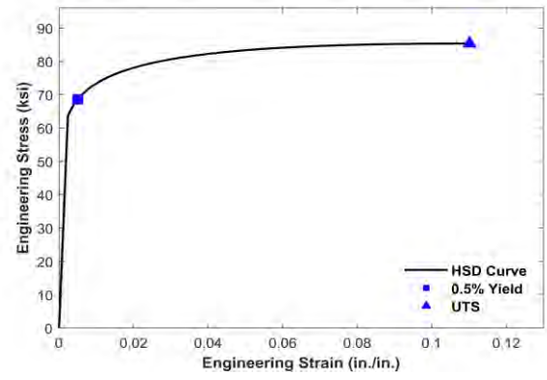
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	68.6	65.3	67.8	66.3
UTS (ksi)	85.3	86.4	85.2	84.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522160301	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	42-Q1	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials		
Test Name	42-Q1_BM-01_7003-EB7003_190522160301			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

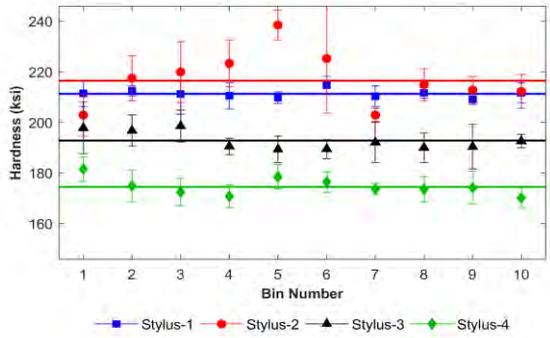
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	211.3	3.93	46
Stylus-2	216.5	13.32	53
Stylus-3	192.8	6.79	51
Stylus-4	174.4	5.45	49

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.69	0.033	0.030	< 0.01	< 0.01	0.01	0.11	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.7

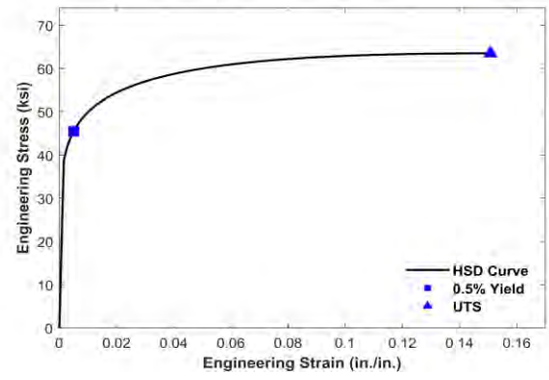
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.5	46.5	45.4	44.7
UTS (ksi)	63.5	63.3	64.1	63.1



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520150358	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	42-Q1	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	42-Q1_BM-03_7001-EB7001_190520150358			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

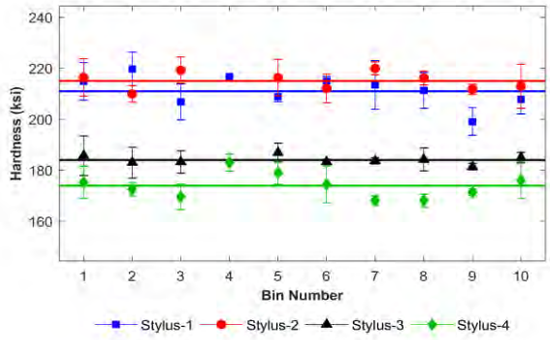
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	210.9	7.84	28
Stylus-2	214.9	5.67	29
Stylus-3	184.0	4.17	30
Stylus-4	173.9	6.24	33

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.69	0.033	0.030	< 0.01	< 0.01	0.01	0.11	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

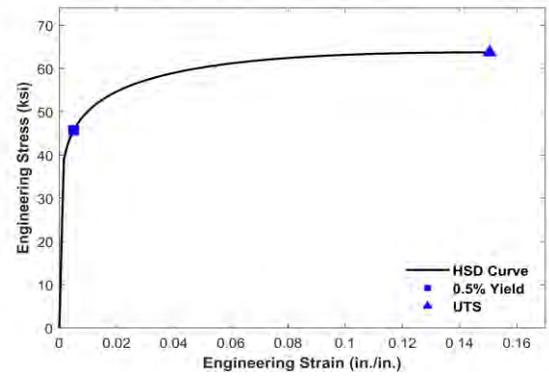
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.7	44.4	47.5	45.1
UTS (ksi)	63.7	65.0	63.3	63.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523102610	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:26	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	43-Q1	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials		
Test Name	43-Q1_BM-01_7003-EB7003_190523102610			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

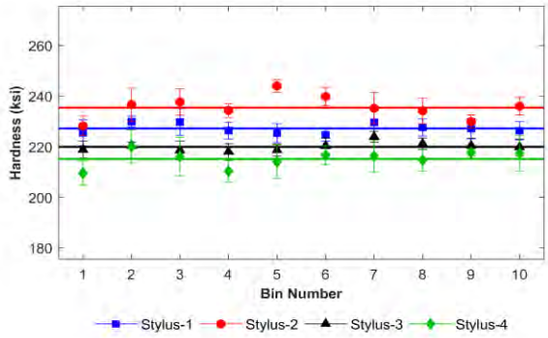
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	227.2	4.20	51
Stylus-2	235.5	5.78	52
Stylus-3	220.0	3.02	45
Stylus-4	215.2	5.99	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.53	0.012	0.020	0.03	< 0.01	0.03	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

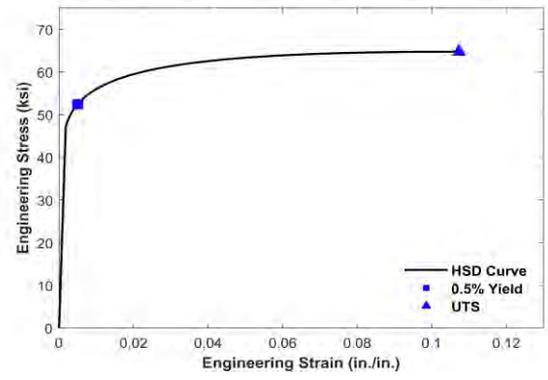
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.4	52.2	52.2	52.9
UTS (ksi)	64.7	64.7	64.7	64.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522191318	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:13	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	43-Q2	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	43-Q2_BM-03_7001-EB7001_190522191318			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

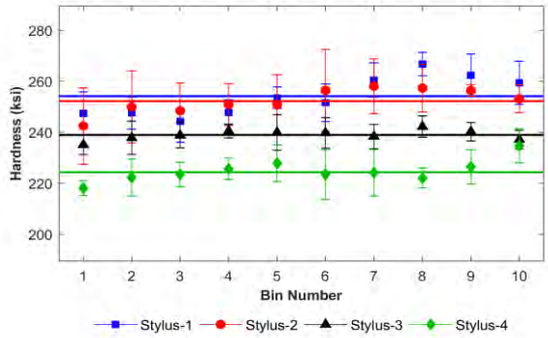
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	254.1	9.62	56
Stylus-2	252.2	11.45	57
Stylus-3	238.9	4.97	50
Stylus-4	224.3	6.98	53

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.53	0.012	0.020	0.03	< 0.01	0.03	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

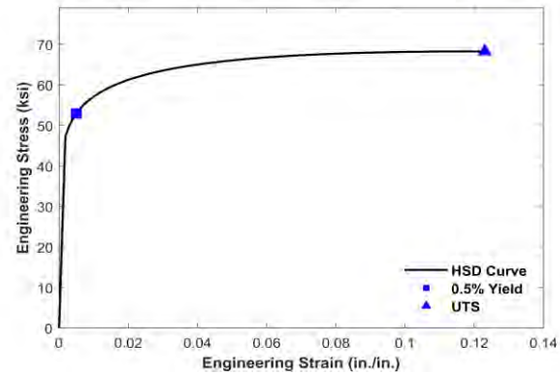
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.0	53.1	53.5	52.4
UTS (ksi)	68.3	67.3	68.4	69.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531100354	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	44-Q1	Pipe Size	26 OD x 0.39 WT (in)	Operator Initials	JJ	
Test Name	44-Q1_BM-02_5002-EB5002_190531100354			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

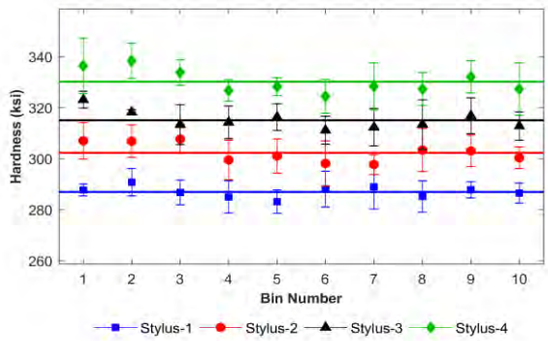
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	286.9	5.65	66
Stylus-2	302.3	7.19	68
Stylus-3	315.1	6.91	65
Stylus-4	330.2	7.90	65

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.48	0.012	< 0.005	< 0.01	< 0.01	< 0.01	0.03	< 0.01	0.01	0.28	< 0.01	0.04	< 0.0005

Grain Size

mli (µm)
10.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

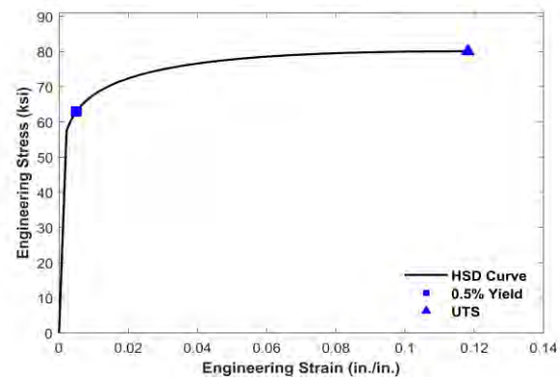
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	63.0	62.9	62.8	63.2
UTS (ksi)	80.1	80.0	79.9	80.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531102016	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	44-Q1	Pipe Size	26 OD x 0.39 WT (in)	Operator Initials	JJ	
Test Name	44-Q1_BM-03_5002-EB5002_190531102016			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

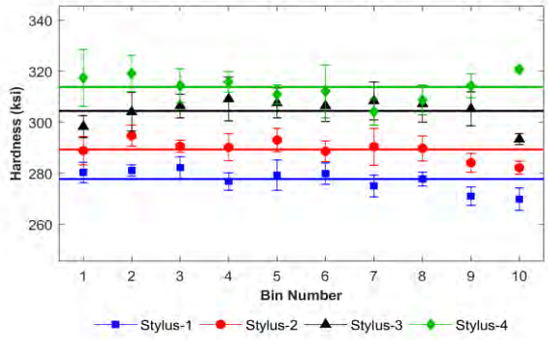
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	277.7	5.26	58
Stylus-2	289.4	5.49	60
Stylus-3	304.5	7.54	60
Stylus-4	313.8	7.67	61

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	1.48	0.012	< 0.005	< 0.01	< 0.01	< 0.01	0.03	< 0.01	0.01	0.28	< 0.01	0.04	< 0.0005

Grain Size

mli (µm)
10.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

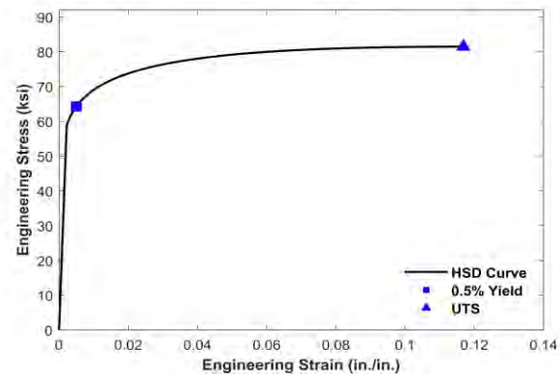
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.3	64.7	64.7	63.2
UTS (ksi)	81.4	81.9	81.9	80.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531083958	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	8:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	50-Q1	Pipe Size	24 OD x 0.37 WT (in)	Operator Initials	JJ	
Test Name	50-Q1_BM-01_5002-EB5002_190531083958			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

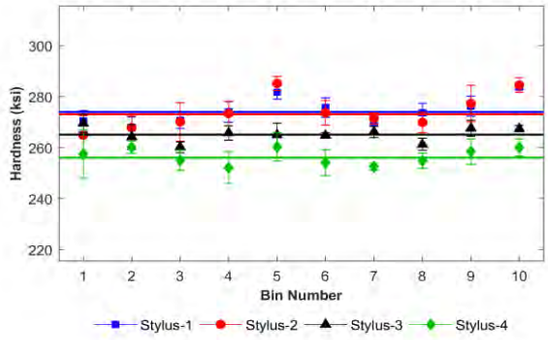
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	273.9	5.50	52
Stylus-2	273.1	7.60	54
Stylus-3	265.0	3.83	50
Stylus-4	256.1	5.47	53

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.22	0.023	0.010	0.04	0.03	< 0.01	0.03	< 0.01	0.01	0.17	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

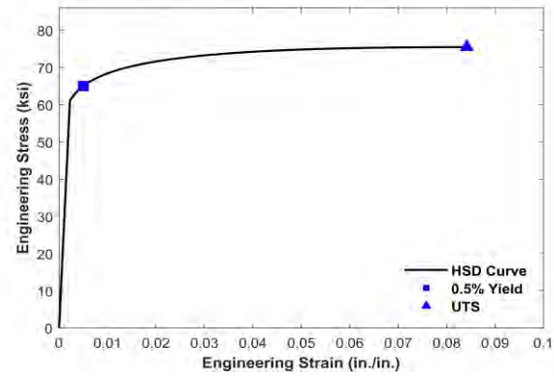
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	65.0	65.9	64.4	64.9
UTS (ksi)	75.5	75.2	75.6	75.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531090012	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	9:00	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	50-Q1	Pipe Size	24 OD x 0.37 WT (in)	Operator Initials	JJ	
Test Name	50-Q1_BM-02_5002-EB5002_190531090012			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

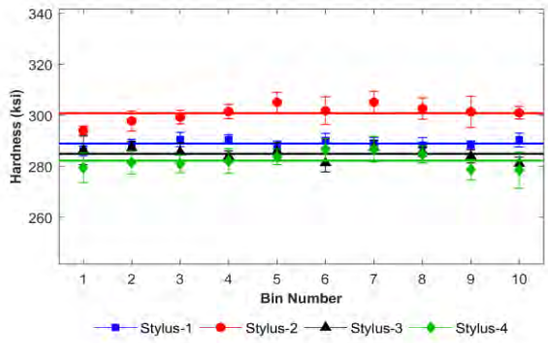
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	289.0	2.63	60
Stylus-2	300.8	4.82	61
Stylus-3	285.0	3.71	58
Stylus-4	282.3	5.25	61

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.22	0.023	0.010	0.04	0.03	< 0.01	0.03	< 0.01	0.01	0.17	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

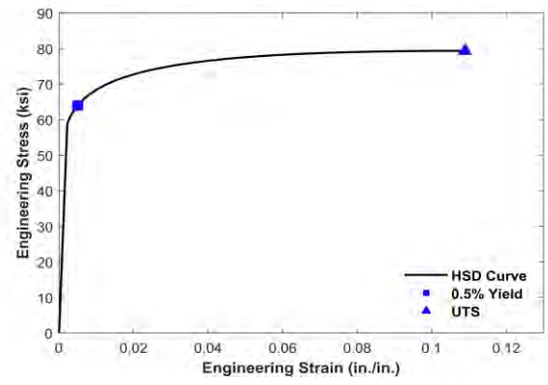
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.0	63.9	64.3	70.4
UTS (ksi)	79.3	79.1	79.5	79.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531104359	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:43	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	50-Q1	Pipe Size	24 OD x 0.37 WT (in)	Operator Initials	JJ	
Test Name	50-Q1_BM-03_5002-EB5002_190531104359			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

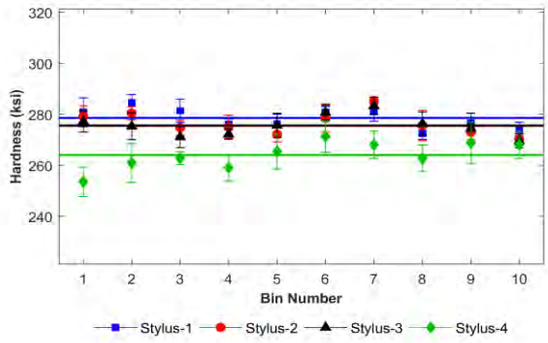
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	278.6	4.91	65
Stylus-2	275.6	5.10	56
Stylus-3	275.7	5.51	61
Stylus-4	264.0	7.31	58

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.22	0.023	0.010	0.04	0.03	< 0.01	0.03	< 0.01	0.01	0.17	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

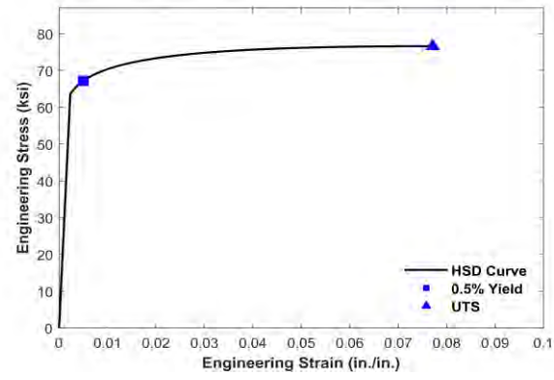
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	67.2	65.7	67.4	61.6
UTS (ksi)	76.6	76.6	76.6	76.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523174239	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:42	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	107-Q1	Pipe Size	6 OD x 0.24 WT (in)	Operator Initials	JJ	
Test Name	107-Q1_BM-01_7001-EB7001_190523174239			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

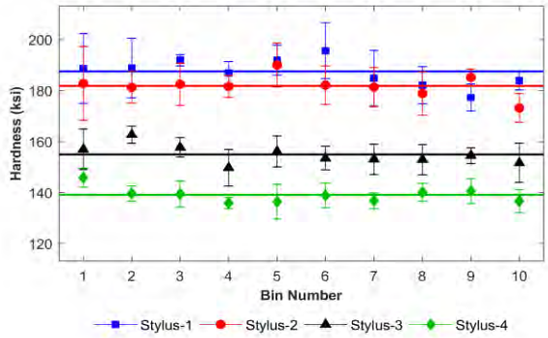
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	187.5	9.26	52
Stylus-2	181.8	8.23	53
Stylus-3	155.0	6.41	56
Stylus-4	139.0	4.82	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.42	0.034	0.020	0.01	< 0.01	0.02	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
31.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

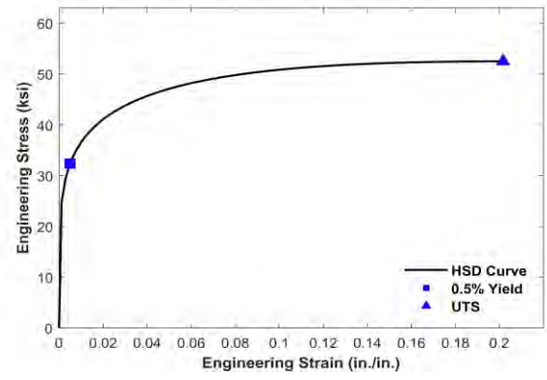
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	32.4	32.9	31.6	32.8
UTS (ksi)	52.5	52.6	53.6	51.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523150452	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	107-Q1	Pipe Size	6 OD x 0.24 WT (in)	Operator Initials	JN	
Test Name	107-Q1_BM-01_7003-EB7003_190523150452			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

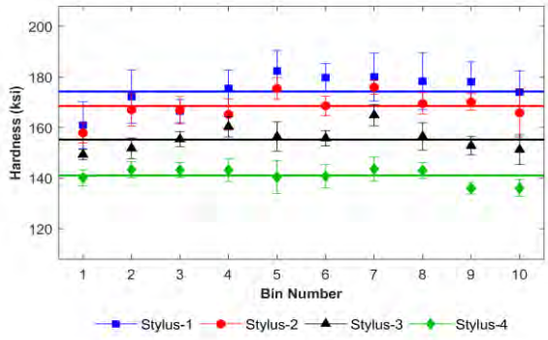
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	174.2	10.09	50
Stylus-2	168.5	6.63	48
Stylus-3	155.2	5.56	47
Stylus-4	141.1	4.54	49

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.42	0.034	0.020	0.01	< 0.01	0.02	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
31.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

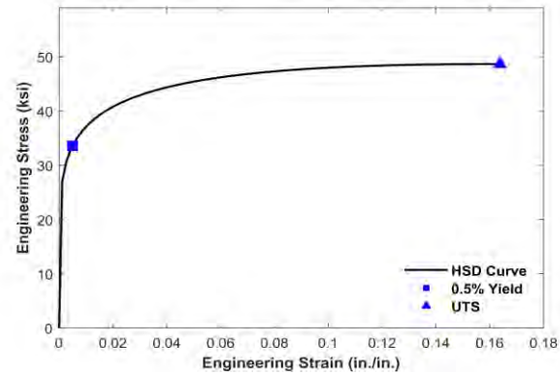
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	33.6	34.5	33.4	32.8
UTS (ksi)	48.6	47.5	49.5	49.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521110448	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	107-Q2	Pipe Size	6 OD x 0.24 WT (in)	Operator Initials	RP	
Test Name	107-Q2_BM-01_5002-EB5002_190521110448			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

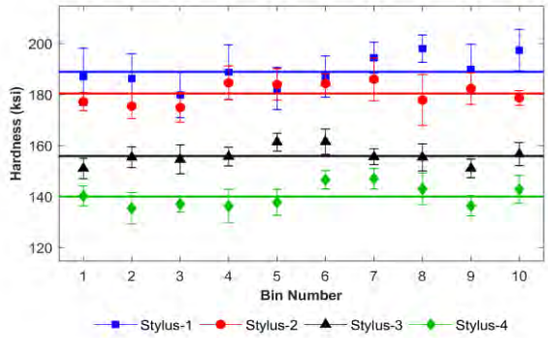
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	188.8	10.02	63
Stylus-2	180.4	6.94	63
Stylus-3	155.8	5.22	64
Stylus-4	140.0	6.15	65

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.42	0.034	0.020	0.01	< 0.01	0.02	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (μm)
31.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

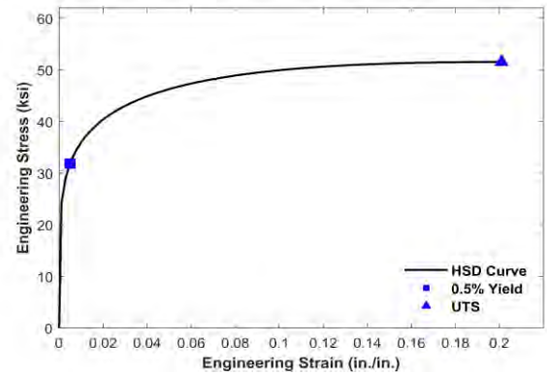
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	31.8	31.6	32.3	31.6
UTS (ksi)	51.5	50.7	51.6	52.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425185942	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:59	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	108-Q1	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	108-Q1_BM-01_5001-EB5001_190425185942			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

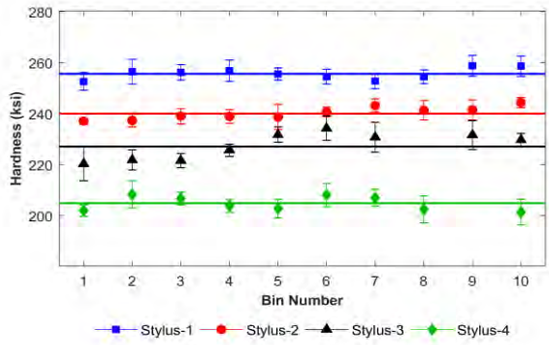
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	255.6	3.77	54
Stylus-2	240.0	3.53	55
Stylus-3	227.1	6.33	55
Stylus-4	204.9	4.42	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.79	0.007	0.028	0.02	< 0.01	0.06	< 0.01	< 0.01	0.02	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.7

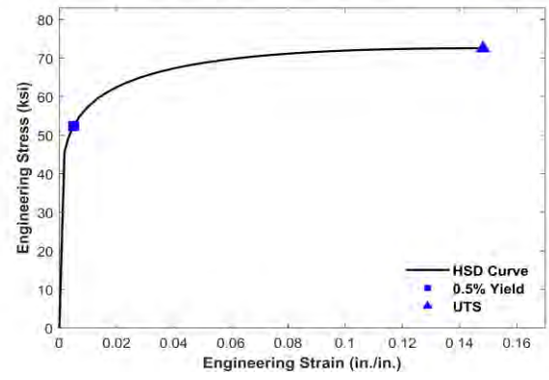
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.4	52.1	53.0	51.8
UTS (ksi)	72.5	72.1	72.5	73.2



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507155933	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:59	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	108-Q1	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	108-Q1_BM-01_7001-EB7001_190507155933			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

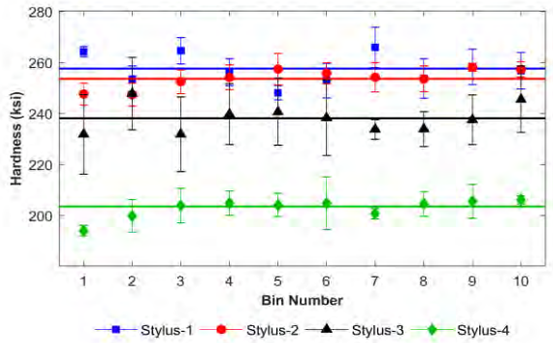
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.7	7.60	46
Stylus-2	253.7	5.52	48
Stylus-3	238.1	12.35	49
Stylus-4	203.6	5.78	42

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.79	0.007	0.028	0.02	< 0.01	0.06	< 0.01	< 0.01	0.02	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

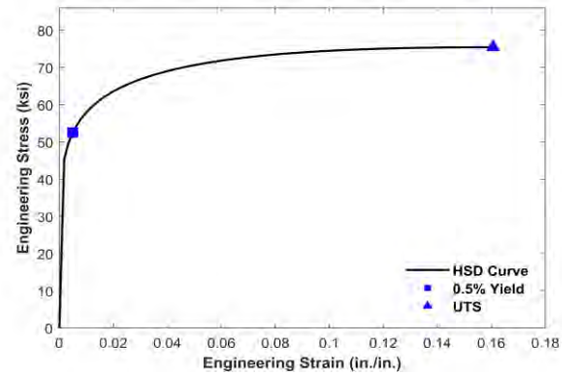
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.5	51.2	53.1	53.2
UTS (ksi)	75.4	75.9	75.1	75.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530142125	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	109-Q1	Pipe Size	4 OD x 0.33 WT (in)	Operator Initials	JN	
Test Name	109-Q1_BM-01_7001-EB7001_190530142125			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

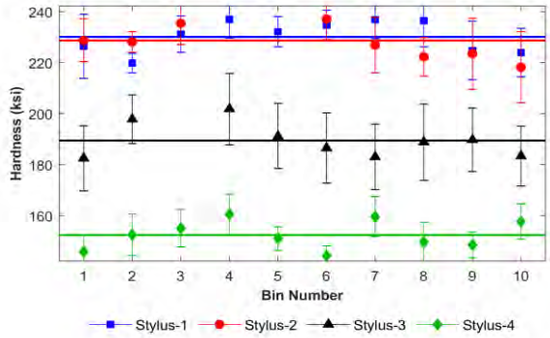
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	230.1	9.85	52
Stylus-2	228.7	11.39	45
Stylus-3	189.5	13.28	48
Stylus-4	152.5	8.23	51

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.52	0.005	0.030	0.02	< 0.01	< 0.01	0.02	0.02	0.02	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

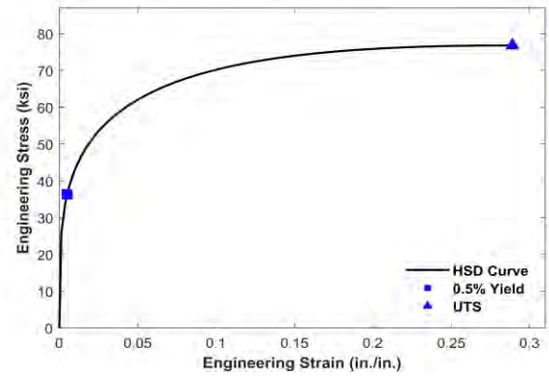
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	36.3	36.6	36.2	36.4
UTS (ksi)	76.8	75.2	80.1	75.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530113404	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:34	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	109-Q1	Pipe Size	4 OD x 0.33 WT (in)	Operator Initials	JJ	
Test Name	109-Q1_BM-02_5001-EB5001_190530113404			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

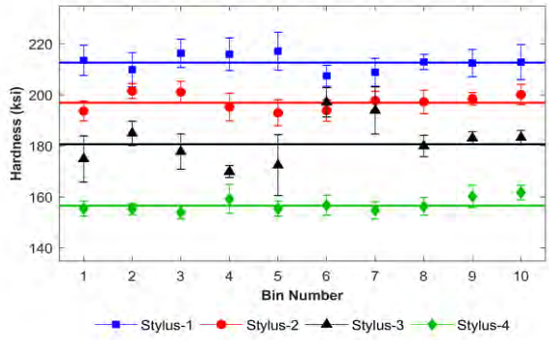
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	212.7	6.20	63
Stylus-2	196.9	4.77	56
Stylus-3	180.6	9.93	61
Stylus-4	156.4	3.85	55

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.52	0.005	0.030	0.02	< 0.01	< 0.01	0.02	0.02	0.02	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

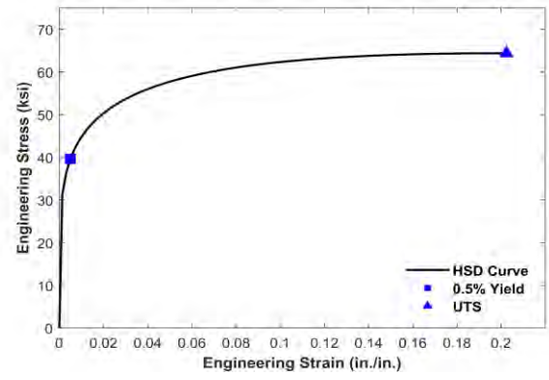
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	39.6	38.7	39.4	40.6
UTS (ksi)	64.4	65.1	63.6	64.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521102244	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	110-Q1	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	110-Q1_BM-01_5002-EB5002_190521102244			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

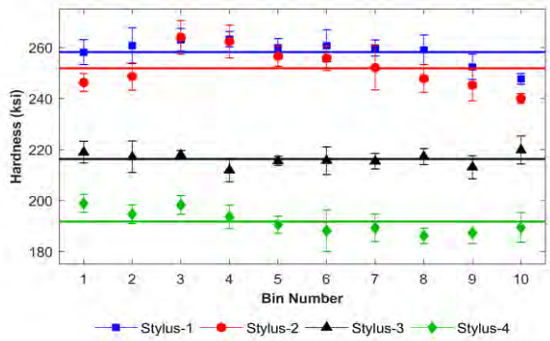
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	258.2	6.41	64
Stylus-2	251.8	9.08	69
Stylus-3	216.2	4.55	67
Stylus-4	191.7	6.09	68

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.81	0.011	0.030	0.03	< 0.01	0.17	< 0.01	0.03	0.03	0.07	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.4

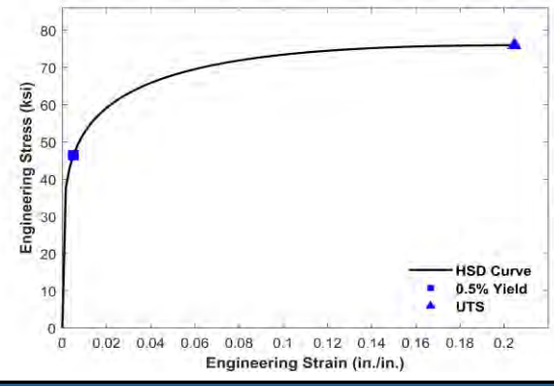
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.4	48.0	45.6	46.0
UTS (ksi)	76.0	75.7	77.5	74.7



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506123436	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:34	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	110-Q1	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	110-Q1_BM-01_7001-EB7001_190506123436			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

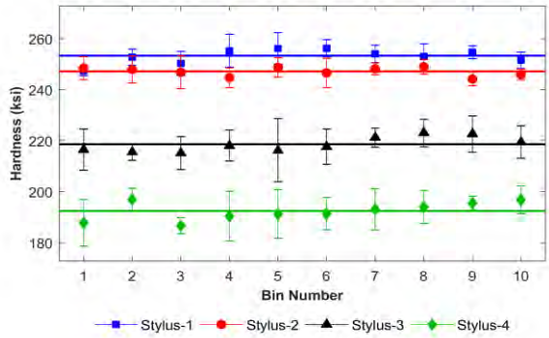
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	253.3	4.67	54
Stylus-2	247.0	4.12	50
Stylus-3	218.6	6.85	57
Stylus-4	192.4	7.16	56

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.81	0.011	0.030	0.03	< 0.01	0.17	< 0.01	0.03	0.03	0.07	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

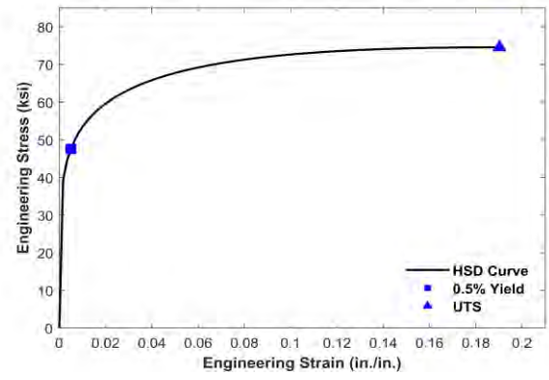
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.6	46.8	47.4	48.5
UTS (ksi)	74.5	74.5	74.9	74.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507123025	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:30	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	111-Q1	Pipe Size	4 OD x 0.24 WT (in)	Operator Initials	JJ	
Test Name	111-Q1_BM-01_7001-EB7001_190507123025			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

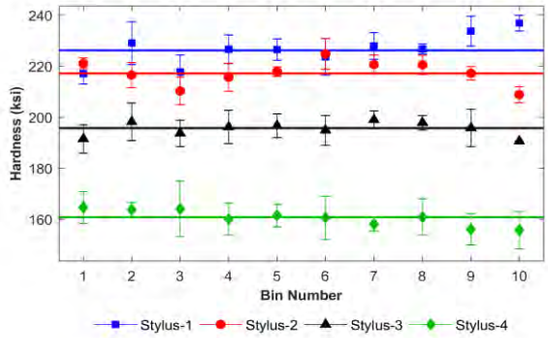
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	226.2	7.85	43
Stylus-2	217.1	6.07	37
Stylus-3	195.6	5.51	45
Stylus-4	160.8	6.64	46

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.010	0.038	0.02	< 0.01	0.01	< 0.01	0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

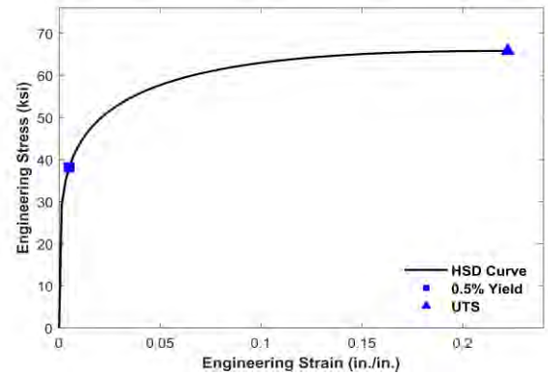
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	38.1	---	38.8	37.4
UTS (ksi)	65.8	---	65.1	66.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507125659	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:56	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	111-Q1	Pipe Size	4 OD x 0.24 WT (in)	Operator Initials	JJ	
Test Name	111-Q1_BM-01_7001-EB7001_190507125659			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

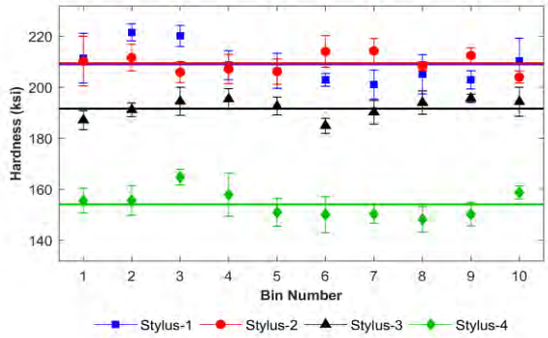
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	209.0	8.75	46
Stylus-2	209.4	5.96	45
Stylus-3	191.6	5.04	42
Stylus-4	154.0	6.93	44

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.010	0.038	0.02	< 0.01	0.01	< 0.01	0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

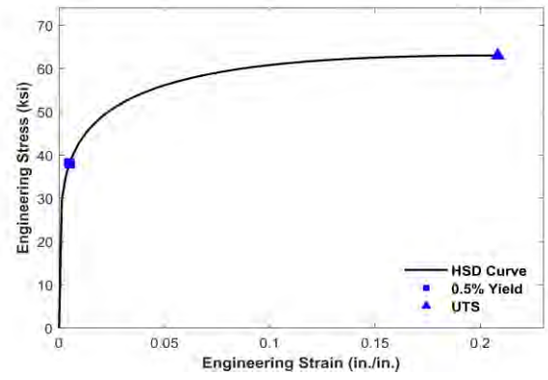
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	38.1	38.2	38.0	38.1
UTS (ksi)	63.0	63.9	62.6	62.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530134549	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:45	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	111-Q1	Pipe Size	4 OD x 0.24 WT (in)	Operator Initials	JN	
Test Name	111-Q1_BM-02_7001-EB7001_190530134549			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

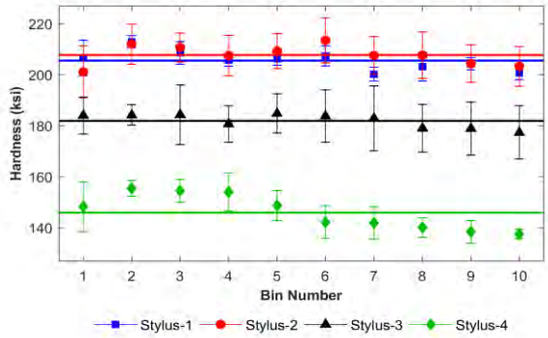
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	205.5	4.98	57
Stylus-2	207.7	8.24	60
Stylus-3	181.9	9.08	57
Stylus-4	145.9	8.48	59

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.010	0.038	0.02	< 0.01	0.01	< 0.01	0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

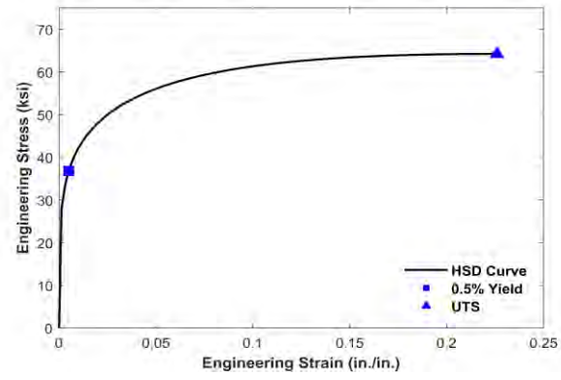
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	36.8	38.0	37.4	35.4
UTS (ksi)	64.2	64.1	64.2	64.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507144942	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:49	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	112-Q2	Pipe Size	4 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	112-Q2_BM-01_7001-EB7001_190507144942			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

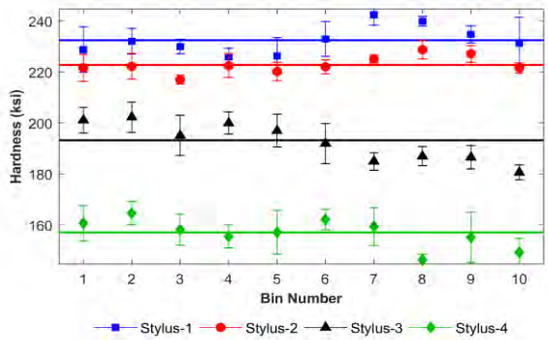
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	232.4	7.42	49
Stylus-2	222.8	4.53	46
Stylus-3	193.1	8.86	52
Stylus-4	157.1	7.74	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.50	0.007	0.041	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

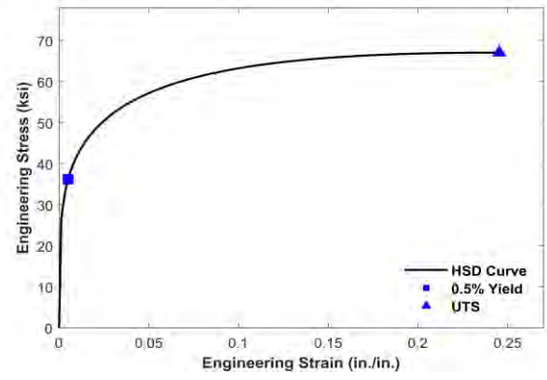
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	36.3	38.4	37.0	34.3
UTS (ksi)	67.1	65.8	66.0	69.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530180914	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:09	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	112-Q2	Pipe Size	4 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	112-Q2_BM-02_5002-EB5002_190530180914			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

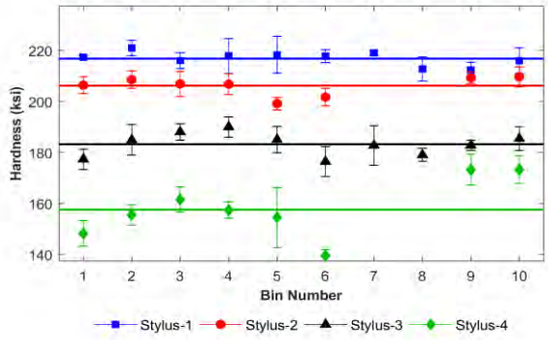
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	216.8	4.51	37
Stylus-2	206.3	4.72	50
Stylus-3	183.3	6.13	37
Stylus-4	157.6	11.17	47

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.50	0.007	0.041	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
13.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

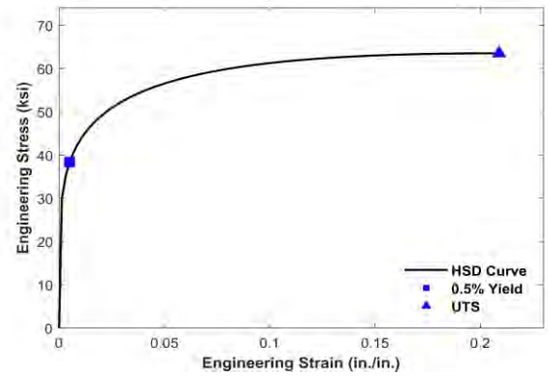
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	38.3	37.8	37.2	---
UTS (ksi)	63.5	64.2	63.7	---

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506165415	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	113-Q2	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	113-Q2_BM-01_7001-EB7001_190506165415			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

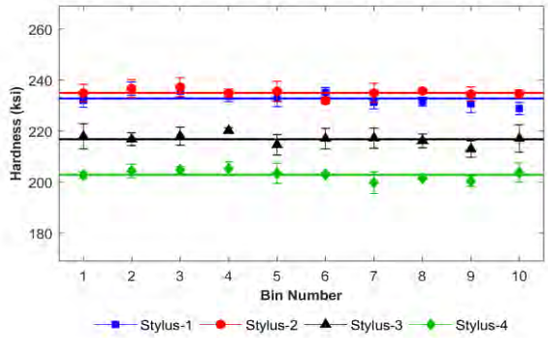
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	232.8	3.29	46
Stylus-2	235.0	2.89	45
Stylus-3	216.8	3.82	52
Stylus-4	202.8	3.01	46

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.89	0.007	0.022	0.02	< 0.01	0.03	0.02	< 0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

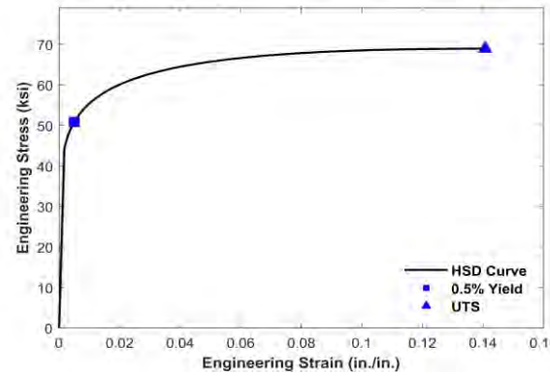
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.9	51.0	50.9	50.6
UTS (ksi)	68.9	69.1	69.0	68.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520173954	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	113-Q2	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	113-Q2_BM-02_5002-EB5002_190520173954			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

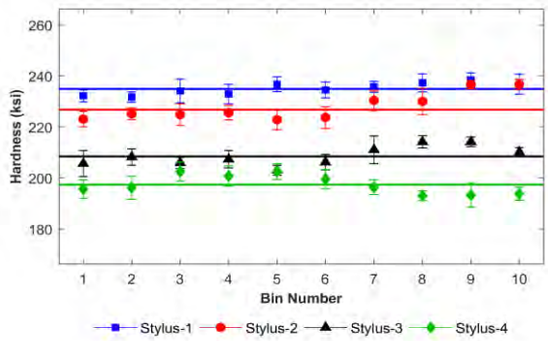
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	234.8	3.67	61
Stylus-2	226.8	5.52	56
Stylus-3	208.4	4.62	63
Stylus-4	197.4	4.80	61

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.89	0.007	0.022	0.02	< 0.01	0.03	0.02	< 0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

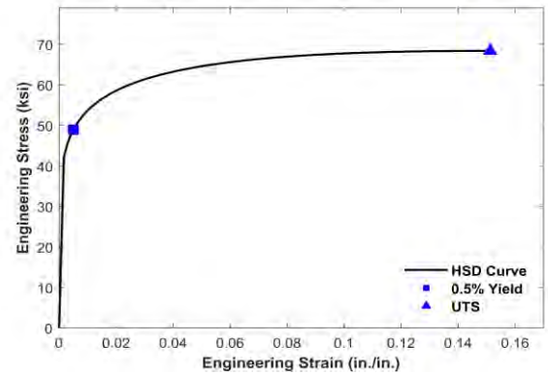
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	48.9	49.1	49.5	48.2
UTS (ksi)	68.4	68.0	68.0	69.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521152136	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	114-Q1	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	114-Q1_BM-01_7001-EB7001_190521152136			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

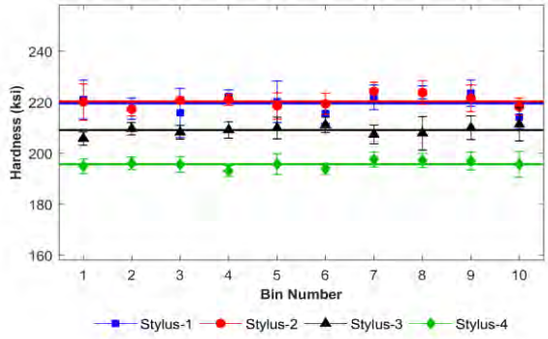
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	219.5	6.19	48
Stylus-2	220.3	4.35	46
Stylus-3	209.0	3.93	51
Stylus-4	195.7	3.13	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.71	0.006	0.014	0.02	< 0.01	0.04	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
21.0

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

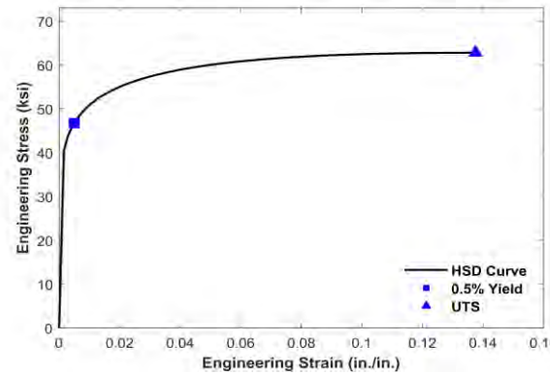
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.7	46.6	46.7	46.7
UTS (ksi)	62.8	62.7	62.6	63.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507141927	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:19	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	114-Q2	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	114-Q2_BM-01_5002-EB5002_190507141927			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

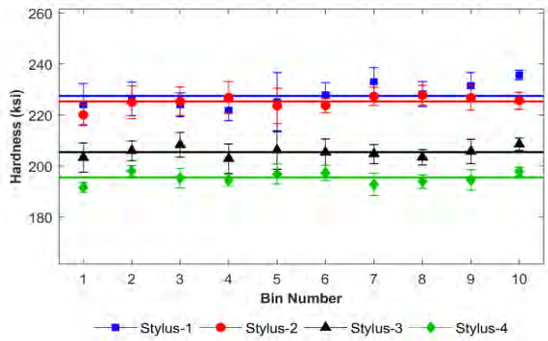
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	227.5	7.27	65
Stylus-2	225.3	5.05	60
Stylus-3	205.4	4.92	62
Stylus-4	195.5	3.51	59

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.71	0.006	0.014	0.02	< 0.01	0.04	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
21.0

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

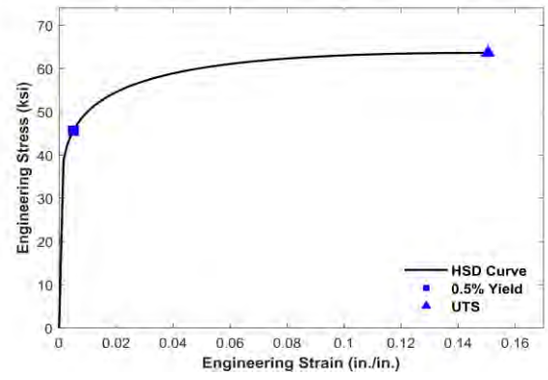
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.6	46.0	45.9	45.0
UTS (ksi)	63.6	63.2	63.4	64.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509173852	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:38	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	114-Q2	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	114-Q2_BM-02_5001-EB5001_190509173852			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

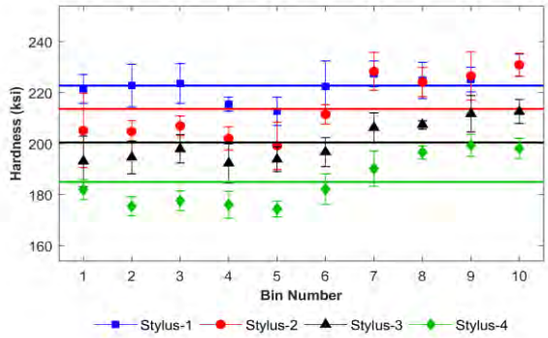
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	222.8	7.77	58
Stylus-2	213.6	13.59	60
Stylus-3	200.4	9.57	57
Stylus-4	184.9	10.25	60

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.71	0.006	0.014	0.02	< 0.01	0.04	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
21.0

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

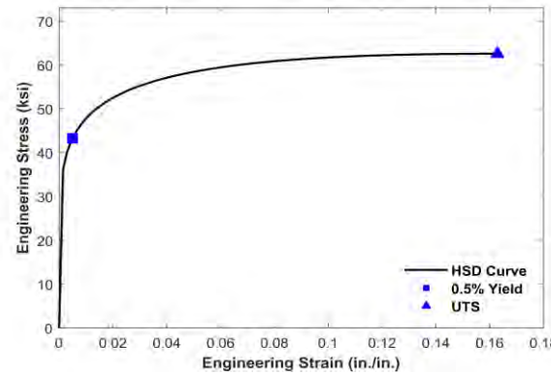
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	43.3	41.6	42.1	46.3
UTS (ksi)	62.5	62.0	61.8	63.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529124859	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:48	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	115-Q1	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	115-Q1_BM-01_5002-EB5002_190529124859			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

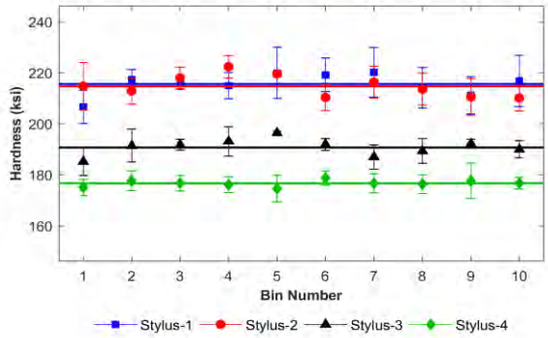
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	215.6	7.61	51
Stylus-2	214.7	6.53	49
Stylus-3	190.7	4.75	46
Stylus-4	176.6	3.74	48

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.85	0.007	0.023	0.02	< 0.01	0.09	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
19.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

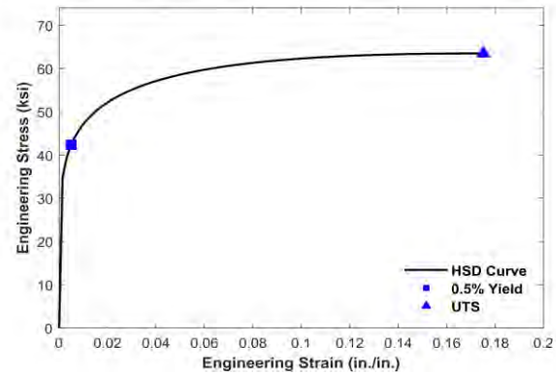
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	42.4	42.5	42.2	42.4
UTS (ksi)	63.5	63.3	63.8	63.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530164130	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:41	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	115-Q1	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JN	
Test Name	115-Q1_BM-01_7001-EB7001_190530164130			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

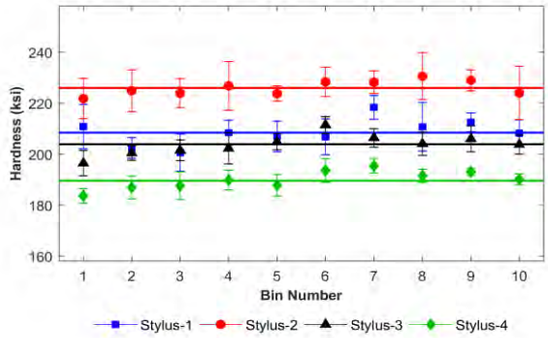
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	208.5	7.53	53
Stylus-2	226.0	7.04	53
Stylus-3	204.0	5.39	53
Stylus-4	189.6	4.76	51

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.85	0.007	0.023	0.02	< 0.01	0.09	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
19.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

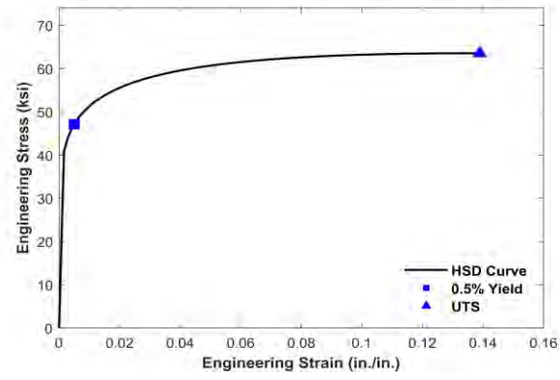
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.1	46.3	47.5	47.4
UTS (ksi)	63.5	63.0	63.7	63.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507141345	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:13	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	116-Q1	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	116-Q1_BM-01_5001-EB5001_190507141345			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

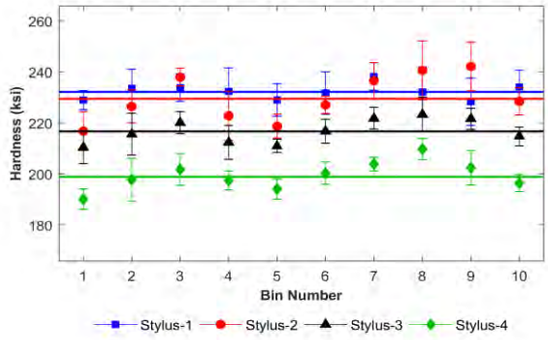
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	232.2	7.35	62
Stylus-2	229.4	11.04	63
Stylus-3	216.6	6.72	60
Stylus-4	198.9	6.99	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.68	0.005	0.024	0.02	< 0.01	0.07	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
19.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

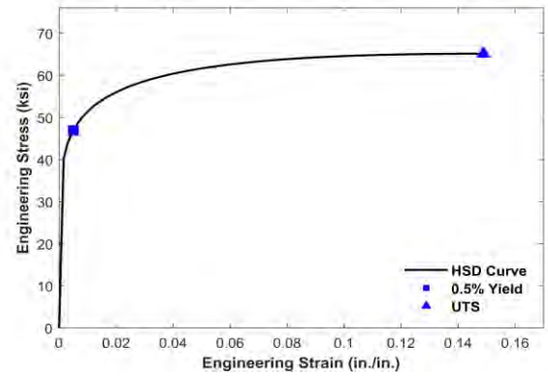
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.9	46.4	46.6	47.9
UTS (ksi)	65.1	65.0	64.8	65.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507152744	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:27	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	116-Q2	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	116-Q2_BM-01_5002-EB5002_190507152744			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

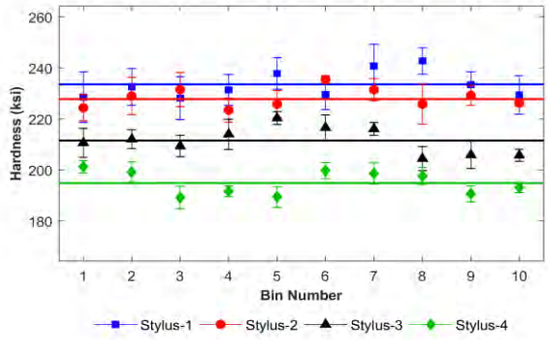
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	233.6	8.31	64
Stylus-2	227.8	5.95	59
Stylus-3	211.5	6.41	64
Stylus-4	194.9	5.47	60

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.68	0.005	0.024	0.02	< 0.01	0.07	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
19.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

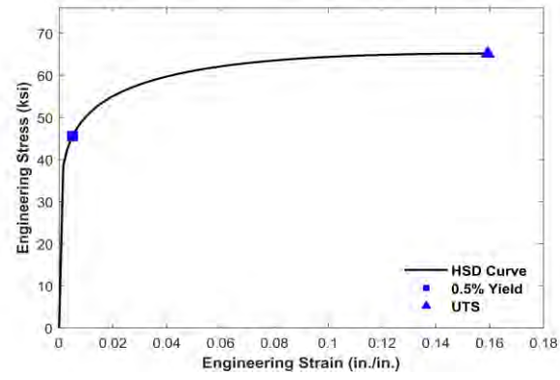
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.6	46.5	45.3	45.0
UTS (ksi)	65.1	64.7	65.4	65.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425134314	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:43	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	117-Q1	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	RP	
Test Name	117-Q1_BM-01_5001-EB5001_190425134314			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

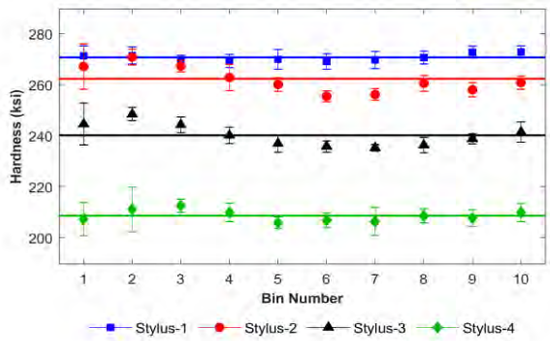
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.7	3.02	56
Stylus-2	262.3	6.24	63
Stylus-3	240.1	5.25	60
Stylus-4	208.6	4.54	59

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	1.07	0.009	0.025	0.08	< 0.01	0.04	0.01	0.02	0.02	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

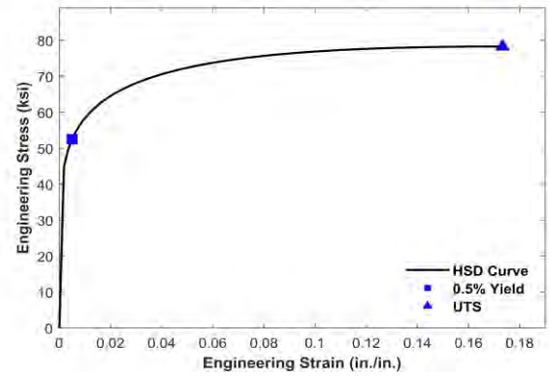
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.5	53.9	52.2	51.8
UTS (ksi)	78.3	78.9	77.7	78.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425172128	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	117-Q1	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	JJ	
Test Name	117-Q1_BM-02_7001-EB7001_190425172128			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

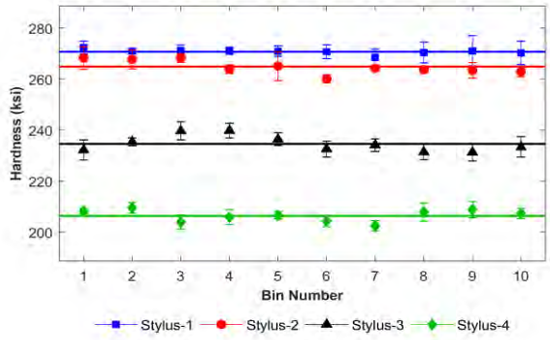
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.8	3.16	49
Stylus-2	264.9	3.56	46
Stylus-3	234.7	4.15	49
Stylus-4	206.4	3.16	45

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	1.07	0.009	0.025	0.08	< 0.01	0.04	0.01	0.02	0.02	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

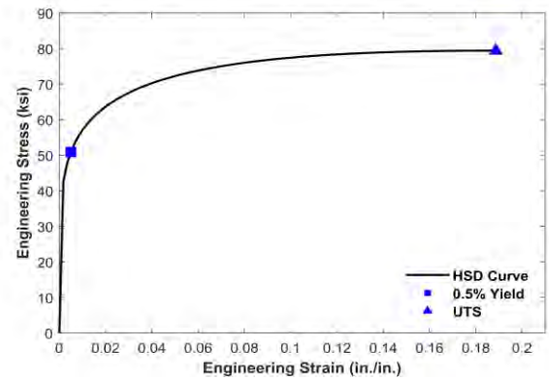
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.9	51.0	50.5	51.1
UTS (ksi)	79.4	79.9	79.4	78.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506125223	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:52	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	118-Q1	Pipe Size	10 OD x 0.28 WT (in)	Operator Initials	RP	
Test Name	118-Q1_BM-01_5001-EB5001_190506125223			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

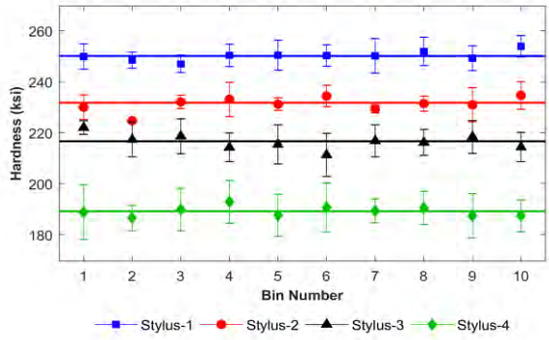
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	250.1	4.83	68
Stylus-2	231.8	4.64	54
Stylus-3	216.6	6.43	65
Stylus-4	189.2	7.53	68

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.90	< 0.005	0.020	0.04	< 0.01	0.04	0.02	0.02	0.02	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.1

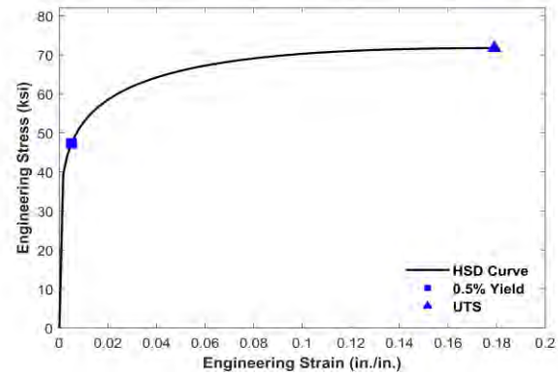
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.3	48.1	47.2	46.5
UTS (ksi)	71.7	71.3	71.7	72.1



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506145853	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	118-Q1	Pipe Size	10 OD x 0.28 WT (in)	Operator Initials		
Test Name	118-Q1_BM-01_5001-EB5001_190506145853			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

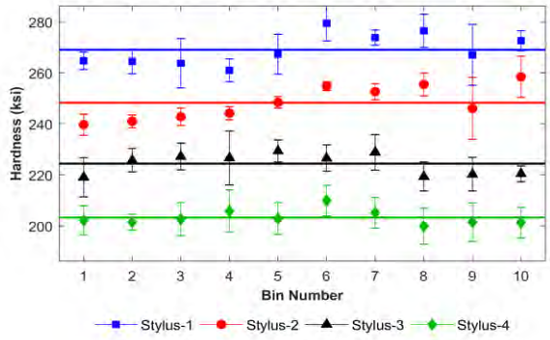
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	269.1	8.63	67
Stylus-2	248.3	7.79	65
Stylus-3	224.5	7.07	68
Stylus-4	203.2	6.49	64

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.90	< 0.005	0.020	0.04	< 0.01	0.04	0.02	0.02	0.02	0.06	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

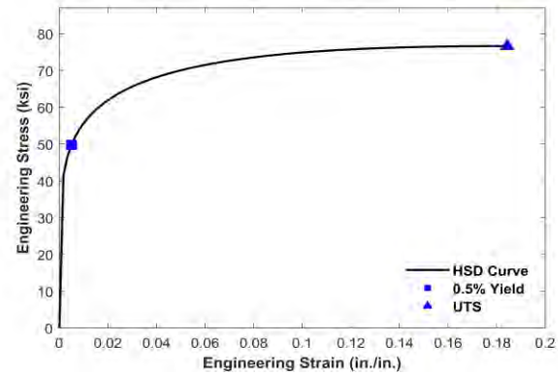
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.8	49.6	50.9	48.9
UTS (ksi)	76.6	75.0	75.9	78.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506180347	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	119-Q1	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	RP	
Test Name	119-Q1_BM-01_5001-EB5001_190506180347			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

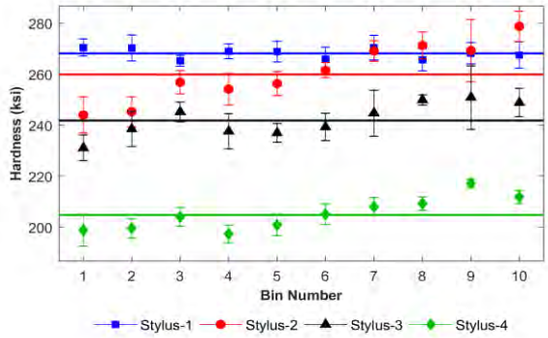
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	268.2	4.30	62
Stylus-2	259.9	12.38	65
Stylus-3	241.8	8.58	65
Stylus-4	204.7	6.84	65

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	1.03	0.008	0.021	0.04	< 0.01	0.04	< 0.01	0.02	0.02	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

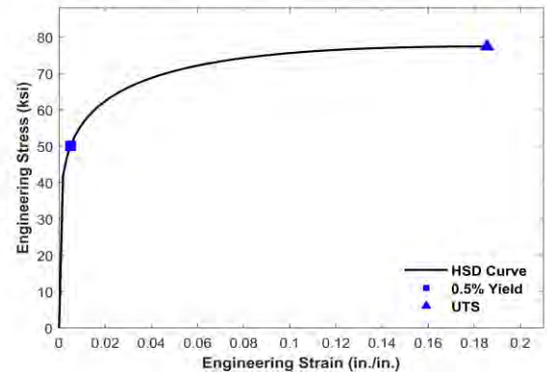
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.1	49.0	49.2	52.1
UTS (ksi)	77.4	77.0	77.4	77.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506172406	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:24	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	119-Q2	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	RP	
Test Name	119-Q2_BM-01_5002-EB5002_190506172406			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

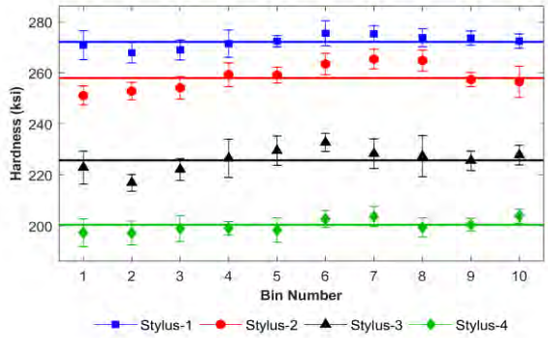
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	272.2	4.36	62
Stylus-2	257.9	6.06	62
Stylus-3	225.7	6.64	64
Stylus-4	200.4	4.17	56

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	1.03	0.008	0.021	0.04	< 0.01	0.04	< 0.01	0.02	0.02	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

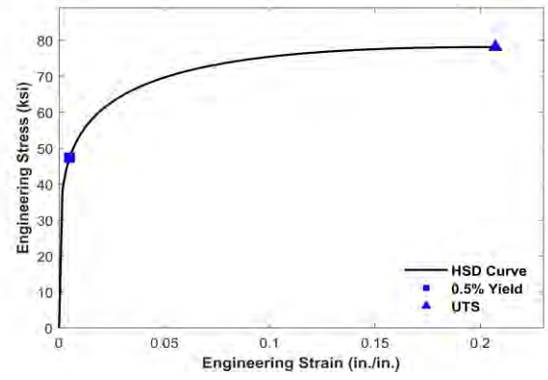
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.4	46.8	47.4	47.6
UTS (ksi)	78.1	77.4	78.5	78.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506130316	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	121-Q1	Pipe Size	6 OD x 0.27 WT (in)	Operator Initials	JJ	
Test Name	121-Q1_BM-01_7001-EB7001_190506130316			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

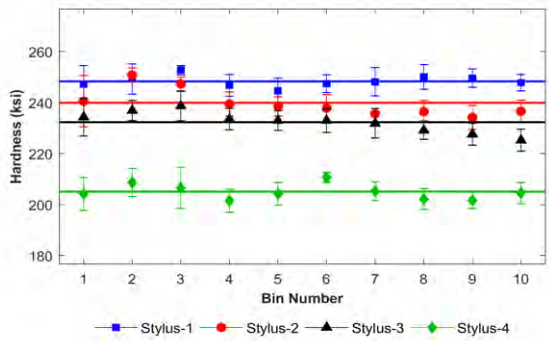
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	248.3	4.73	50
Stylus-2	240.0	6.96	52
Stylus-3	232.3	5.85	48
Stylus-4	205.1	5.38	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.70	0.007	0.024	0.05	< 0.01	0.03	< 0.01	0.02	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.5

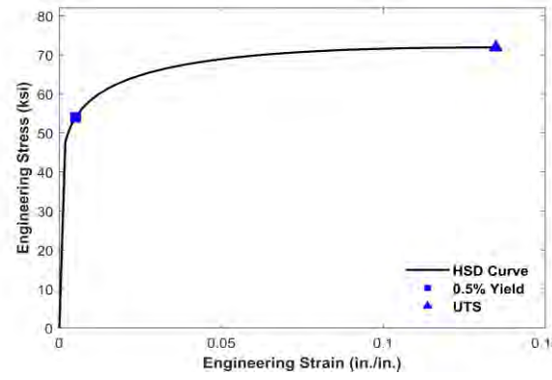
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.9	54.6	54.8	52.7
UTS (ksi)	71.9	72.9	71.4	71.5



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522141919	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:19	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	121-Q1	Pipe Size	6 OD x 0.27 WT (in)	Operator Initials	JJ	
Test Name	121-Q1_BM-02_7001-EB7001_190522141919			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

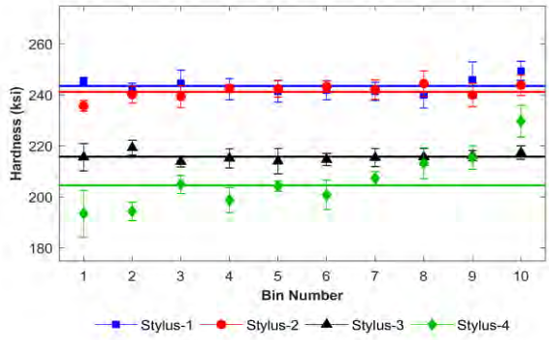
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	243.4	4.68	49
Stylus-2	241.1	4.07	49
Stylus-3	215.6	3.58	49
Stylus-4	204.5	10.35	40

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.70	0.007	0.024	0.05	< 0.01	0.03	< 0.01	0.02	0.01	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

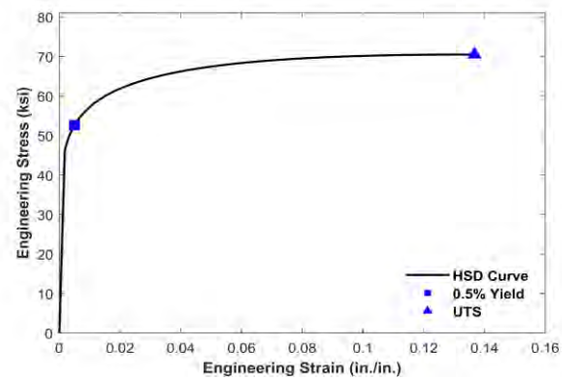
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.6	50.3	53.4	58.1
UTS (ksi)	70.5	70.9	70.2	70.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506133345	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:33	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	122-Q1	Pipe Size	10 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	122-Q1_BM-01_5001-EB5001_190506133345			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

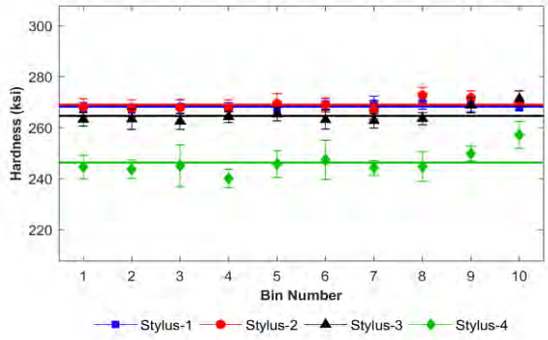
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	268.2	2.41	58
Stylus-2	269.0	3.37	56
Stylus-3	264.6	3.72	52
Stylus-4	246.3	6.48	57

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.17	0.95	0.009	0.020	0.02	0.04	0.01	< 0.01	< 0.01	0.01	0.03	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

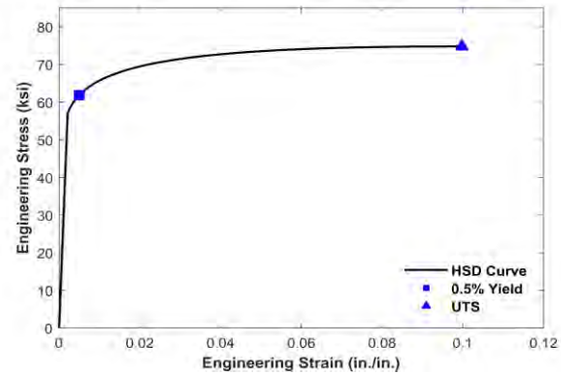
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	61.8	61.2	61.6	63.1
UTS (ksi)	74.8	74.5	74.7	75.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425162217	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	122-Q1	Pipe Size	10 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	122-Q1_BM-02_5001-EB5001_190425162217			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

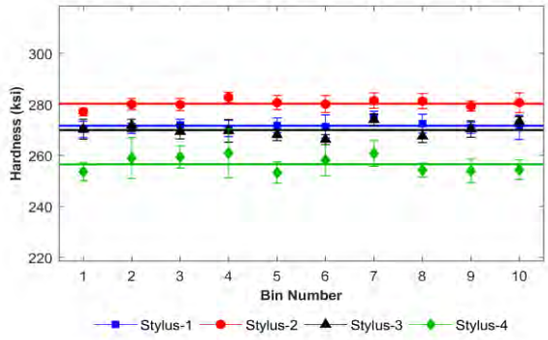
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	271.6	3.30	67
Stylus-2	280.3	2.81	60
Stylus-3	270.0	3.58	64
Stylus-4	256.5	5.68	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.17	0.95	0.009	0.020	0.02	0.04	0.01	< 0.01	< 0.01	0.01	0.03	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

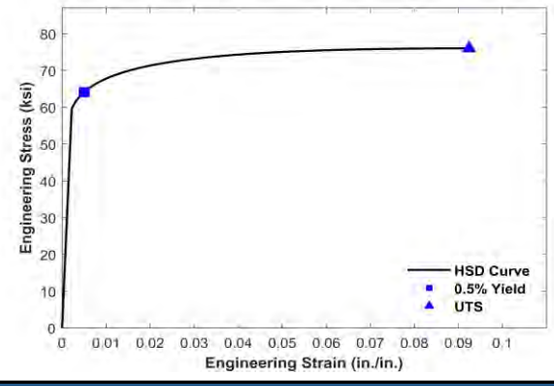
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.1	64.3	64.1	63.9
UTS (ksi)	76.0	75.9	76.0	76.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425171021	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:10	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	123-Q1	Pipe Size	10 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	123-Q1_BM-02_5001-EB5001_190425171021			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

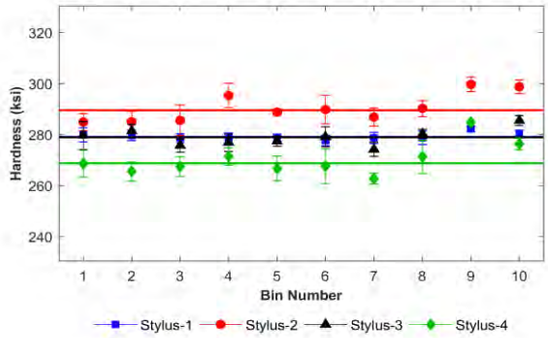
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	279.1	2.10	56
Stylus-2	289.5	6.11	54
Stylus-3	278.9	4.15	52
Stylus-4	268.7	5.95	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	0.73	0.005	0.018	0.01	0.03	0.03	0.05	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

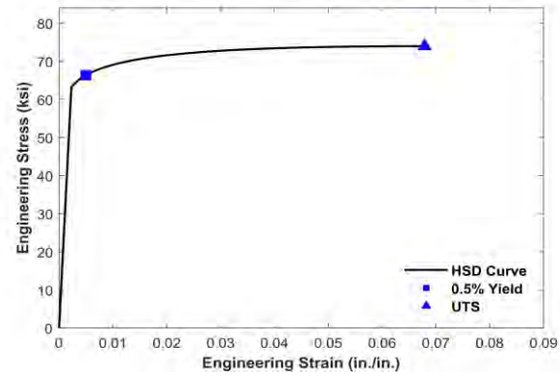
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	66.3	66.1	66.2	67.0
UTS (ksi)	74.0	73.7	73.9	74.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529163957	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	123-Q1	Pipe Size	10 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	123-Q1_BM-03_5002-EB5002_190529163957			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

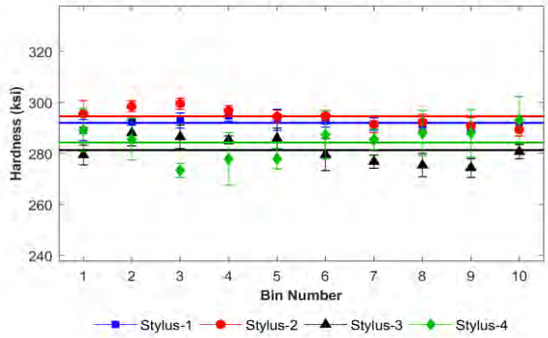
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	292.0	2.92	64
Stylus-2	294.6	4.18	65
Stylus-3	281.3	5.98	63
Stylus-4	284.3	9.40	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.10	0.73	0.005	0.018	0.01	0.03	0.03	0.05	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

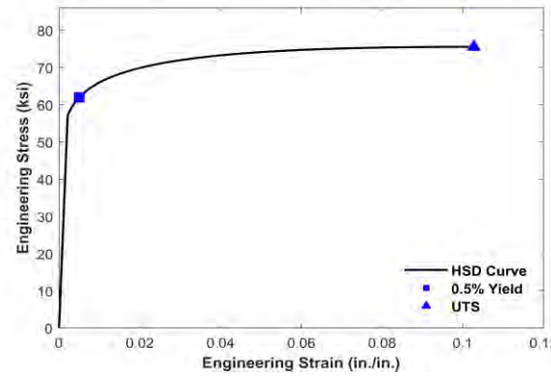
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.0	68.4	67.7	62.8
UTS (ksi)	75.5	75.7	75.5	75.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521092648	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	9:26	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	124-Q2	Pipe Size	6 OD x 0.16 WT (in)	Operator Initials	RP	
Test Name	124-Q2_BM-01_5002-EB5002_190521092648			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

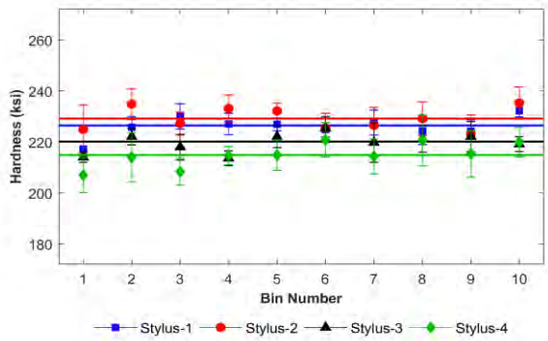
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	226.5	4.97	55
Stylus-2	229.2	7.14	58
Stylus-3	220.1	5.48	53
Stylus-4	214.9	7.96	58

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.64	0.005	0.012	0.01	< 0.01	0.08	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

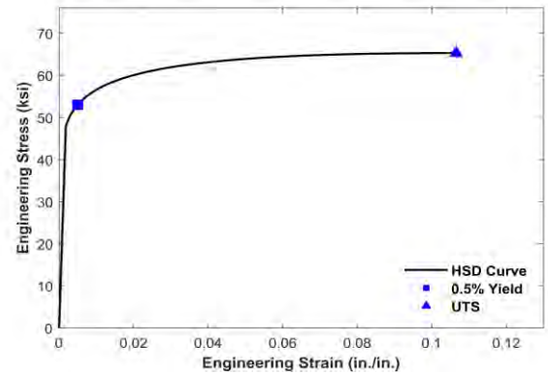
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.0	51.8	53.5	53.5
UTS (ksi)	65.3	65.1	65.4	65.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520125642	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:56	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	124-Q2	Pipe Size	6 OD x 0.16 WT (in)	Operator Initials	RP	
Test Name	124-Q2_BM-02_5001-EB5001_190520125642			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

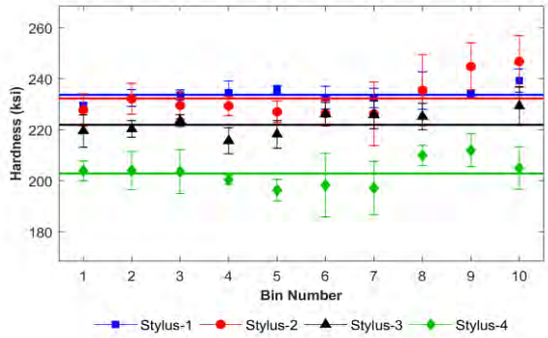
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	233.7	4.06	46
Stylus-2	232.2	10.26	55
Stylus-3	221.9	6.18	52
Stylus-4	202.9	8.17	46

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.64	0.005	0.012	0.01	< 0.01	0.08	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

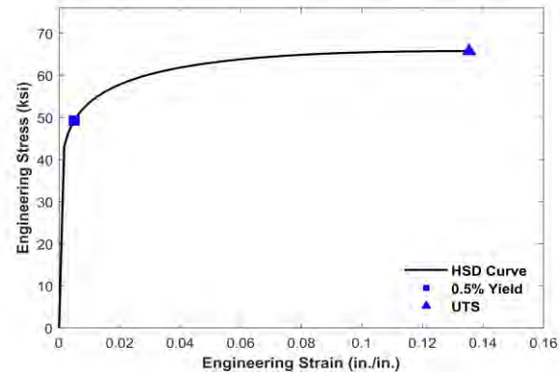
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.2	49.4	48.9	50.2
UTS (ksi)	65.7	65.5	65.4	66.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529181230	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:12	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	124-Q2	Pipe Size	6 OD x 0.16 WT (in)	Operator Initials	JJ	
Test Name	124-Q2_BM-03_5002-EB5002_190529181230			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

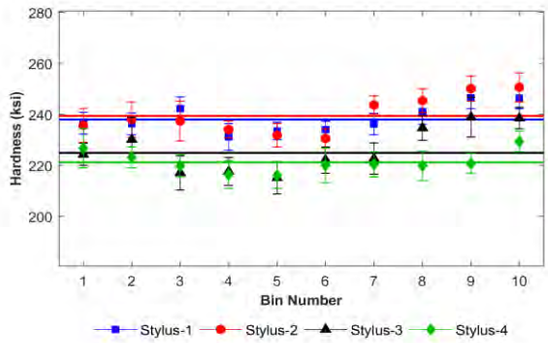
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	237.9	6.32	66
Stylus-2	239.4	8.37	66
Stylus-3	225.0	9.76	64
Stylus-4	221.2	6.43	61

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.18	0.64	0.005	0.012	0.01	< 0.01	0.08	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
12.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

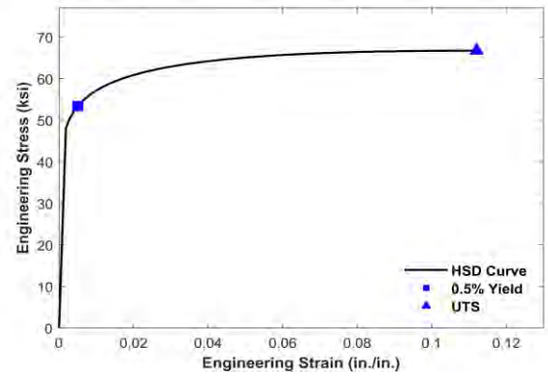
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.4	53.8	52.6	53.8
UTS (ksi)	66.7	66.6	65.8	67.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508163256	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:32	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	125-Q2	Pipe Size	10 OD x 0.22 WT (in)	Operator Initials	RP	
Test Name	125-Q2_BM-01_5002-EB5002_190508163256			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

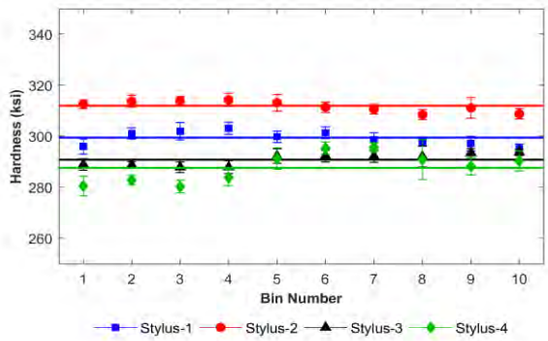
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	299.4	3.41	63
Stylus-2	311.9	3.06	59
Stylus-3	290.8	3.12	60
Stylus-4	287.5	6.59	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.14	0.008	0.007	0.02	0.05	< 0.01	0.03	0.01	< 0.01	0.20	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

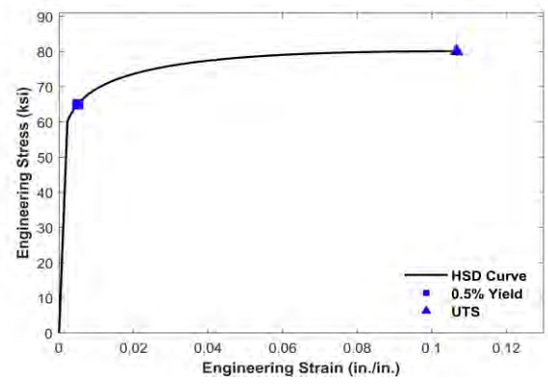
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	65.0	69.9	65.3	66.2
UTS (ksi)	80.1	79.9	80.3	80.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529150105	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:01	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	125-Q2	Pipe Size	10 OD x 0.22 WT (in)	Operator Initials	JN	
Test Name	125-Q2_BM-01_7001-EB7001_190529150105			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

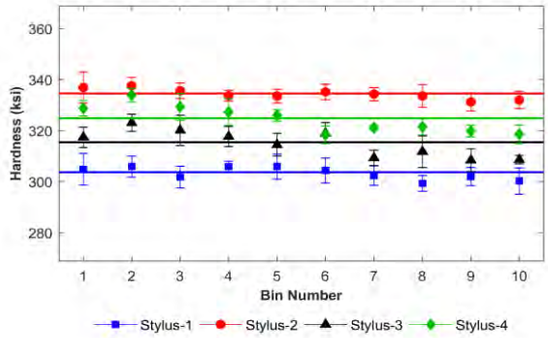
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	303.6	4.53	49
Stylus-2	334.6	3.92	46
Stylus-3	315.5	6.31	55
Stylus-4	324.9	5.97	52

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.14	0.008	0.007	0.02	0.05	< 0.01	0.03	0.01	< 0.01	0.20	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

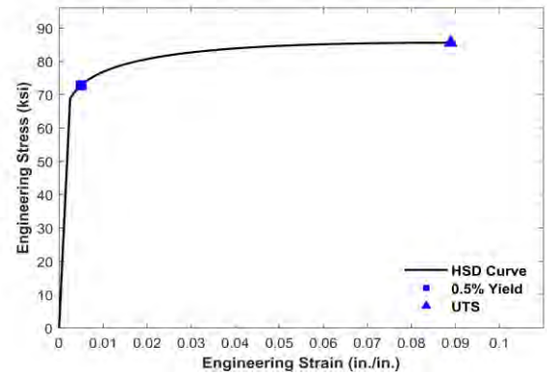
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	72.8	73.9	72.4	71.6
UTS (ksi)	85.5	86.8	85.2	84.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531114611	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:46	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	125-Q2	Pipe Size	10 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	125-Q2_BM-02_5002-EB5002_190531114611			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

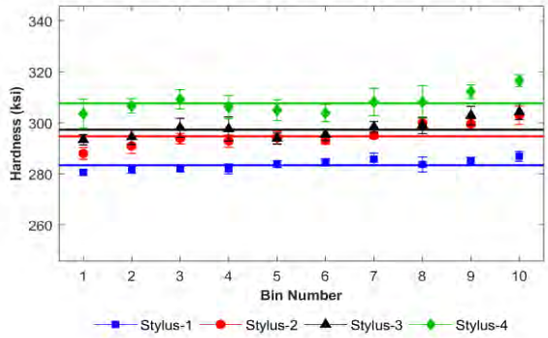
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	283.4	2.45	57
Stylus-2	294.8	4.84	54
Stylus-3	297.3	4.26	56
Stylus-4	307.6	5.34	58

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.06	1.14	0.008	0.007	0.02	0.05	< 0.01	0.03	0.01	< 0.01	0.20	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
5.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

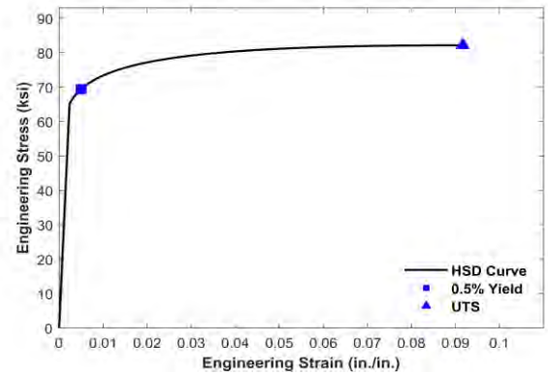
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	69.4	68.9	69.6	69.8
UTS (ksi)	82.2	81.7	82.4	82.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506171006	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:10	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	126-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	126-Q1_BM-01_5001-EB5001_190506171006			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

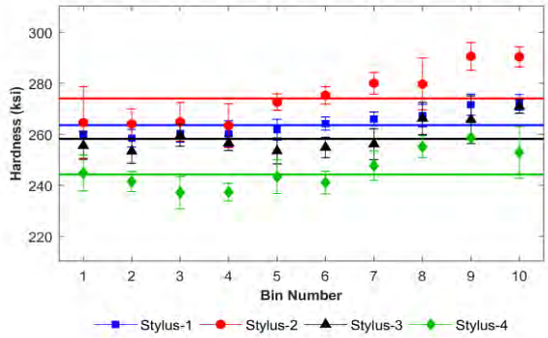
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	263.6	5.62	61
Stylus-2	274.1	12.05	68
Stylus-3	258.2	7.12	59
Stylus-4	244.3	8.06	57

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.91	0.011	0.011	0.02	< 0.01	0.03	0.03	< 0.01	0.01	0.17	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

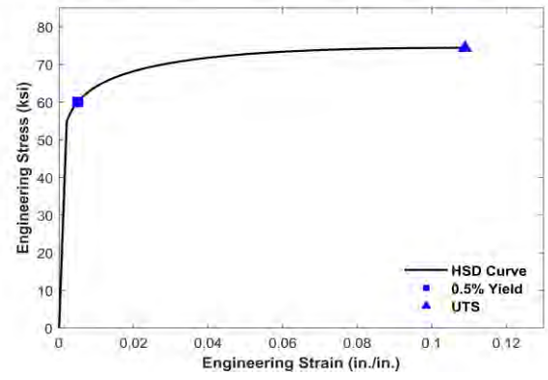
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	60.0	59.7	59.1	61.9
UTS (ksi)	74.4	73.6	74.0	75.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506180031	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:00	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	126-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	126-Q1_BM-01_5002-EB5002_190506180031			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

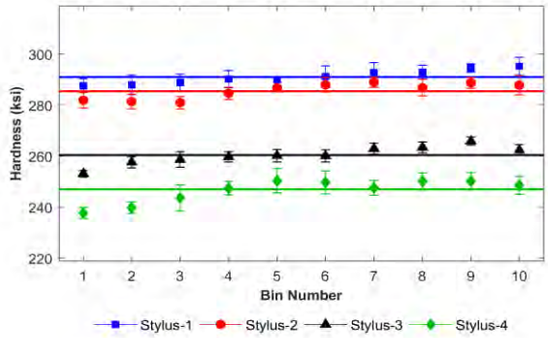
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	291.0	3.86	64
Stylus-2	285.4	3.93	62
Stylus-3	260.3	3.97	60
Stylus-4	247.0	5.16	57

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.91	0.011	0.011	0.02	< 0.01	0.03	0.03	< 0.01	0.01	0.17	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

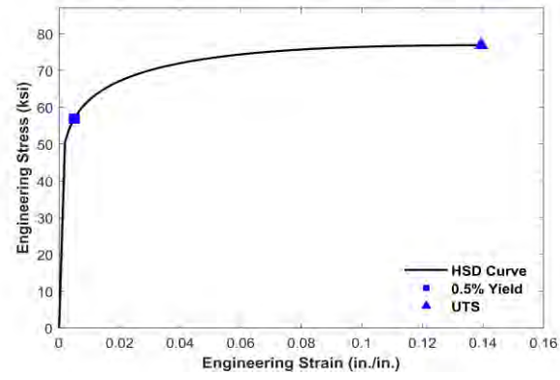
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	56.9	55.4	57.2	57.4
UTS (ksi)	76.9	76.3	76.9	77.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529160934	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:09	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	127-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	127-Q1_BM-02_5002-EB5002_190529160934			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

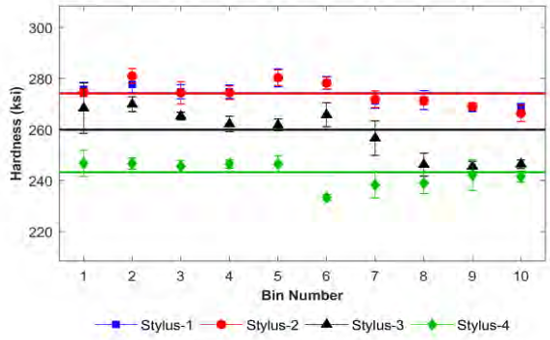
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	274.2	4.58	51
Stylus-2	274.2	5.14	51
Stylus-3	259.9	9.46	46
Stylus-4	243.2	5.19	46

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.95	0.008	0.013	0.01	0.05	0.02	0.03	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.2

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

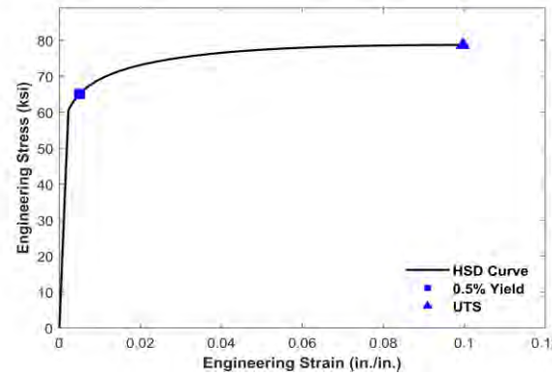
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	65.1	66.7	65.1	63.5
UTS (ksi)	78.7	79.5	79.4	77.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530202522	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	20:25	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	127-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	127-Q1_BM-03_5002-EB5002_190530202522			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

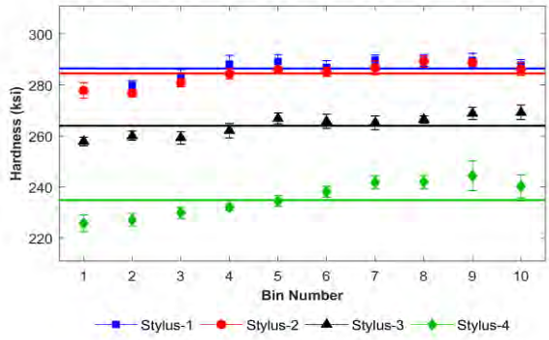
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	286.5	4.49	60
Stylus-2	284.5	4.24	61
Stylus-3	264.0	4.50	62
Stylus-4	234.9	6.85	62

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.95	0.008	0.013	0.01	0.05	0.02	0.03	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.2

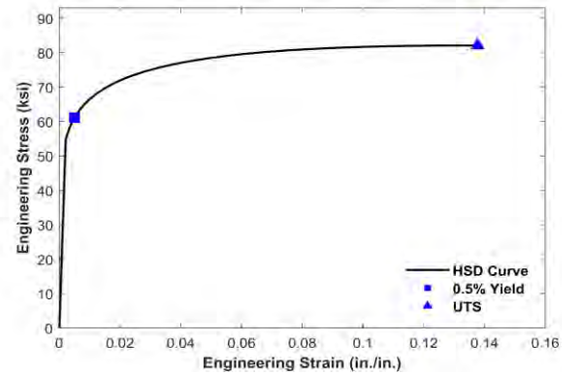
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	61.1	59.0	60.8	63.4
UTS (ksi)	82.1	80.7	82.5	82.6



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531110826	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	130-Q1	Pipe Size	4 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	130-Q1_BM-01_5002-EB5002_190531110826			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

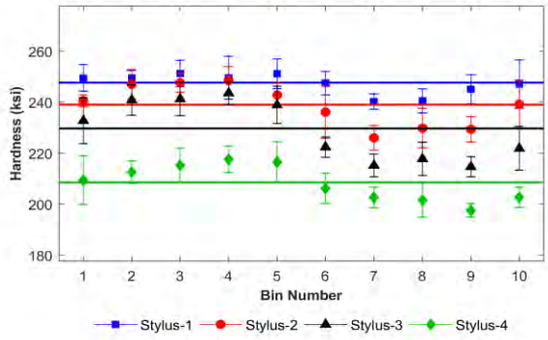
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	247.5	6.57	63
Stylus-2	239.0	9.78	64
Stylus-3	229.7	12.61	65
Stylus-4	208.5	8.78	64

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.91	0.009	0.027	0.02	< 0.01	0.09	0.01	< 0.01	0.03	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

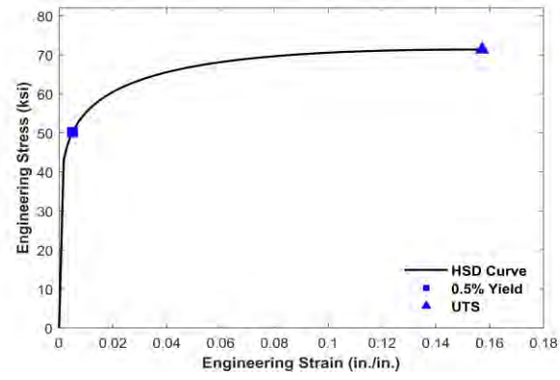
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.2	51.3	51.6	48.0
UTS (ksi)	71.3	72.2	71.6	70.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531112344	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:23	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	130-Q1	Pipe Size	4 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	130-Q1_BM-02_5002-EB5002_190531112344			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

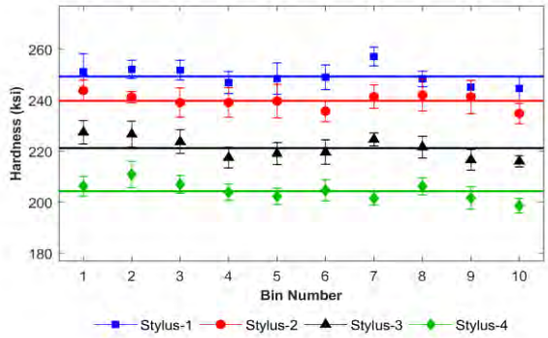
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	249.4	5.48	63
Stylus-2	239.8	5.45	61
Stylus-3	221.3	5.46	61
Stylus-4	204.3	4.64	61

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.91	0.009	0.027	0.02	< 0.01	0.09	0.01	< 0.01	0.03	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
14.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

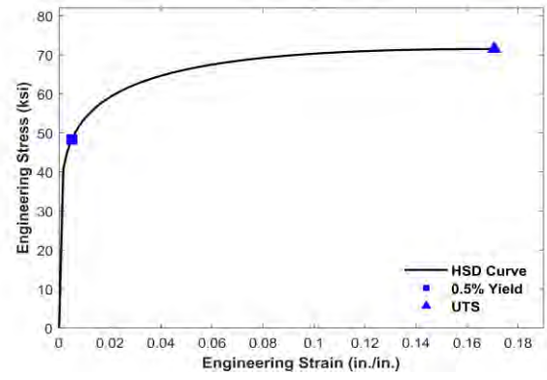
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	48.3	49.4	48.5	47.8
UTS (ksi)	71.5	72.0	71.3	71.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509163316	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:33	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	132-Q1	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	132-Q1_BM-01_5002-EB5002_190509163316			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

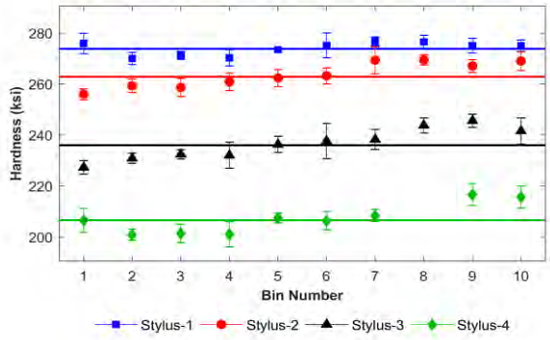
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	273.7	3.61	65
Stylus-2	262.9	5.54	61
Stylus-3	236.0	6.68	63
Stylus-4	206.5	6.33	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	0.82	0.011	0.034	0.02	< 0.01	0.02	0.01	< 0.01	0.01	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.1

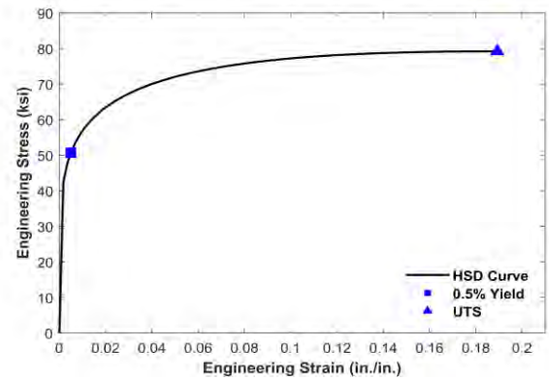
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.7	49.3	50.2	53.4
UTS (ksi)	79.2	78.6	79.2	79.5



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520121540	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:15	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	132-Q1	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	132-Q1_BM-01_7001-EB7001_190520121540			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

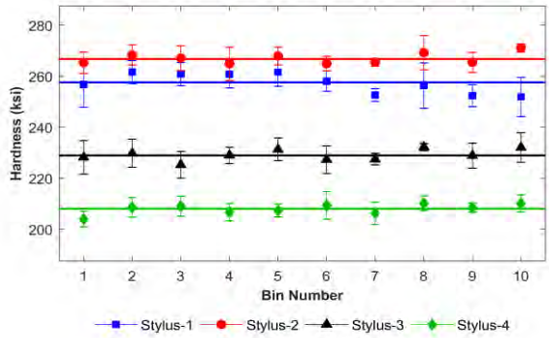
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.6	6.45	51
Stylus-2	266.8	4.33	49
Stylus-3	229.0	4.88	50
Stylus-4	208.1	3.77	50

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	0.82	0.011	0.034	0.02	< 0.01	0.02	0.01	< 0.01	0.01	0.05	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.1

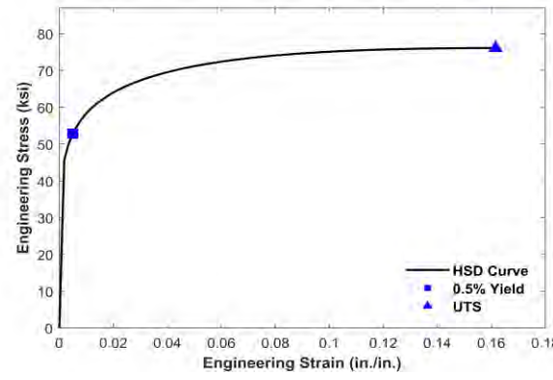
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.8	52.3	52.3	53.9
UTS (ksi)	76.1	76.7	76.4	75.3



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507125837	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	133-Q1	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	133-Q1_BM-01_5001-EB5001_190507125837			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

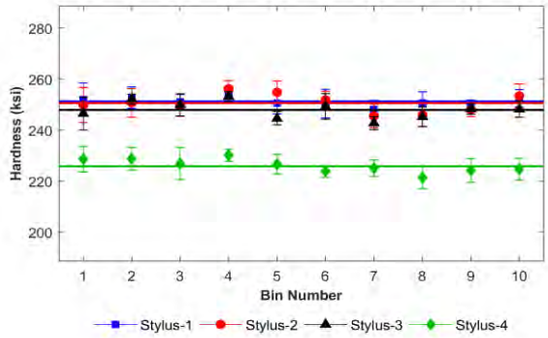
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	251.2	4.18	54
Stylus-2	250.6	5.38	58
Stylus-3	247.9	4.58	56
Stylus-4	225.8	4.57	54

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.55	0.007	0.018	0.01	< 0.01	0.06	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

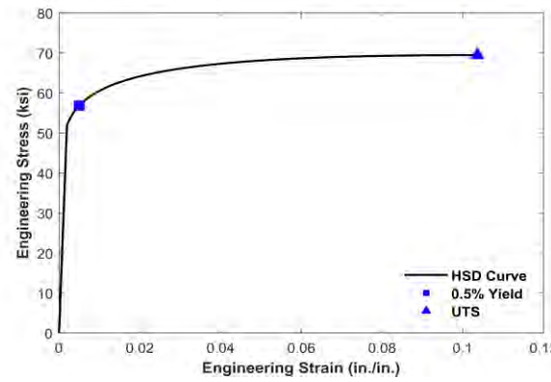
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	56.8	57.5	56.8	56.3
UTS (ksi)	69.4	69.6	69.5	69.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506180859	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	133-Q2	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	133-Q2_BM-01_7001-EB7001_190506180859			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

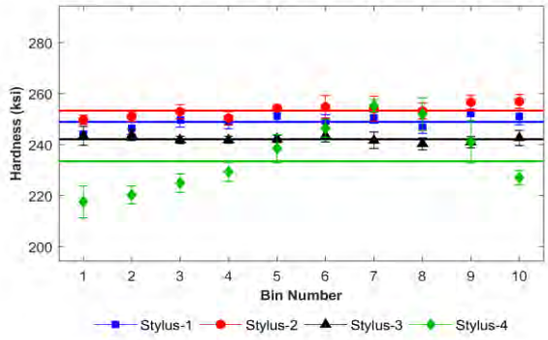
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	249.0	3.39	47
Stylus-2	253.3	3.56	47
Stylus-3	242.2	2.33	45
Stylus-4	233.5	13.34	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.55	0.007	0.018	0.01	< 0.01	0.06	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.4

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

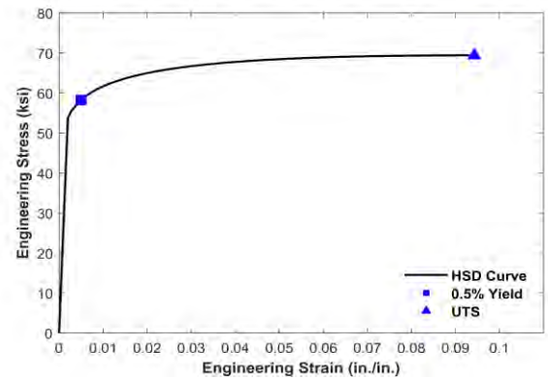
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.2	55.8	59.3	53.3
UTS (ksi)	69.4	68.9	69.6	69.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530200643	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	20:06	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	134-Q1	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	134-Q1_BM-02_5002-EB5002_190530200643			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

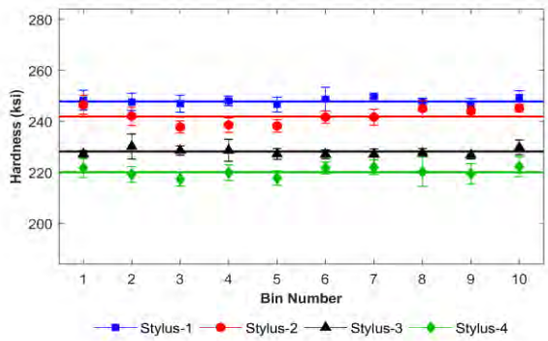
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	247.8	3.04	61
Stylus-2	241.9	4.10	59
Stylus-3	228.1	2.88	54
Stylus-4	220.1	3.58	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.54	0.011	0.020	0.01	< 0.01	0.05	0.02	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

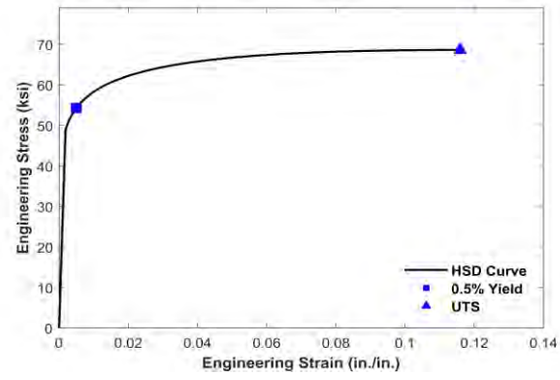
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	54.3	54.3	54.4	54.3
UTS (ksi)	68.6	68.7	68.4	68.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507143347	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:33	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	134-Q2	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	134-Q2_BM-01_5001-EB5001_190507143347			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

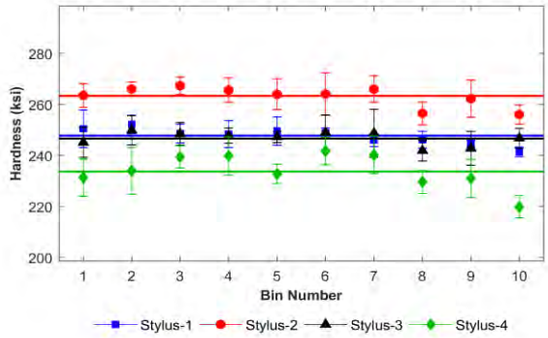
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	247.8	4.83	59
Stylus-2	263.3	5.99	59
Stylus-3	246.6	5.59	55
Stylus-4	233.7	8.62	60

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.54	0.011	0.020	0.01	< 0.01	0.05	0.02	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

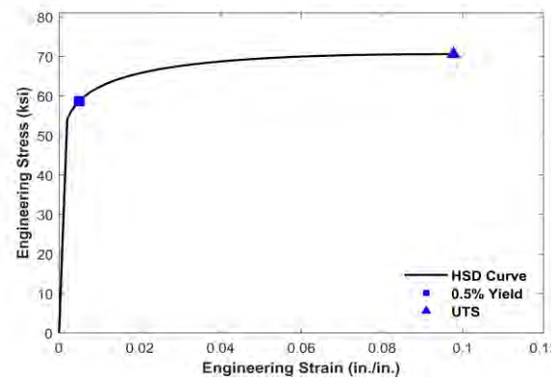
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.7	58.7	60.0	57.5
UTS (ksi)	70.6	70.9	71.0	69.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507122145	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	134-Q2	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	134-Q2_BM-01_5002-EB5002_190507122145			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

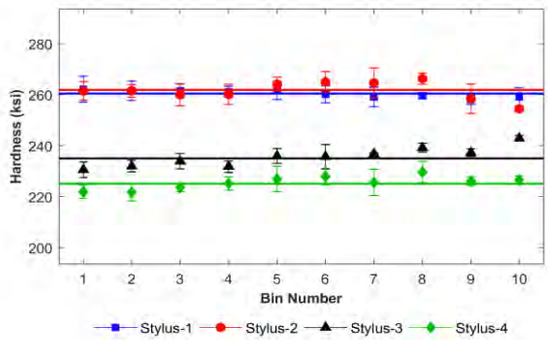
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	260.4	3.28	61
Stylus-2	261.8	4.72	61
Stylus-3	235.0	4.08	60
Stylus-4	225.1	3.83	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.54	0.011	0.020	0.01	< 0.01	0.05	0.02	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

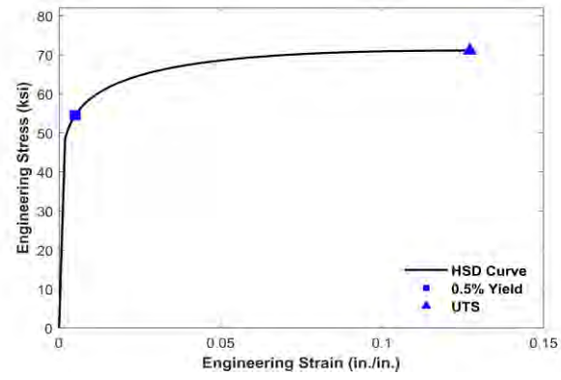
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	54.5	53.6	54.5	55.4
UTS (ksi)	71.1	71.2	71.2	71.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509162929	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:29	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	134-Q2	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	134-Q2_BM-04_5001-EB5001_190509162929			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

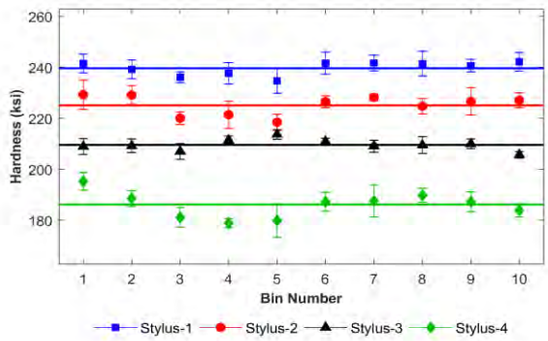
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	239.6	4.34	61
Stylus-2	225.1	5.19	66
Stylus-3	209.6	2.91	58
Stylus-4	186.2	5.97	58

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.54	0.011	0.020	0.01	< 0.01	0.05	0.02	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

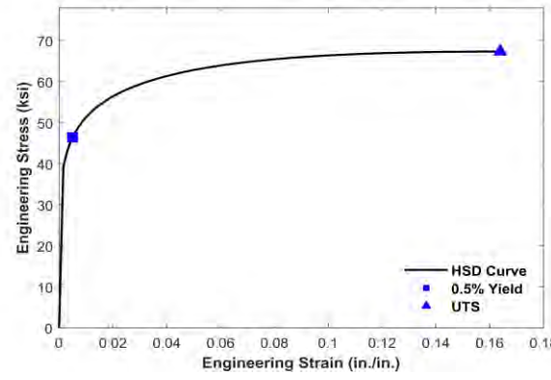
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.5	47.3	45.9	46.3
UTS (ksi)	67.4	67.1	67.3	67.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507132335	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:23	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	136-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	136-Q1_BM-01_5002-EB5002_190507132335			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

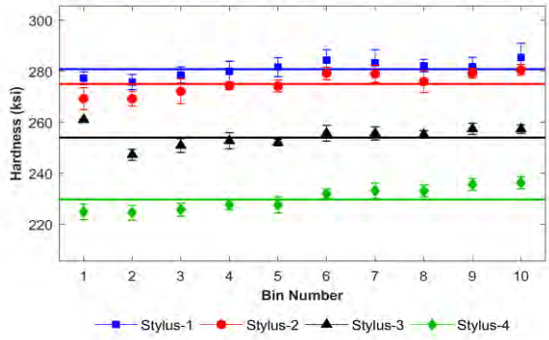
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	280.8	4.62	65
Stylus-2	275.0	4.99	65
Stylus-3	253.9	3.83	57
Stylus-4	229.7	4.92	64

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.06	0.016	0.022	0.03	< 0.01	< 0.01	0.01	< 0.01	0.04	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.7

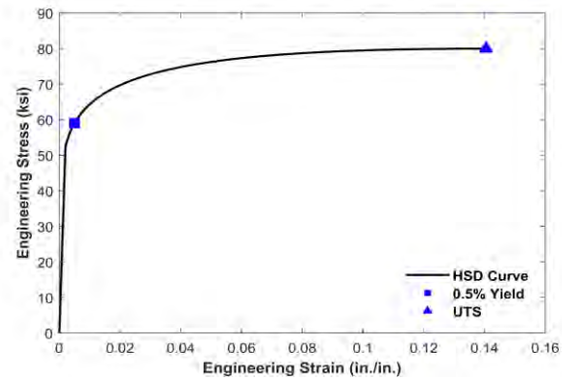
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	59.0	57.8	58.5	60.4
UTS (ksi)	79.9	79.0	80.2	80.5



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530194751	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:47	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	136-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	136-Q1_BM-04_5002-EB5002_190530194751			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

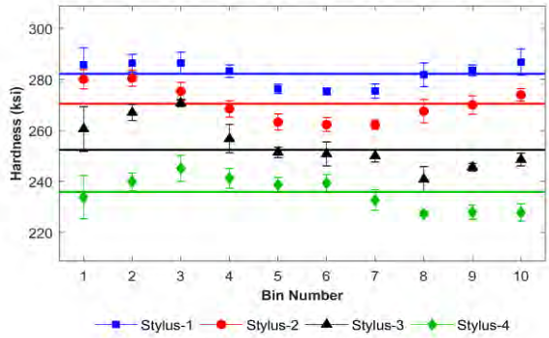
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	282.2	5.73	65
Stylus-2	270.4	7.34	61
Stylus-3	252.4	8.75	54
Stylus-4	235.8	7.25	64

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.06	0.016	0.022	0.03	< 0.01	< 0.01	0.01	< 0.01	0.04	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

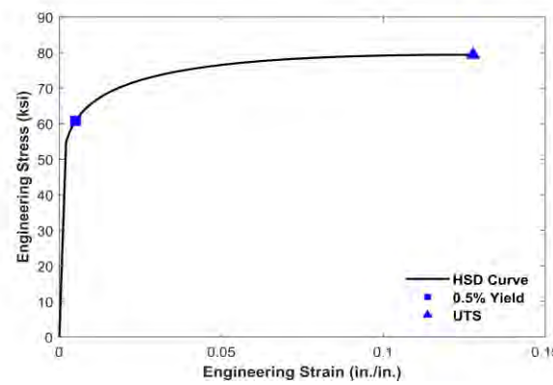
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	60.8	62.6	62.6	57.8
UTS (ksi)	79.4	81.1	78.2	79.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529184330	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:43	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	137-Q2	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	137-Q2_BM-01_5002-EB5002_190529184330			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

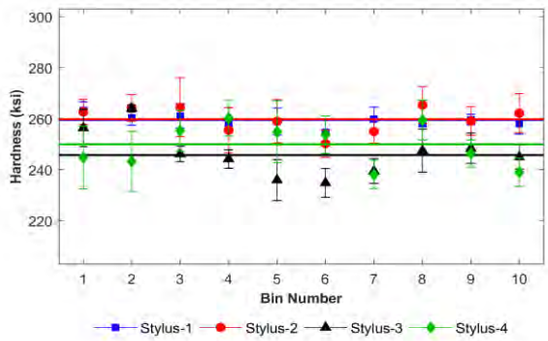
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	259.5	4.02	58
Stylus-2	259.8	8.30	67
Stylus-3	245.7	9.43	57
Stylus-4	249.9	11.24	65

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	1.10	0.012	< 0.005	0.03	0.03	< 0.01	< 0.01	< 0.01	< 0.01	0.19	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

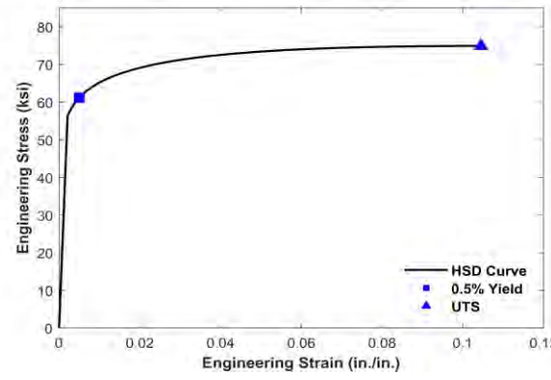
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	61.1	61.0	55.7	60.3
UTS (ksi)	74.9	75.5	74.9	74.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522100548	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:05	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	137-Q2	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	137-Q2_BM-01_7001-EB7001_190522100548			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

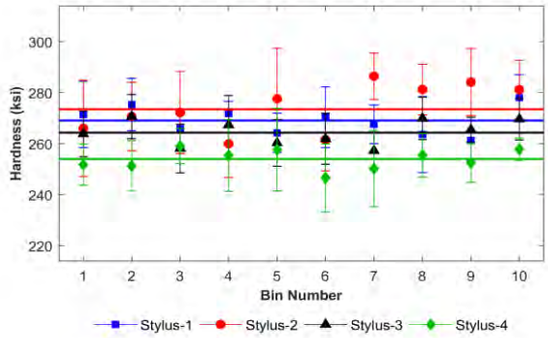
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	269.1	10.06	50
Stylus-2	273.5	15.93	55
Stylus-3	264.3	9.56	53
Stylus-4	254.0	10.74	51

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	1.10	0.012	< 0.005	0.03	0.03	< 0.01	< 0.01	< 0.01	< 0.01	0.19	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

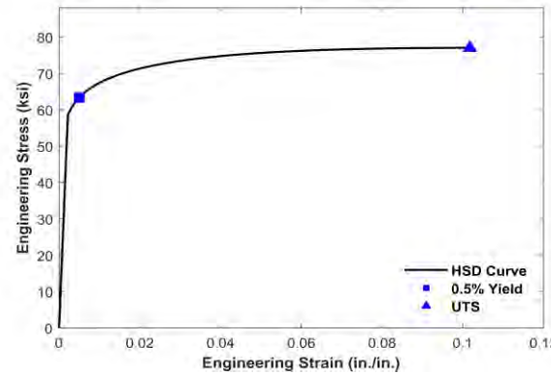
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	63.3	63.2	57.1	63.1
UTS (ksi)	77.0	77.2	76.9	77.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522102959	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	10:29	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	137-Q2	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	137-Q2_BM-02_7001-EB7001_190522102959			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.80002	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

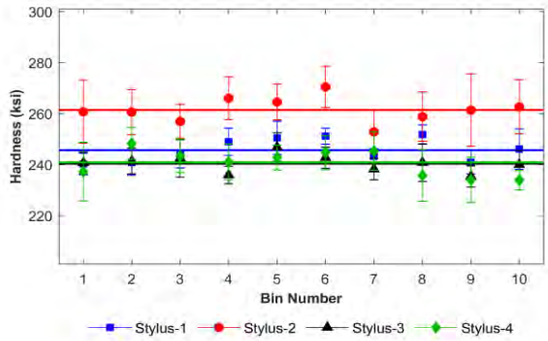
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	245.7	6.39	48
Stylus-2	261.4	9.79	51
Stylus-3	240.4	5.67	48
Stylus-4	240.9	8.21	49

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	1.10	0.012	< 0.005	0.03	0.03	< 0.01	< 0.01	< 0.01	< 0.01	0.19	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.7

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

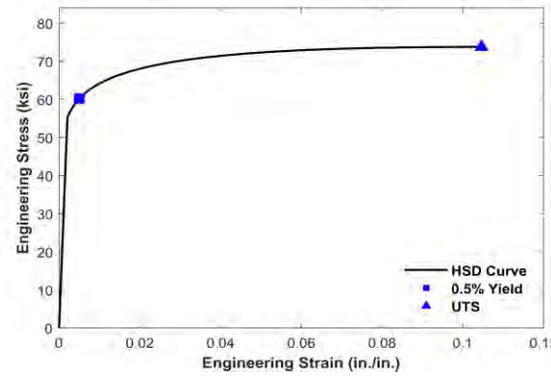
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	60.2	54.7	60.0	59.3
UTS (ksi)	73.8	73.8	74.1	73.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529171522	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:15	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	138-Q1	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	138-Q1_BM-01_5002-EB5002_190529171522			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

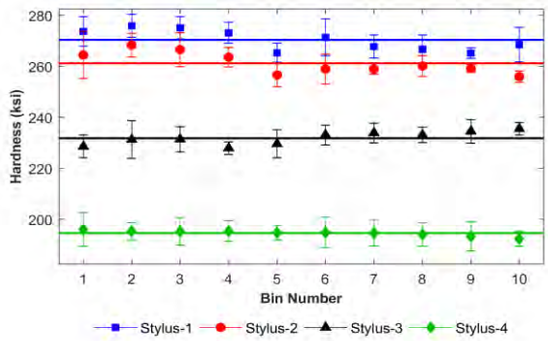
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.3	6.13	67
Stylus-2	261.2	6.03	65
Stylus-3	231.8	4.84	62
Stylus-4	194.6	4.48	61

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.52	0.009	0.021	0.01	< 0.01	< 0.01	0.02	< 0.01	0.02	0.10	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

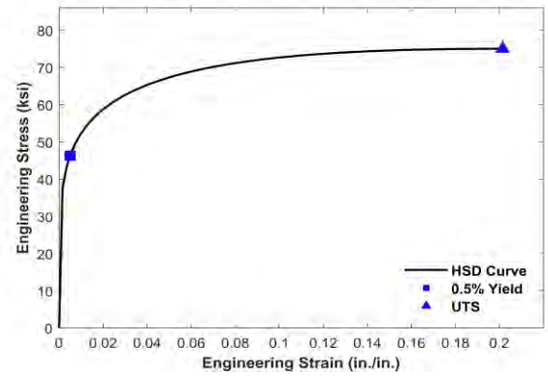
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.3	45.9	46.4	46.6
UTS (ksi)	75.0	76.3	74.5	74.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522111544	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:15	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	138-Q1	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	138-Q1_BM-01_7001-EB7001_190522111544			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

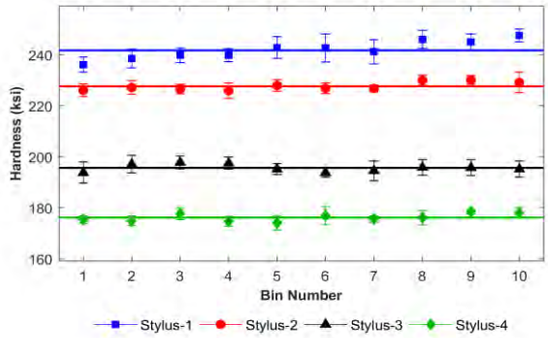
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	241.8	4.80	53
Stylus-2	227.7	2.66	47
Stylus-3	195.7	3.07	55
Stylus-4	176.1	2.48	53

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.52	0.009	0.021	0.01	< 0.01	< 0.01	0.02	< 0.01	0.02	0.10	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

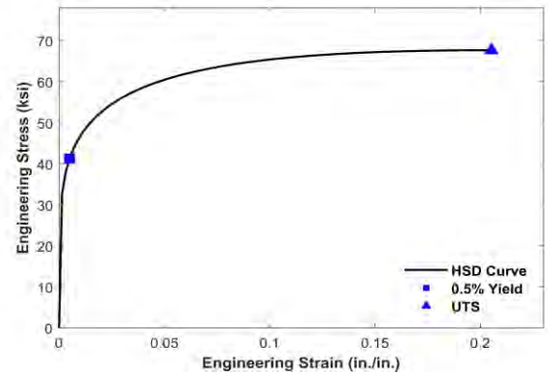
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	41.3	41.8	41.0	41.0
UTS (ksi)	67.7	67.0	67.6	68.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522113910	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	138-Q1	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	138-Q1_BM-03_7001-EB7001_190522113910			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

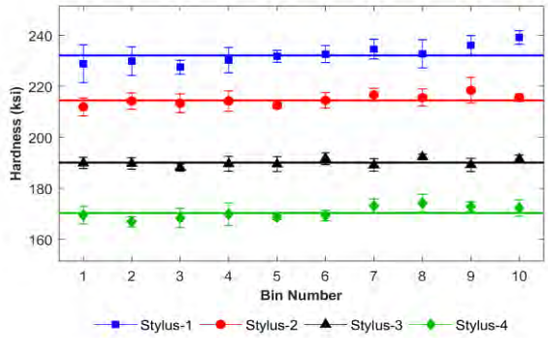
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	232.2	5.29	57
Stylus-2	214.5	3.47	54
Stylus-3	190.0	2.38	54
Stylus-4	170.3	3.54	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	0.52	0.009	0.021	0.01	< 0.01	< 0.01	0.02	< 0.01	0.02	0.10	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

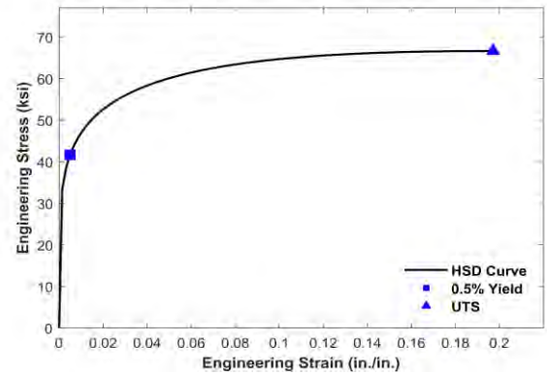
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	41.6	41.5	41.5	42.0
UTS (ksi)	66.6	66.3	66.5	67.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521095816	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	9:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	139-Q1	Pipe Size	6 OD x 0.18 WT (in)	Operator Initials	RP	
Test Name	139-Q1_BM-01_5001-EB5001_190521095816			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

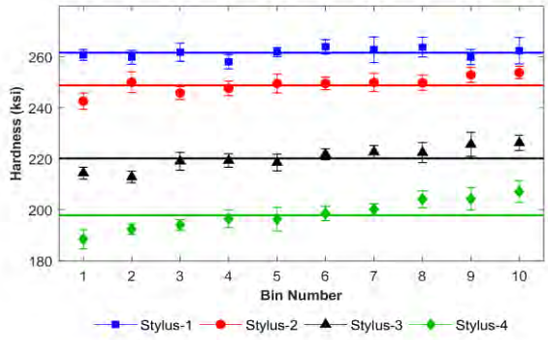
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	261.5	3.68	61
Stylus-2	248.8	4.11	61
Stylus-3	220.2	4.92	64
Stylus-4	197.9	6.43	64

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.52	0.007	0.019	0.01	< 0.01	0.01	0.02	< 0.01	0.02	0.10	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

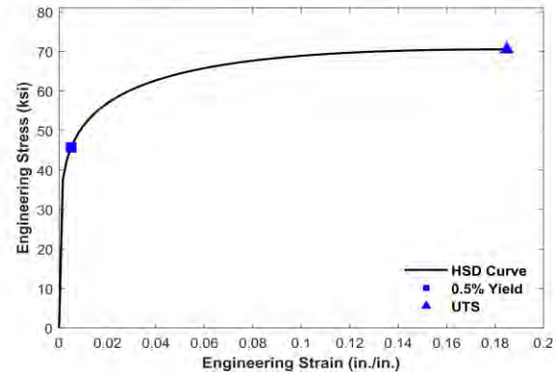
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.7	44.2	45.7	47.5
UTS (ksi)	70.5	70.7	70.5	70.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507152045	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	139-Q1	Pipe Size	6 OD x 0.18 WT (in)	Operator Initials	JJ	
Test Name	139-Q1_BM-01_7001-EB7001_190507152045			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

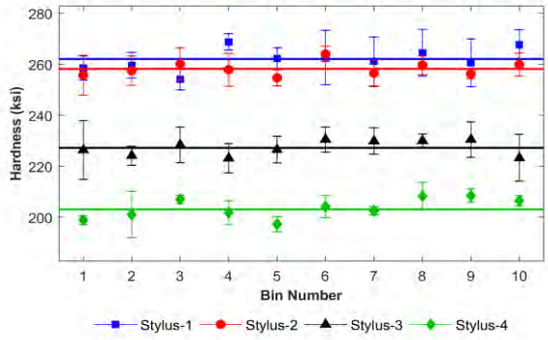
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	262.1	7.47	37
Stylus-2	258.2	5.23	39
Stylus-3	227.2	6.65	42
Stylus-4	203.1	5.41	38

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.52	0.007	0.019	0.01	< 0.01	0.01	0.02	< 0.01	0.02	0.10	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

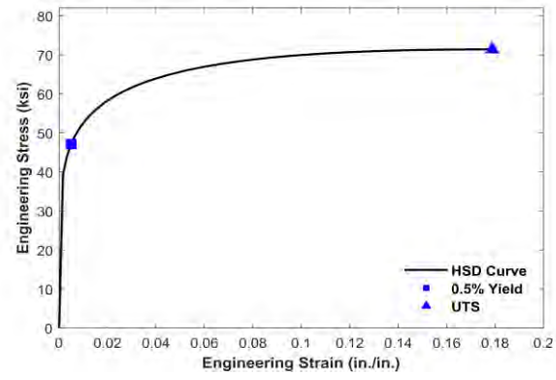
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.1	46.7	47.0	47.6
UTS (ksi)	71.4	70.8	71.3	71.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509124333	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:43	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	140-Q2	Pipe Size	8 OD x 0.18 WT (in)	Operator Initials	JJ	
Test Name	140-Q2_BM-01_5001-EB5001_190509124333			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

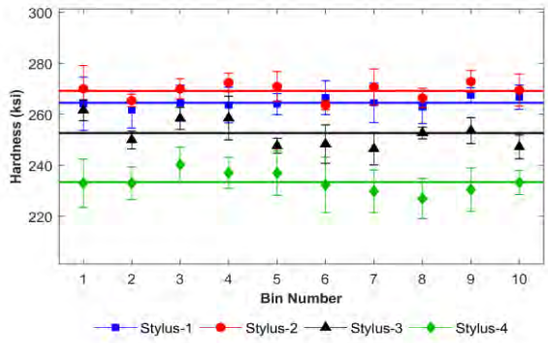
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	264.6	6.47	62
Stylus-2	269.2	5.62	56
Stylus-3	252.6	7.04	56
Stylus-4	233.4	8.26	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.96	0.008	0.025	0.03	< 0.01	0.02	0.01	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

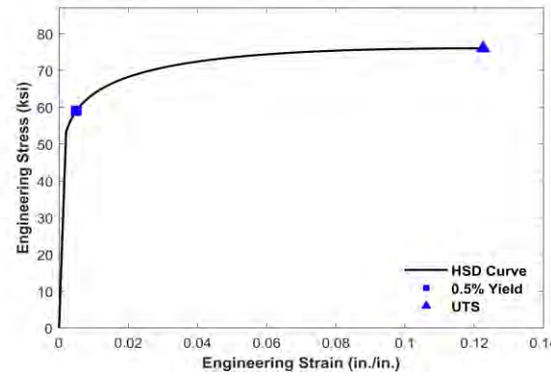
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	59.0	60.0	59.0	58.2
UTS (ksi)	76.0	76.0	76.0	76.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509173130	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:31	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	140-Q2	Pipe Size	8 OD x 0.18 WT (in)	Operator Initials	RP	
Test Name	140-Q2_BM-01_5002-EB5002_190509173130			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

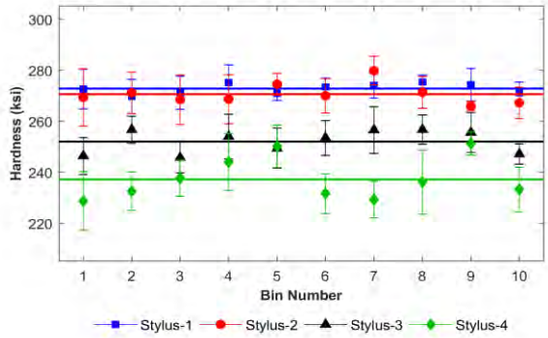
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	272.8	5.46	60
Stylus-2	270.6	7.90	63
Stylus-3	252.0	7.84	66
Stylus-4	237.1	11.38	64

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.96	0.008	0.025	0.03	< 0.01	0.02	0.01	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
6.3

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

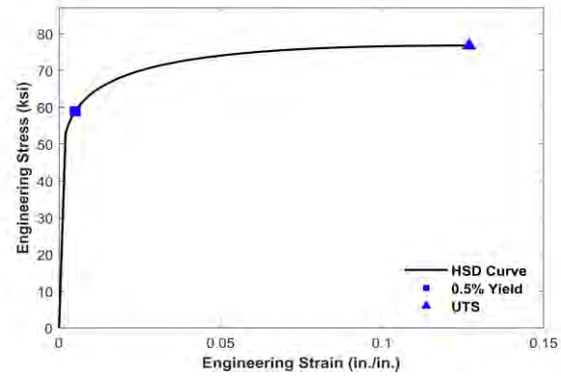
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	58.9	58.0	60.0	58.8
UTS (ksi)	76.8	76.6	76.8	76.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530161145	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:11	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	141-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JN	
Test Name	141-Q1_BM-01_7001-EB7001_190530161145			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

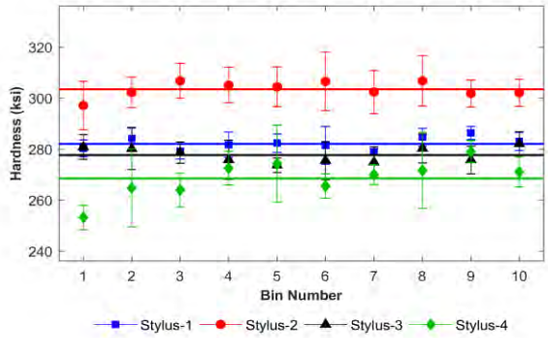
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	282.1	4.13	47
Stylus-2	303.4	7.76	53
Stylus-3	277.7	6.02	50
Stylus-4	268.5	11.07	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.27	0.81	0.008	0.026	0.05	< 0.01	0.03	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

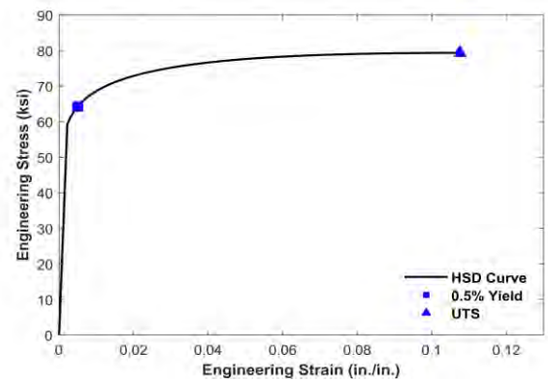
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	64.2	62.8	64.6	65.2
UTS (ksi)	79.3	79.1	79.3	79.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529152443	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:24	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	141-Q2	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	141-Q2_BM-02_5002-EB5002_190529152443			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

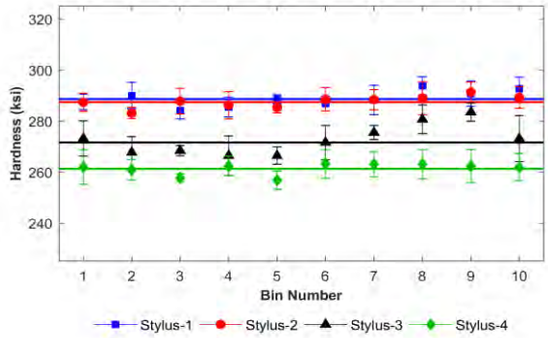
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	288.6	4.75	63
Stylus-2	287.4	4.54	61
Stylus-3	271.6	7.39	60
Stylus-4	261.3	5.03	59

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.27	0.81	0.008	0.026	0.05	< 0.01	0.03	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

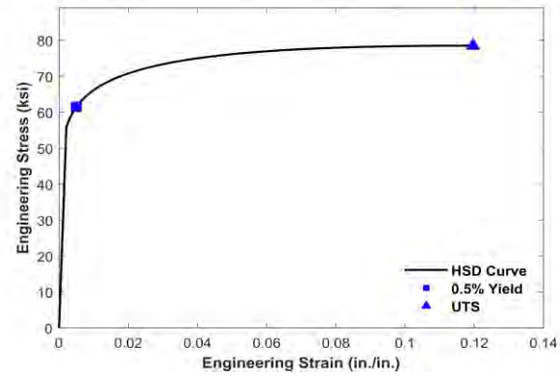
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	61.5	61.6	61.2	61.9
UTS (ksi)	78.5	78.3	78.2	79.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529173923	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	142-Q2	Pipe Size	6 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	142-Q2_BM-01_5002-EB5002_190529173923			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

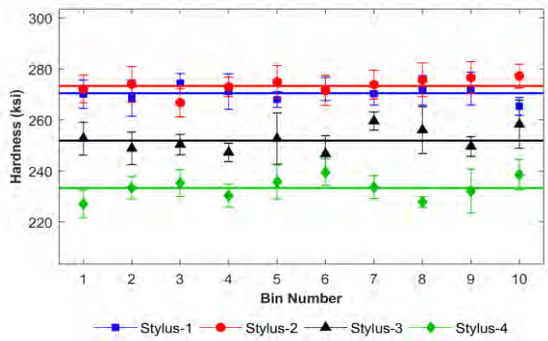
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.5	5.50	60
Stylus-2	273.4	6.08	63
Stylus-3	251.9	7.53	65
Stylus-4	233.3	6.37	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.92	0.015	0.023	0.01	< 0.01	0.01	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
15.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

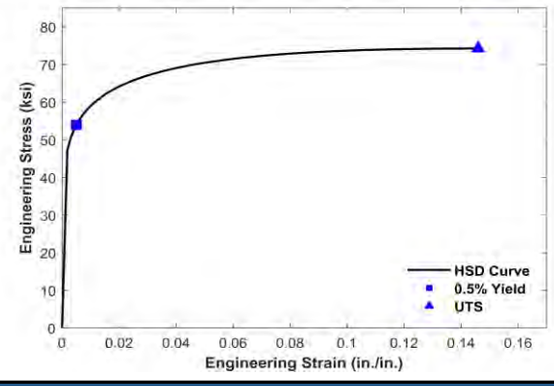
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.9	53.4	54.3	54.1
UTS (ksi)	74.2	74.2	74.0	74.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522121501	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:15	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	142-Q2	Pipe Size	6 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	142-Q2_BM-01_7001-EB7001_190522121501			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

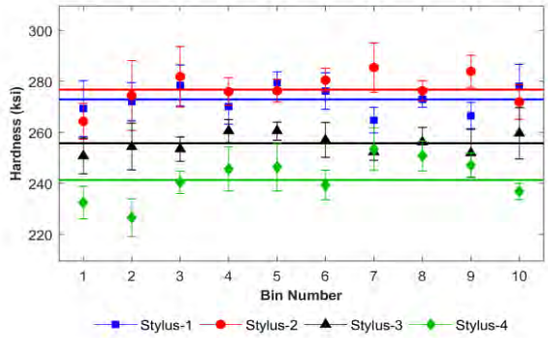
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	273.0	8.28	53
Stylus-2	276.8	9.52	49
Stylus-3	255.9	7.07	53
Stylus-4	241.3	10.15	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.92	0.015	0.023	0.01	< 0.01	0.01	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
15.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

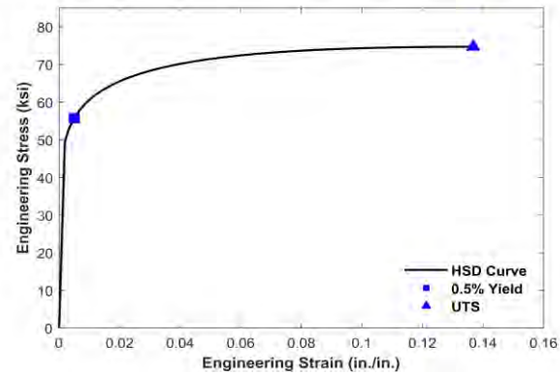
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	55.7	53.7	56.3	57.2
UTS (ksi)	74.7	74.5	75.0	74.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522125508	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:55	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	142-Q2	Pipe Size	6 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	142-Q2_BM-04_7001-EB7001_190522125508			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

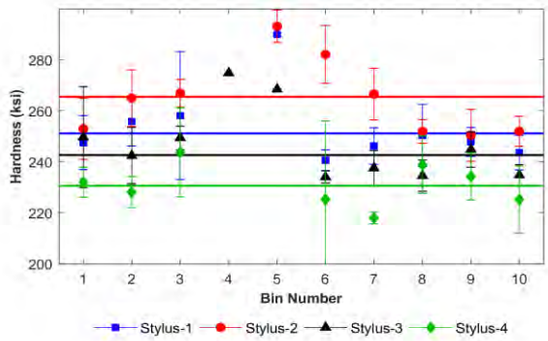
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	251.2	13.99	39
Stylus-2	265.4	18.02	46
Stylus-3	242.6	12.79	40
Stylus-4	230.7	12.79	37

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.92	0.015	0.023	0.01	< 0.01	0.01	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
15.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

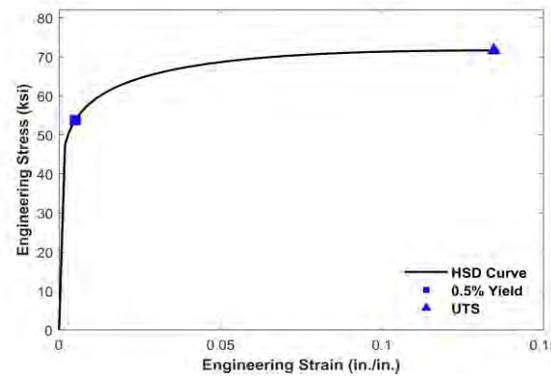
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.8	54.6	50.8	54.1
UTS (ksi)	71.6	71.7	73.7	70.6

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530173816	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:38	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	143-Q2	Pipe Size	4 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	143-Q2_BM-02_5002-EB5002_190530173816			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

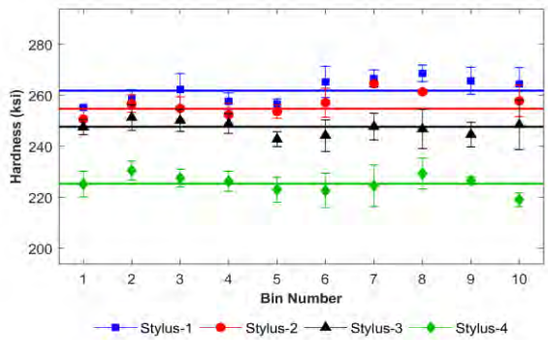
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	261.8	6.07	62
Stylus-2	254.7	4.86	40
Stylus-3	247.6	5.71	57
Stylus-4	225.3	5.64	56

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.50	0.009	0.024	0.04	< 0.01	0.06	0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

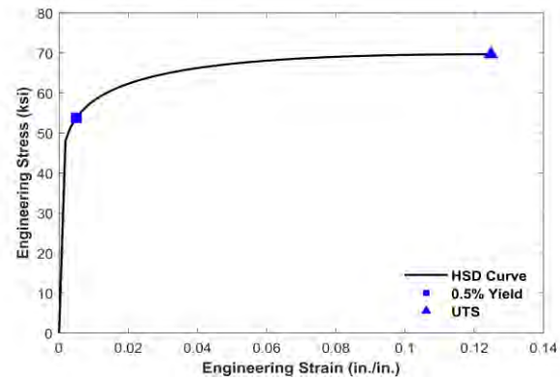
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.8	54.8	53.5	53.1
UTS (ksi)	69.7	69.4	69.5	70.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530190503	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	19:05	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	143-Q2	Pipe Size	4 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	143-Q2_BM-04_5002-EB5002_190530190503			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

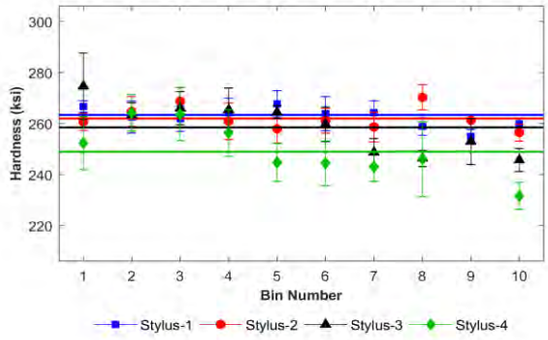
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	263.3	5.51	50
Stylus-2	262.0	6.50	54
Stylus-3	258.5	11.00	50
Stylus-4	248.9	12.48	53

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.50	0.009	0.024	0.04	< 0.01	0.06	0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

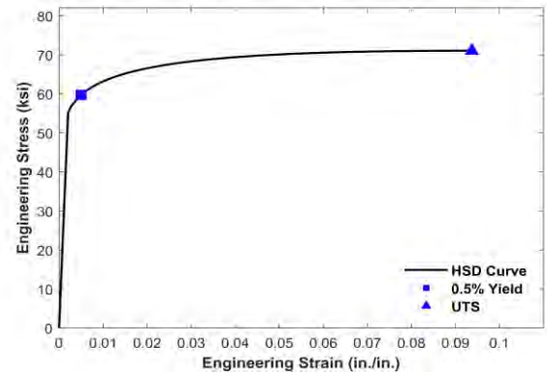
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	59.7	56.1	59.9	57.0
UTS (ksi)	71.0	72.3	71.1	70.3

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509133446	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:34	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	144-Q2	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials	RP	
Test Name	144-Q2_BM-01_5002-EB5002_190509133446			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

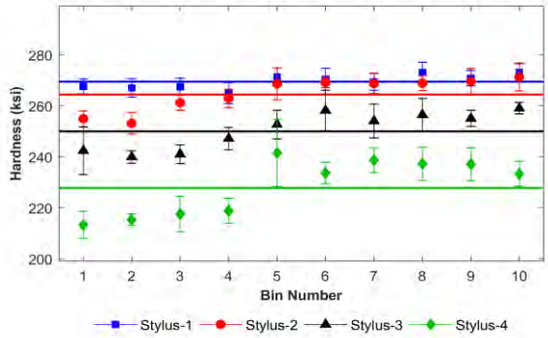
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	269.5	4.19	58
Stylus-2	264.5	7.43	63
Stylus-3	250.0	8.82	64
Stylus-4	227.8	12.36	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.28	0.95	0.011	0.014	0.06	< 0.01	0.02	< 0.01	0.02	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

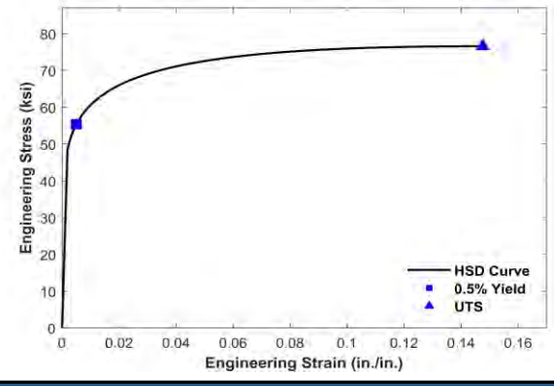
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	55.4	52.3	56.4	57.3
UTS (ksi)	76.6	76.1	76.7	77.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521112949	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:29	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	144-Q2	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	144-Q2_BM-01_7001-EB7001_190521112949			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

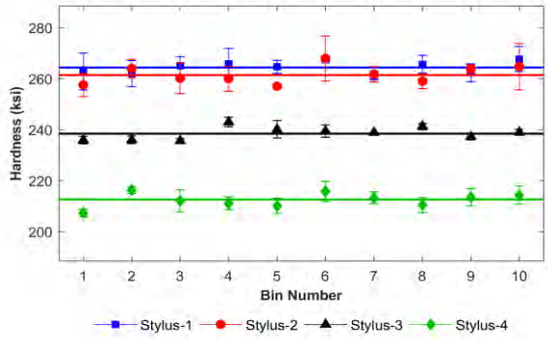
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	264.3	4.30	33
Stylus-2	261.4	5.54	32
Stylus-3	238.4	2.90	29
Stylus-4	212.5	3.63	32

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.28	0.95	0.011	0.014	0.06	< 0.01	0.02	< 0.01	0.02	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

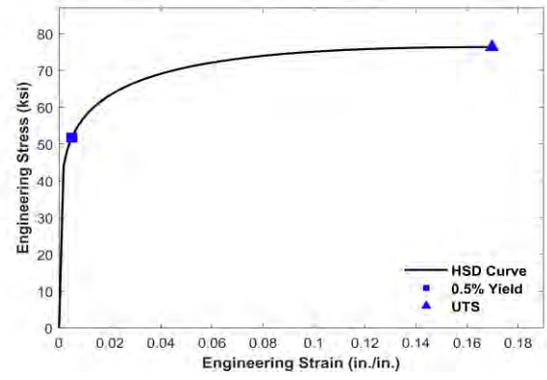
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.8	51.7	51.8	51.8
UTS (ksi)	76.3	76.1	76.5	76.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521115426	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	144-Q2	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	144-Q2_BM-03_7001-EB7001_190521115426			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

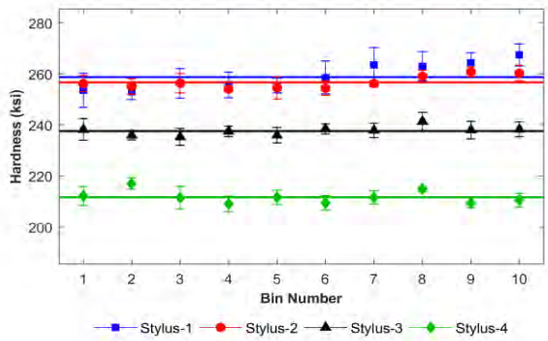
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	258.7	6.80	52
Stylus-2	256.6	3.50	53
Stylus-3	237.6	3.18	52
Stylus-4	211.7	3.54	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.28	0.95	0.011	0.014	0.06	< 0.01	0.02	< 0.01	0.02	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.5

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

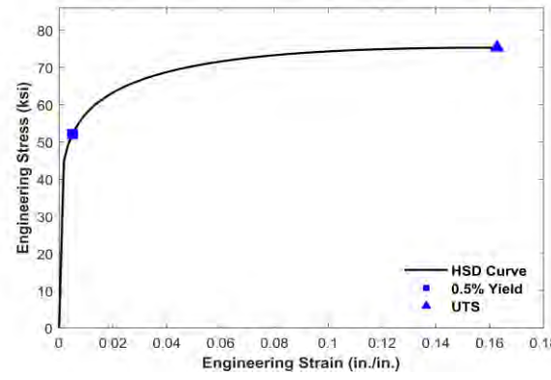
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.1	53.0	51.9	51.6
UTS (ksi)	75.3	74.5	75.1	76.4

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509182030	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	145-Q1	Pipe Size	10 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	145-Q1_BM-01_5001-EB5001_190509182030			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

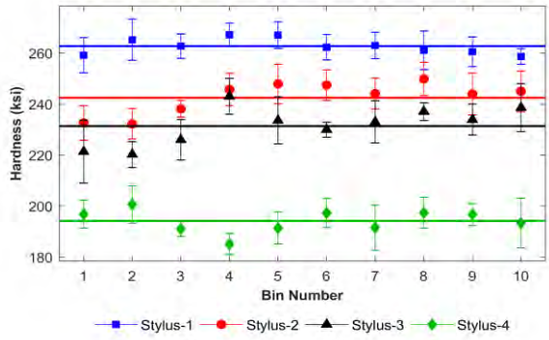
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	262.7	6.07	58
Stylus-2	242.4	8.59	60
Stylus-3	231.3	10.16	62
Stylus-4	194.1	6.99	56

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.014	0.023	0.01	< 0.01	0.03	0.02	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.9

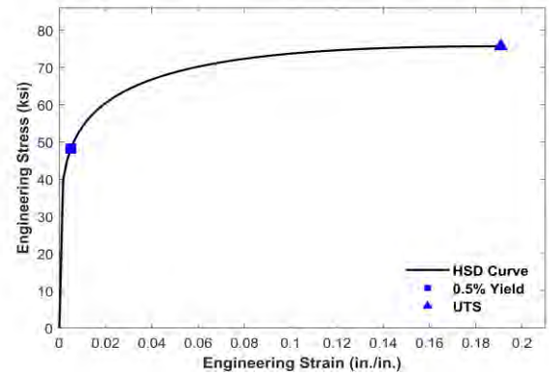
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	48.2	48.2	47.0	49.7
UTS (ksi)	75.7	74.2	77.6	75.2



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508151049	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:10	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	145-Q1	Pipe Size	10 OD x 0.29 WT (in)	Operator Initials	RP	
Test Name	145-Q1_BM-01_5002-EB5002_190508151049			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

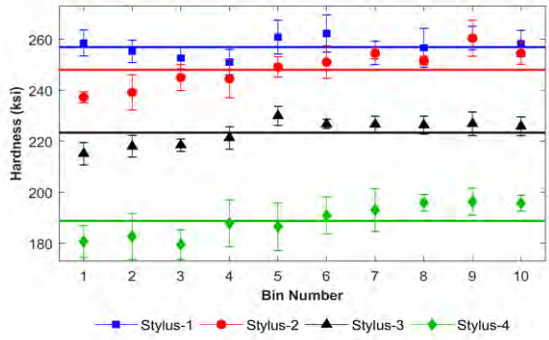
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.0	6.28	65
Stylus-2	248.1	8.18	61
Stylus-3	223.3	5.91	62
Stylus-4	188.8	8.92	60

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.014	0.023	0.01	< 0.01	0.03	0.02	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.9

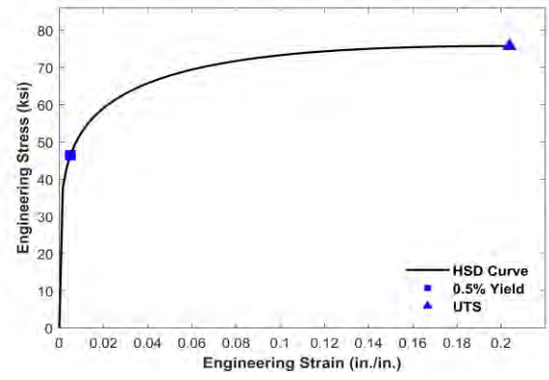
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.4	43.7	46.1	48.7
UTS (ksi)	75.8	75.6	76.2	75.9



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

Prepared: Parth Patel **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521122504	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:25	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	145-Q1	Pipe Size	10 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	145-Q1_BM-01_7001-EB7001_190521122504			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-XXXXXX	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

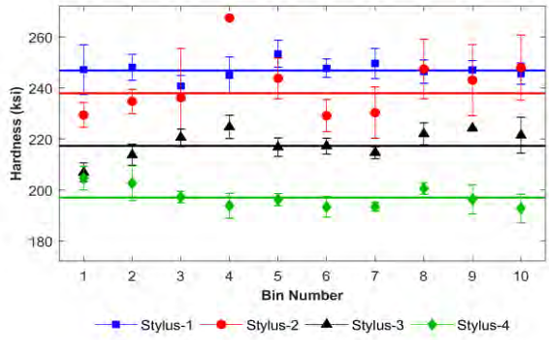
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	246.9	5.85	48
Stylus-2	238.0	13.17	46
Stylus-3	217.4	6.44	48
Stylus-4	197.1	5.51	53

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.014	0.023	0.01	< 0.01	0.03	0.02	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

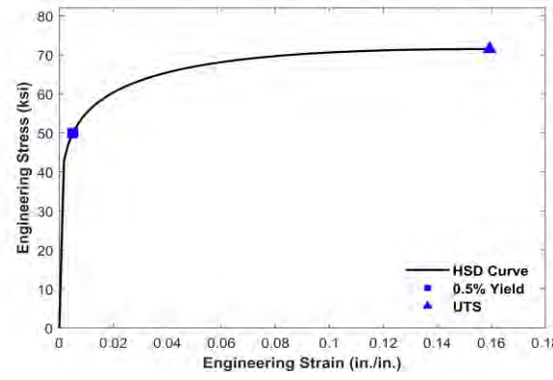
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.9	51.3	48.9	49.9
UTS (ksi)	71.4	69.7	72.4	72.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508160423	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	146-Q1	Pipe Size	10 OD x 0.28 WT (in)	Operator Initials	RP	
Test Name	146-Q1_BM-01_5002-EB5002_190508160423			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

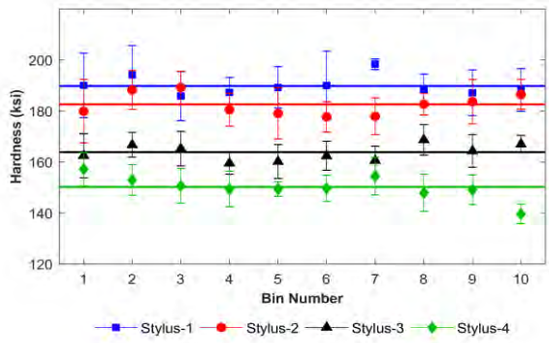
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	189.8	9.22	60
Stylus-2	182.6	8.36	60
Stylus-3	163.8	6.28	60
Stylus-4	150.1	7.14	62

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.04	0.38	0.029	0.013	0.02	< 0.01	0.03	< 0.01	< 0.01	0.03	< 0.01	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
33.5

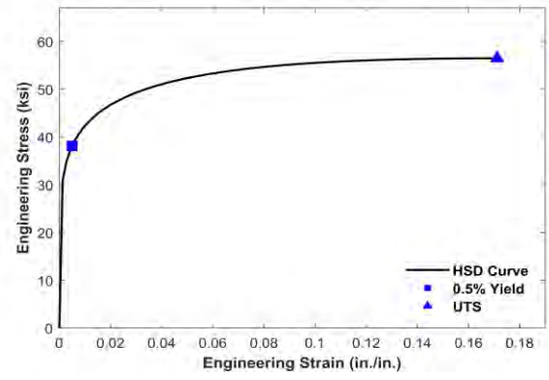
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	38.1	39.2	37.9	37.3
UTS (ksi)	56.4	56.5	56.0	56.8



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521142134	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	146-Q1	Pipe Size	10 OD x 0.28 WT (in)	Operator Initials	JJ	
Test Name	146-Q1_BM-01_7001-EB7001_190521142134			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

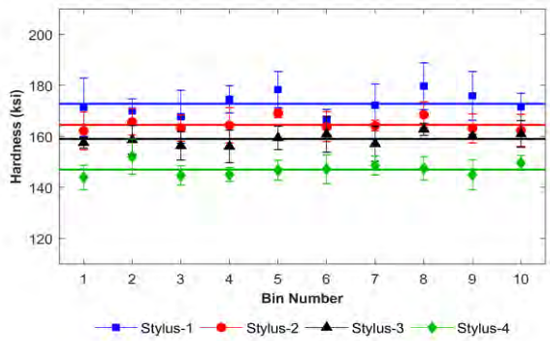
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	172.7	8.34	55
Stylus-2	164.5	5.40	47
Stylus-3	158.9	5.25	53
Stylus-4	146.9	4.80	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.04	0.38	0.029	0.013	0.02	< 0.01	0.03	< 0.01	< 0.01	0.03	< 0.01	0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
33.5

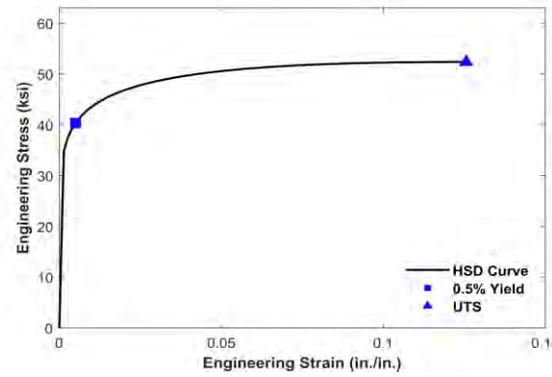
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	40.3	40.5	39.9	40.5
UTS (ksi)	52.4	51.7	52.7	52.7



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509175218	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:52	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	147-Q1	Pipe Size	8 OD x 0.22 WT (in)	Operator Initials	RP	
Test Name	147-Q1_BM-01_5002-EB5002_190509175218			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

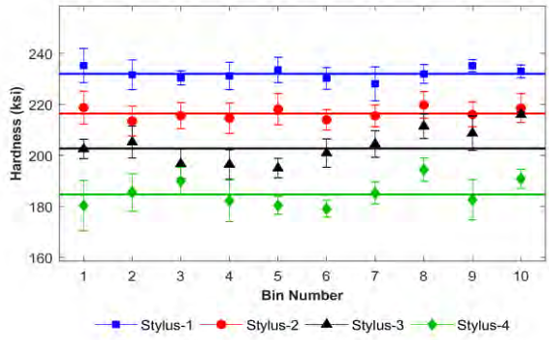
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	232.1	4.91	63
Stylus-2	216.5	5.42	62
Stylus-3	202.7	7.63	60
Stylus-4	184.7	7.48	63

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.49	0.011	0.030	0.07	< 0.01	0.06	< 0.01	< 0.01	0.07	0.12	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.9

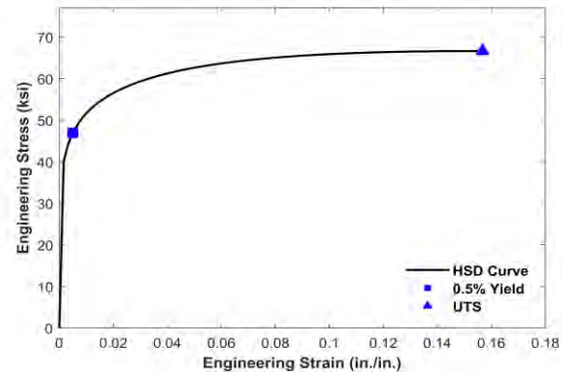
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.9	47.0	45.3	48.6
UTS (ksi)	66.6	66.6	66.6	66.8



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508170648	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:06	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	147-Q1	Pipe Size	8 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	147-Q1_BM-02_5001-EB5001_190508170648			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

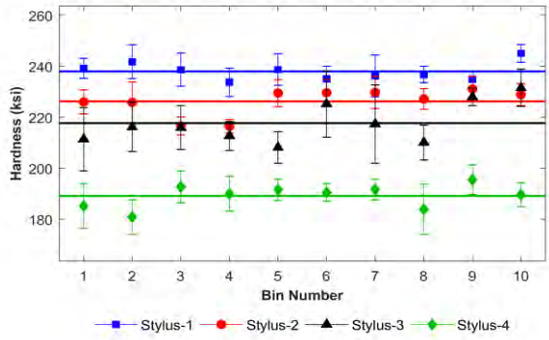
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	238.0	6.03	55
Stylus-2	226.2	6.83	54
Stylus-3	217.7	11.49	56
Stylus-4	189.2	7.05	51

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.49	0.011	0.030	0.07	< 0.01	0.06	< 0.01	< 0.01	0.07	0.12	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
11.9

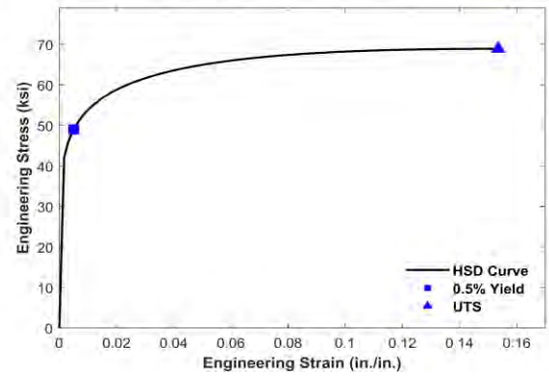
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.0	47.5	49.7	49.6
UTS (ksi)	68.9	69.3	68.3	69.2



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509133341	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:33	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	148-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	148-Q1_BM-01_5001-EB5001_190509133341			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

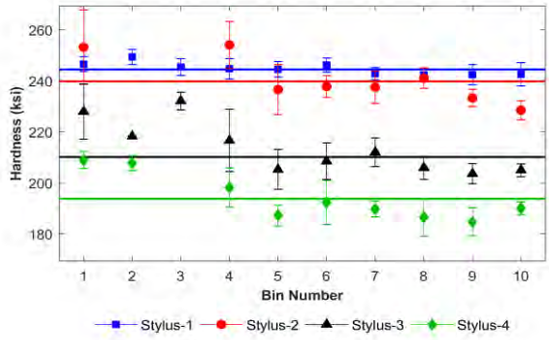
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	244.5	3.61	58
Stylus-2	239.8	10.60	51
Stylus-3	210.1	9.68	50
Stylus-4	193.7	9.89	56

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.44	0.013	0.039	0.13	< 0.01	0.07	< 0.01	0.02	0.14	0.16	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.2

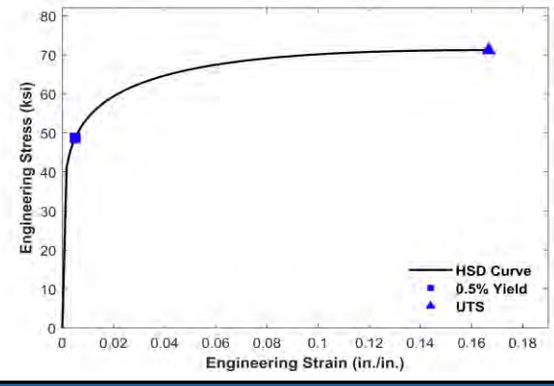
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	48.7	54.7	48.2	46.7
UTS (ksi)	71.2	72.7	71.6	70.7



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508124734	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:47	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	148-Q1	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	148-Q1_BM-01_5002-EB5002_190508124734			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

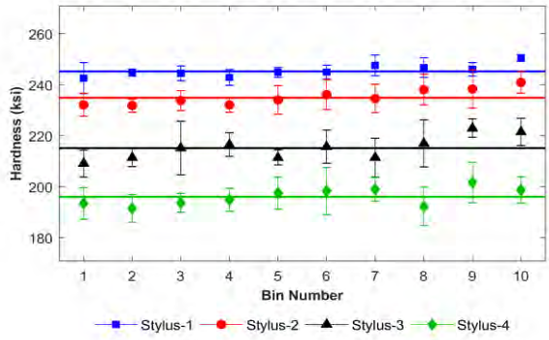
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	245.2	3.67	54
Stylus-2	234.8	5.38	58
Stylus-3	215.0	7.35	63
Stylus-4	195.9	6.57	64

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.44	0.013	0.039	0.13	< 0.01	0.07	< 0.01	0.02	0.14	0.16	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.2

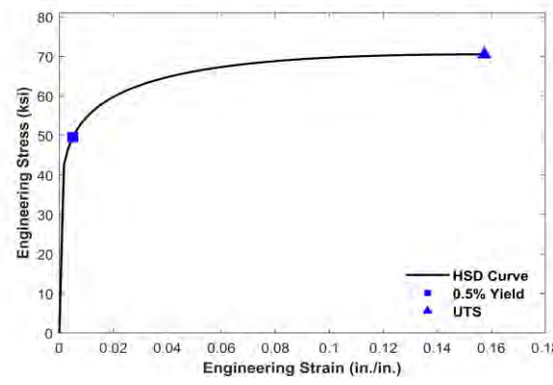
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.6	48.5	49.9	50.2
UTS (ksi)	70.5	70.1	70.2	71.3



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509130826	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	149-Q1	Pipe Size	8 OD x 0.21 WT (in)	Operator Initials	JJ	
Test Name	149-Q1_BM-01_5002-EB5002_190509130826			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

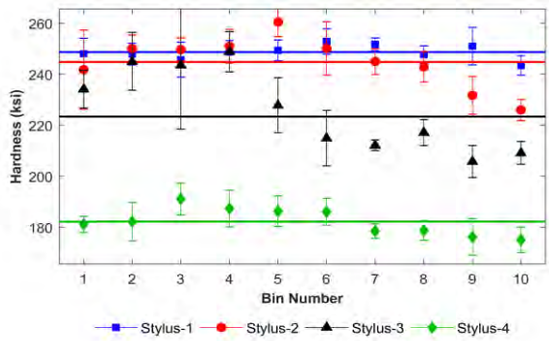
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	248.7	5.29	58
Stylus-2	244.7	12.03	59
Stylus-3	223.4	16.45	54
Stylus-4	182.2	7.15	53

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.54	0.014	0.030	0.08	< 0.01	0.13	< 0.01	< 0.01	0.08	0.14	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.9

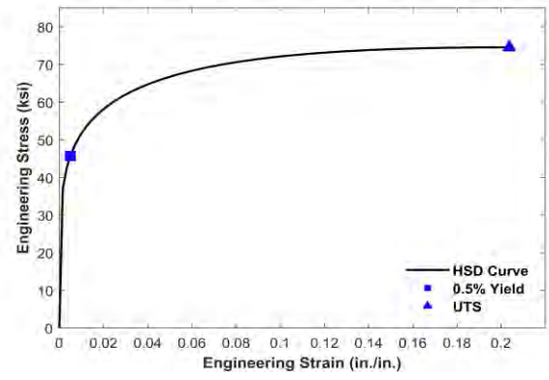
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	45.7	48.5	46.4	43.0
UTS (ksi)	74.5	74.2	75.6	73.8



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

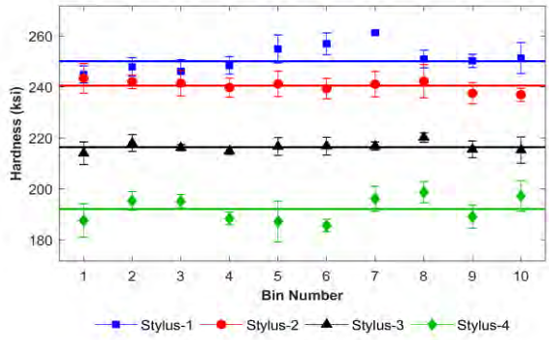
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508133050	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:30	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	149-Q1	Pipe Size	8 OD x 0.21 WT (in)	Operator Initials	RP	
Test Name	149-Q1_BM-01_5002-EB5002_190508133050			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Ver. 2.2

	HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	250.0	5.56	55
Stylus-2	240.5	4.64	63
Stylus-3	216.4	3.27	54
Stylus-4	192.1	6.42	63

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.22	0.54	0.014	0.030	0.08	< 0.01	0.13	< 0.01	< 0.01	0.08	0.14	< 0.01	< 0.01	< 0.0005	9.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

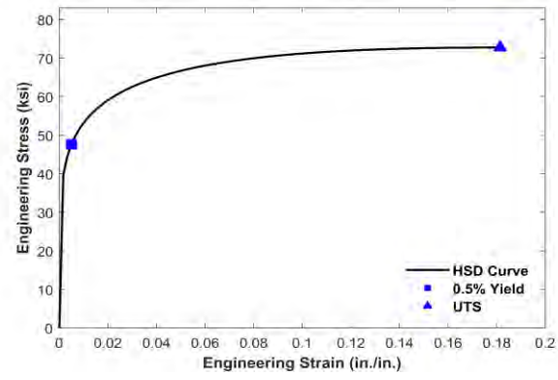
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.6	48.4	45.9	48.6
UTS (ksi)	72.7	72.0	73.9	72.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509171728	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:17	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	150-Q1	Pipe Size	8 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	150-Q1_BM-01_5001-EB5001_190509171728			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

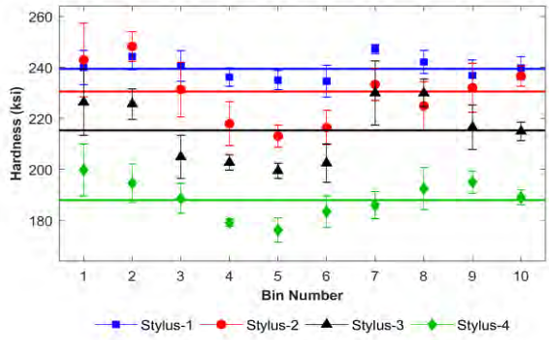
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	239.4	6.01	58
Stylus-2	230.4	13.69	62
Stylus-3	215.2	13.63	62
Stylus-4	187.8	8.85	56

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.43	0.012	0.032	0.07	< 0.01	0.07	< 0.01	< 0.01	0.07	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

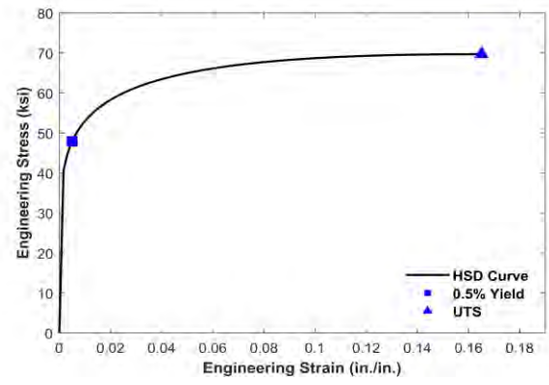
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.9	50.3	44.7	49.6
UTS (ksi)	69.7	70.8	68.1	69.9



The overall results are calculated using the entire sample size.

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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508122825	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:28	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	150-Q1	Pipe Size	8 OD x 0.22 WT (in)	Operator Initials	RP	
Test Name	150-Q1_BM-01_5002-EB5002_190508122825			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

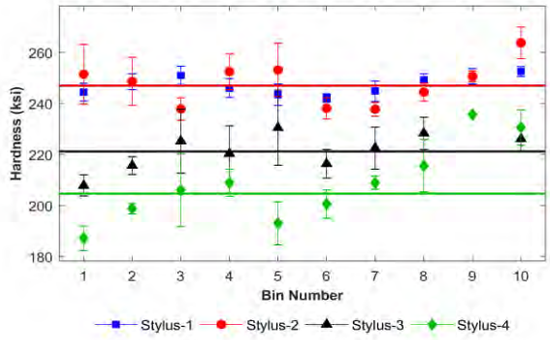
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	247.0	4.47	61
Stylus-2	246.9	9.81	63
Stylus-3	221.1	10.68	57
Stylus-4	204.6	14.43	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.43	0.012	0.032	0.07	< 0.01	0.07	< 0.01	< 0.01	0.07	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

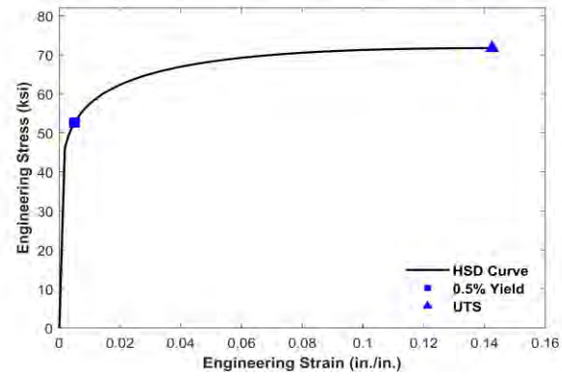
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.6	49.5	51.5	57.4
UTS (ksi)	71.7	72.1	71.6	71.7



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521155411	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:54	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	150-Q1	Pipe Size	8 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	150-Q1_BM-01_7001-EB7001_190521155411			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190520	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

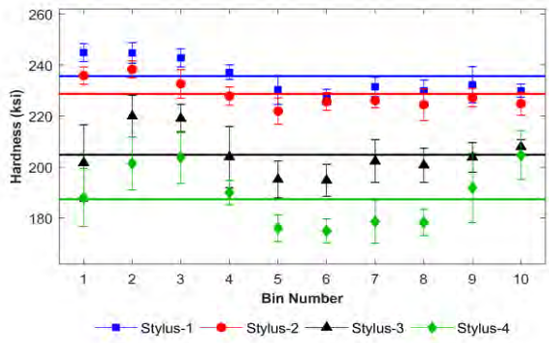
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	235.6	7.65	53
Stylus-2	228.7	6.47	52
Stylus-3	204.8	11.43	54
Stylus-4	187.4	13.23	51

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.43	0.012	0.032	0.07	< 0.01	0.07	< 0.01	< 0.01	0.07	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

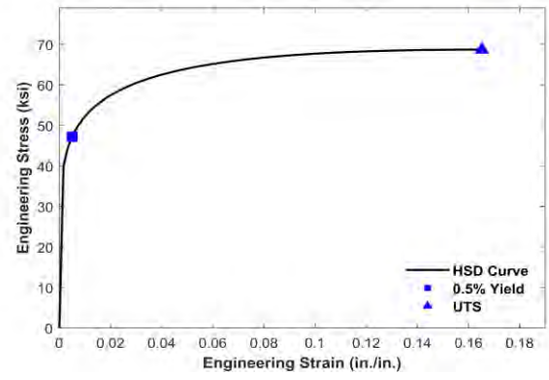
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	47.2	49.5	44.4	48.2
UTS (ksi)	68.7	70.8	68.4	67.2



The overall results are calculated using the entire sample size.

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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509154832	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:48	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	151-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	JJ	
Test Name	151-Q1_BM-01_5001-EB5001_190509154832			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

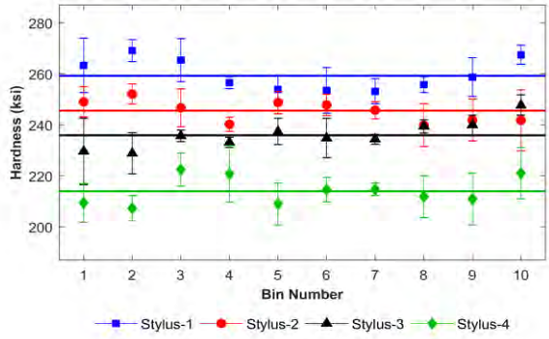
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	259.2	8.27	46
Stylus-2	245.5	6.94	46
Stylus-3	235.9	6.76	44
Stylus-4	214.0	8.57	47

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.46	0.009	0.029	0.08	< 0.01	0.08	< 0.01	< 0.01	0.09	0.15	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

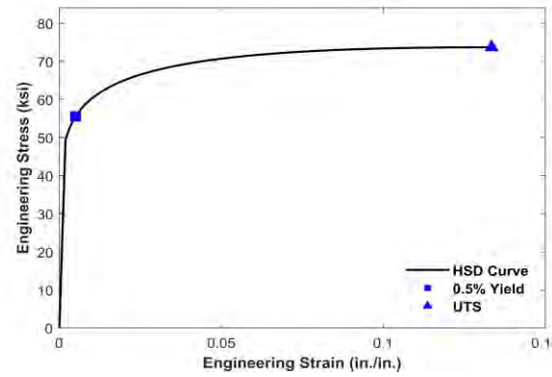
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	55.5	53.9	56.3	56.5
UTS (ksi)	73.7	74.9	72.8	73.4



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509182118	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	151-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	RP	
Test Name	151-Q1_BM-01_5002-EB5002_190509182118			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

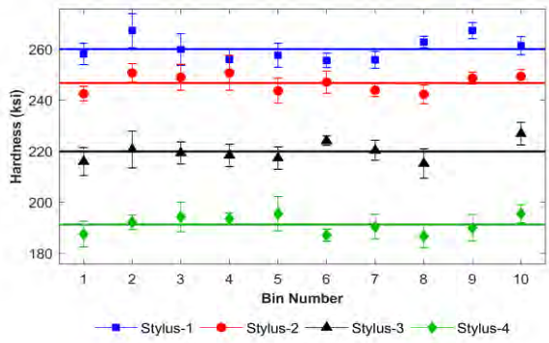
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	260.0	5.85	68
Stylus-2	246.7	4.91	64
Stylus-3	219.8	5.75	55
Stylus-4	191.3	5.31	59

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.46	0.009	0.029	0.08	< 0.01	0.08	< 0.01	< 0.01	0.09	0.15	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

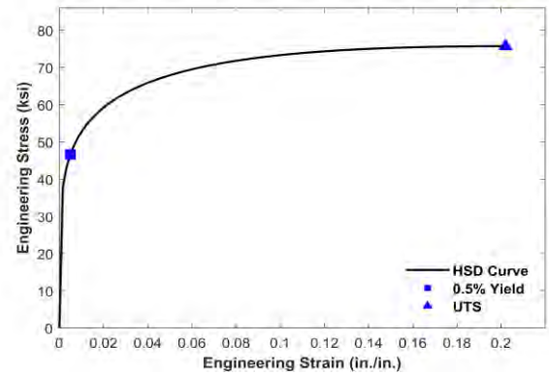
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	46.6	46.5	46.9	46.5
UTS (ksi)	75.7	76.0	74.9	76.2



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Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190528183818	REV --
Test Location	Gas Technology Institute			Test Date	5/28/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:38	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	151-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	JJ	
Test Name	151-Q1_BM-03_5002-EB5002_190528183818			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

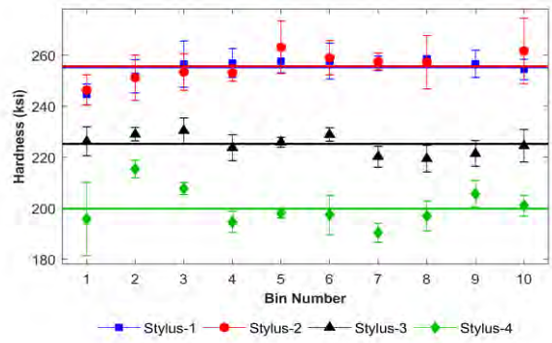
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	255.2	6.35	57
Stylus-2	255.5	8.70	49
Stylus-3	225.1	5.51	55
Stylus-4	199.7	8.73	55

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.46	0.009	0.029	0.08	< 0.01	0.08	< 0.01	< 0.01	0.09	0.15	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
9.0

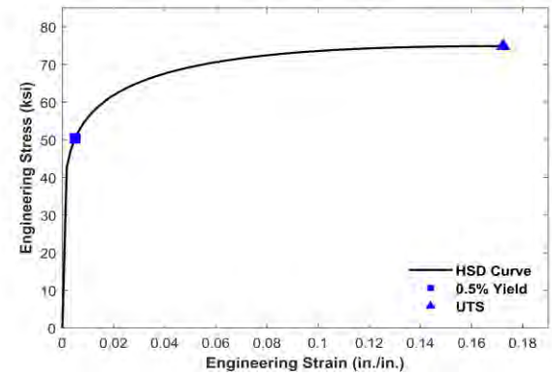
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.4	53.2	49.2	49.5
UTS (ksi)	74.9	73.0	76.0	75.5



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

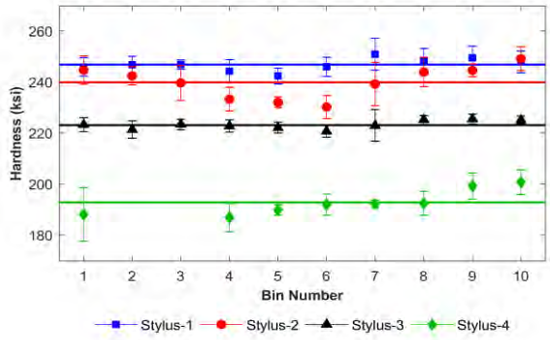
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508174626	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:46	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	155-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	JJ	
Test Name	155-Q1_BM-02_5001-EB5001_190508174626			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190107	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Ver. 2.2

	HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	246.8	4.42	57
Stylus-2	239.9	7.66	60
Stylus-3	223.1	3.10	53
Stylus-4	192.7	6.36	45

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (µm)
0.21	0.40	0.011	0.030	0.06	< 0.01	0.07	< 0.01	< 0.01	0.09	0.11	< 0.01	< 0.01	< 0.0005	10.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

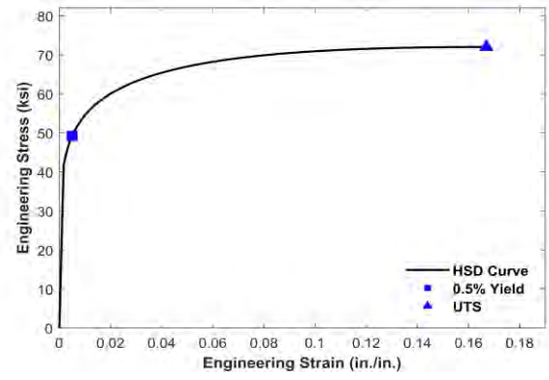
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.2	47.6	48.7	50.0
UTS (ksi)	72.0	72.9	70.9	72.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529132121	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	155-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	JJ	
Test Name	155-Q1_BM-03_5002-EB5002_190529132121			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

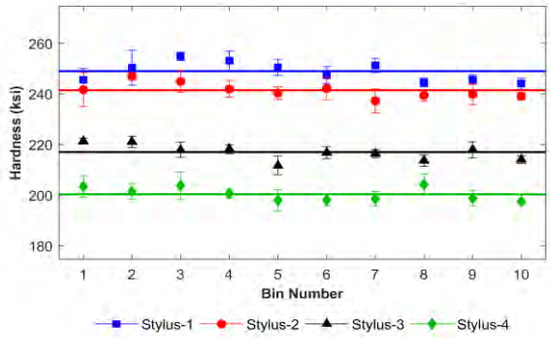
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	249.1	4.91	53
Stylus-2	241.5	4.51	53
Stylus-3	217.0	3.69	49
Stylus-4	200.4	3.96	42

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.40	0.011	0.030	0.06	< 0.01	0.07	< 0.01	< 0.01	0.09	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.6

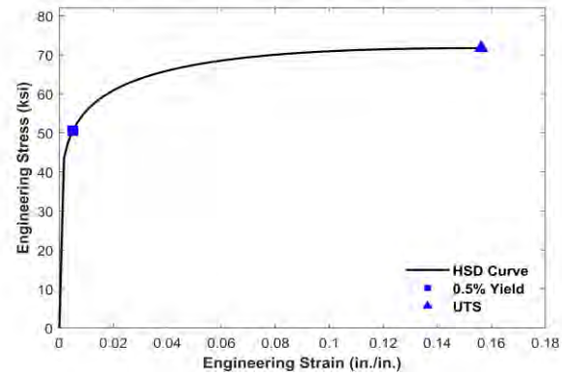
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.6	51.4	49.9	50.5
UTS (ksi)	71.7	72.3	72.1	70.9



The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529133848	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:38	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	155-Q1	Pipe Size	8 OD x 0.23 WT (in)	Operator Initials	JJ	
Test Name	155-Q1_BM-04_5002-EB5002_190529133848			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

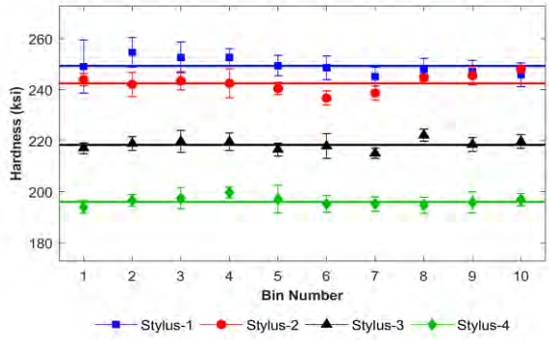
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	249.3	5.86	56
Stylus-2	242.4	4.41	55
Stylus-3	218.4	3.37	49
Stylus-4	196.1	3.43	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.21	0.40	0.011	0.030	0.06	< 0.01	0.07	< 0.01	< 0.01	0.09	0.11	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.6

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

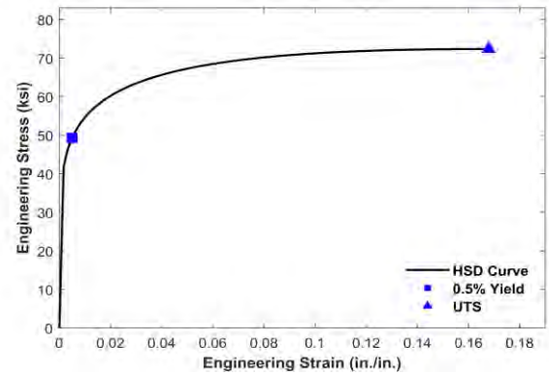
Results

Prediction Ver. H2.4 v190728

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.3	48.9	49.6	49.5
UTS (ksi)	72.3	73.0	72.0	72.0

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507164705	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:47	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	165-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	165-Q1_BM-01_5002-EB5002_190507164705			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.33	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

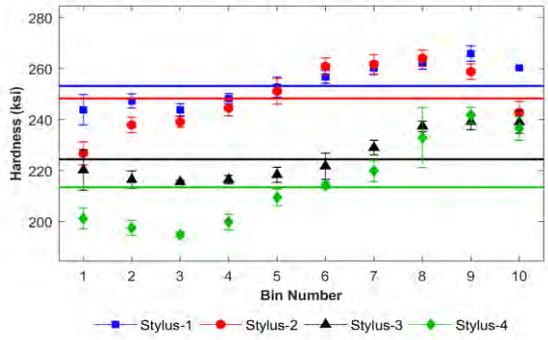
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	253.2	7.97	54
Stylus-2	248.2	12.56	65
Stylus-3	224.4	9.70	48
Stylus-4	213.5	16.84	64

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	0.68	0.008	0.033	0.01	< 0.01	0.14	0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

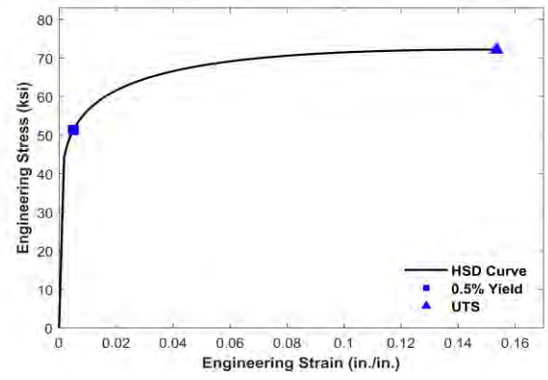
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.3	48.3	49.9	55.9
UTS (ksi)	72.2	70.9	73.2	73.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521125628	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:56	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	165-Q1	Pipe Size	10 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	165-Q1_BM-01_7001-EB7001_190521125628			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

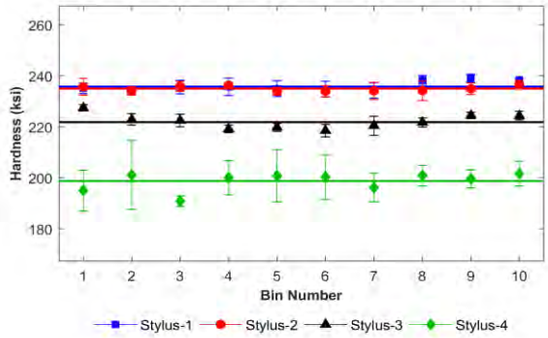
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	235.8	2.82	49
Stylus-2	235.0	2.38	48
Stylus-3	221.8	3.04	46
Stylus-4	198.7	7.87	52

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	0.68	0.008	0.033	0.01	< 0.01	0.14	0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
10.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

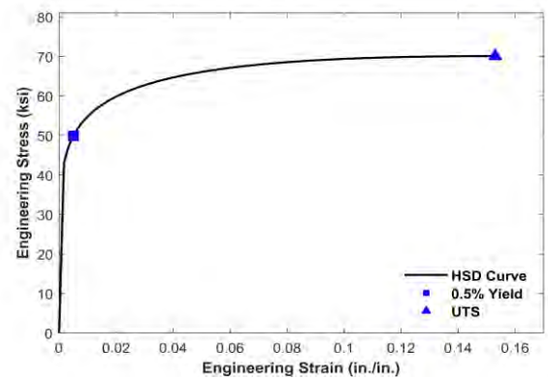
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	49.9	49.6	50.0	50.0
UTS (ksi)	70.1	70.1	69.9	70.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521162209	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	167-Q1	Pipe Size	10 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	167-Q1_BM-01_7001-EB7001_190521162209			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

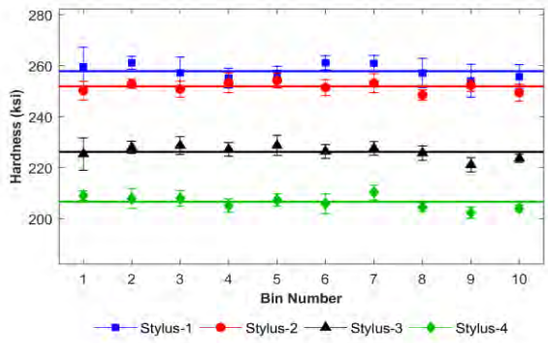
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	257.9	4.99	40
Stylus-2	251.9	3.17	35
Stylus-3	226.2	3.82	42
Stylus-4	206.6	3.37	38

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.80	0.007	0.014	< 0.01	< 0.01	0.08	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

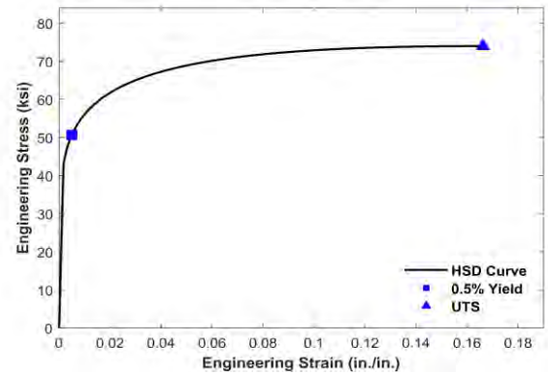
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	50.7	51.0	50.8	50.2
UTS (ksi)	74.0	74.0	74.1	73.9

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523132044	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:20	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	167-Q1	Pipe Size	10 OD x 0.20 WT (in)	Operator Initials		
Test Name	167-Q1_BM-01_7003-EB7003_190523132044			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

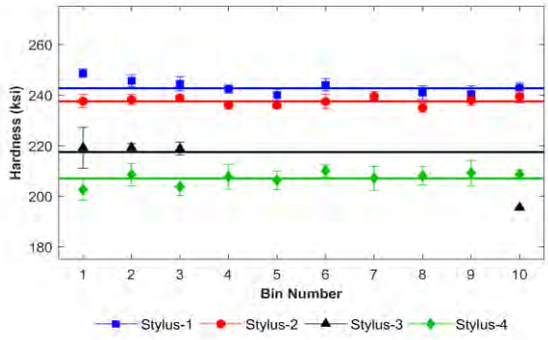
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	242.8	3.41	53
Stylus-2	237.5	2.31	51
Stylus-3	217.5	7.61	15
Stylus-4	207.1	4.32	55

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.80	0.007	0.014	< 0.01	< 0.01	0.08	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

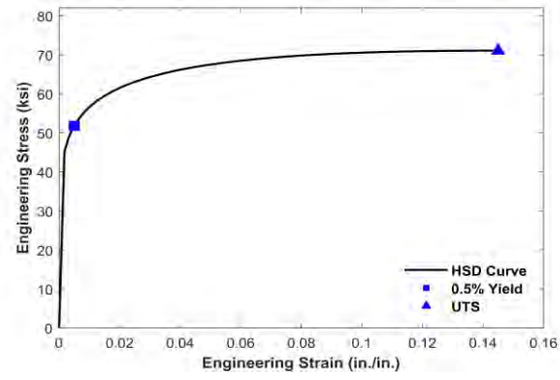
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	51.8	49.8	51.6	50.7
UTS (ksi)	71.1	71.9	71.3	70.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523133828	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:38	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	167-Q1	Pipe Size	10 OD x 0.20 WT (in)	Operator Initials		
Test Name	167-Q1_BM-02_7003-EB7003_190523133828			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

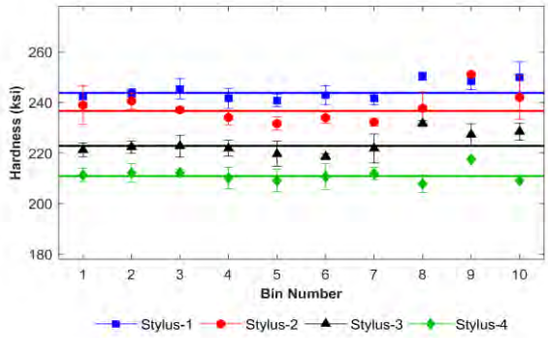
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	243.8	4.13	48
Stylus-2	236.6	5.62	47
Stylus-3	222.8	4.72	46
Stylus-4	210.8	3.59	41

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.80	0.007	0.014	< 0.01	< 0.01	0.08	0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.9

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

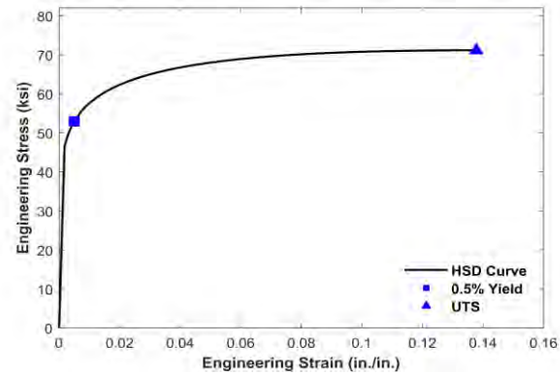
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	52.9	53.0	53.0	52.5
UTS (ksi)	71.1	71.3	70.6	71.8

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508175807	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	169-Q1	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	169-Q1_BM-01_5002-EB5002_190508175807			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

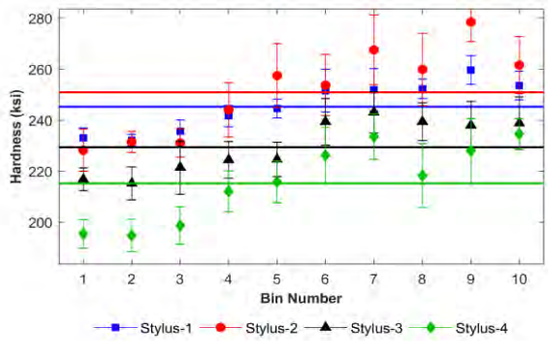
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	245.3	10.41	105
Stylus-2	250.9	18.86	106
Stylus-3	229.4	12.74	102
Stylus-4	215.1	16.87	105

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.27	0.71	0.005	0.024	0.02	< 0.01	0.07	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

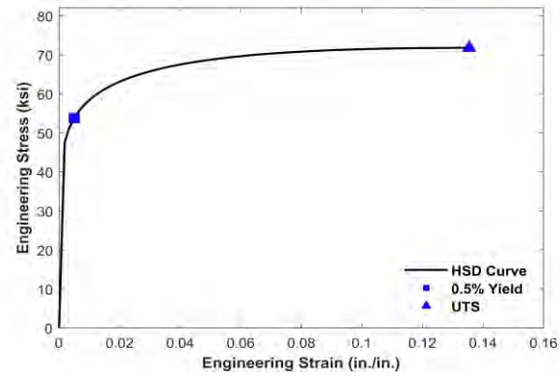
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.8	50.2	54.7	56.3
UTS (ksi)	71.8	69.7	72.1	73.7

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521110246	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:02	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	169-Q1	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	169-Q1_BM-01_7001-EB7001_190521110246			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

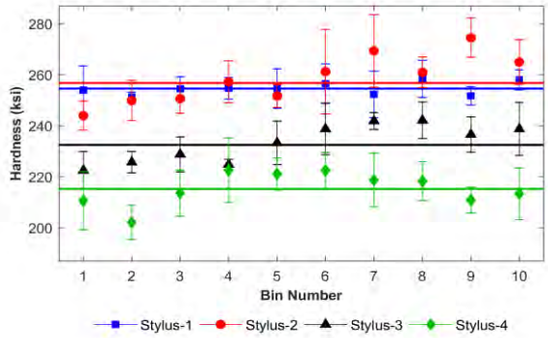
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	254.6	6.15	44
Stylus-2	256.7	11.76	49
Stylus-3	232.5	9.55	50
Stylus-4	215.2	10.49	54

$$\text{Hardness} = (\text{Stylus force})/(\text{Contact area})$$



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.27	0.71	0.005	0.024	0.02	< 0.01	0.07	< 0.01	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
7.8

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

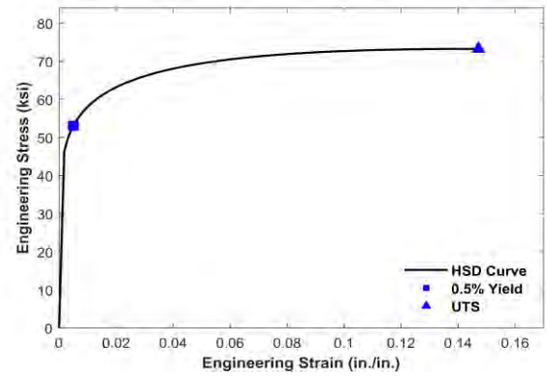
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	53.1	51.7	54.2	53.4
UTS (ksi)	73.3	72.5	73.1	74.2

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522162951	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:29	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	170-Q1	Pipe Size	20 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	170-Q1_BM-01_7001-EB7001_190522162951			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

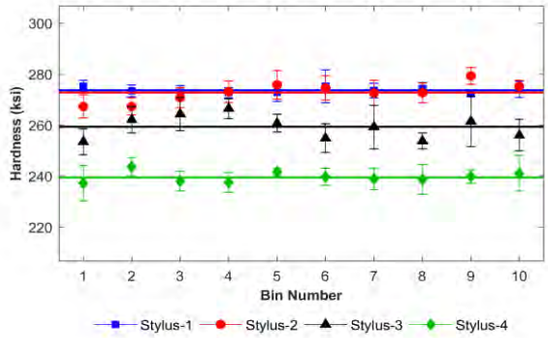
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	273.6	2.76	48
Stylus-2	272.7	5.17	51
Stylus-3	259.4	6.94	54
Stylus-4	239.4	4.63	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	1.12	0.006	0.022	0.02	< 0.01	0.03	< 0.01	0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

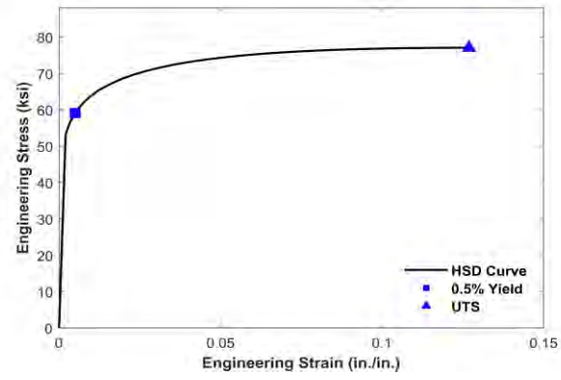
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	59.1	59.1	59.2	59.0
UTS (ksi)	77.0	76.8	77.2	77.1

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522182241	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:22	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	170-Q1	Pipe Size	20 OD x 0.26 WT (in)	Operator Initials		
Test Name	170-Q1_BM-01_7003-EB7003_190522182241			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	1.333	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

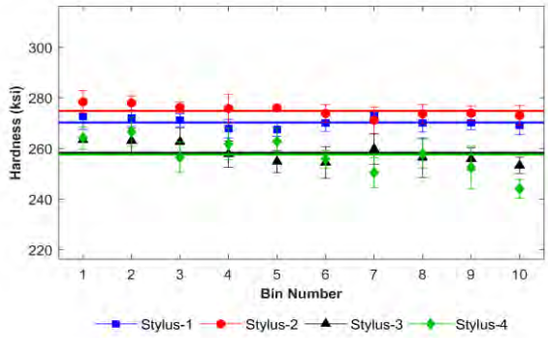
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.3	3.46	52
Stylus-2	274.8	4.06	47
Stylus-3	258.2	5.90	51
Stylus-4	257.6	8.25	50

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	1.12	0.006	0.022	0.02	< 0.01	0.03	< 0.01	0.01	0.02	0.04	< 0.01	< 0.01	< 0.0005

Grain Size

mli (µm)
8.1

Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

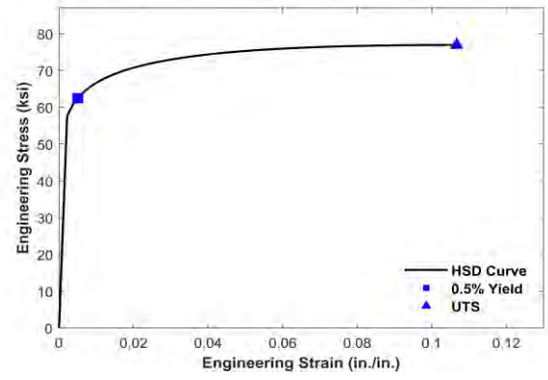
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	62.4	63.7	63.0	60.8
UTS (ksi)	76.9	77.5	76.9	76.5

The overall results are calculated using the entire sample size.

Each subset is calculated using one-third of the measurements



Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

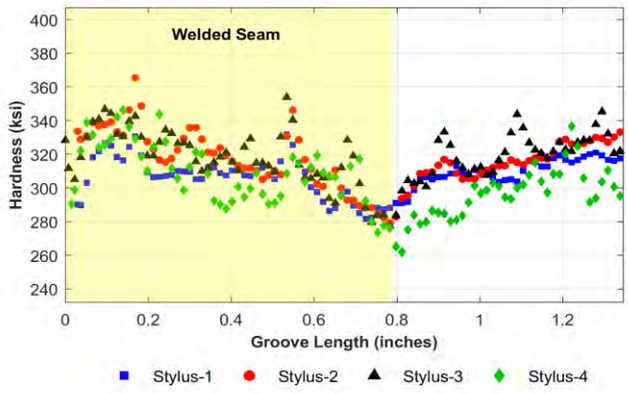
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190424165813	REV --
Test Location	Gas Technology Institute			Test Date	4/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:58	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	3	Pipe Size	12 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	3-Q1_WD-01_7001-EB7001_190424165813			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	306.2	309.8	-3.6	-1.2
Stylus-2	318.0	315.1	2.8	0.9
Stylus-3	318.2	319.4	-1.3	-0.4
Stylus-4	309.1	296.1	13.0	4.4



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.75	inches	Normalized Macroetch Weld Width:	287	% of pipe wall thickness

Seam Type Determination

[ ]	**Submerged Arc Welded (SAW)**	[X]	**ERW [calculated percent probability below]**
[ ]	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
[ ]	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
[ ]	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

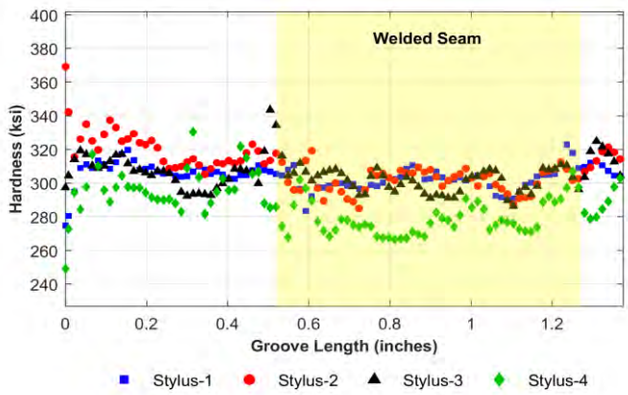
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190424140955	REV --
Test Location	Gas Technology Institute			Test Date	4/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:09	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	4	Pipe Size	12 OD x 0.22 WT (in)	Operator Initials	JJ	
Test Name	4-Q1_WD-01_7001-EB7001_190424140955			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	301.7	307.9	-6.2	-2.0
Stylus-2	301.4	317.9	-16.5	-5.2
Stylus-3	301.3	308.9	-7.7	-2.5
Stylus-4	278.9	296.1	-17.2	-5.8



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.88	inches	Normalized Macroetch Weld Width:	391	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

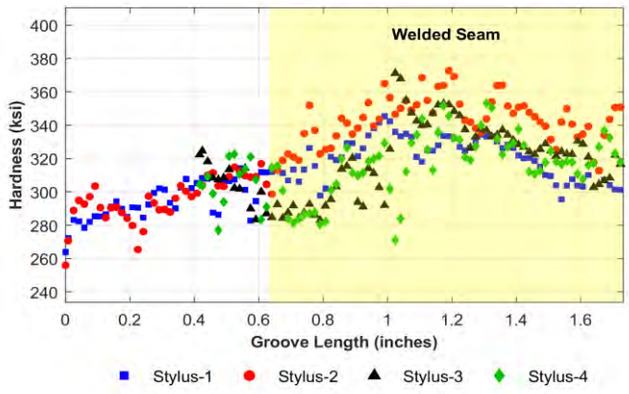
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425180039	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:00	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	13	Pipe Size	16 OD x 0.22 WT (in)	Operator Initials	RP	
Test Name	13-Q1_WD-01_5001-EB5001_190425180039			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	320.4	295.8	24.6	8.3
Stylus-2	342.4	297.5	44.9	15.1
Stylus-3	320.6	305.8	14.8	4.8
Stylus-4	316.9	304.2	12.7	4.2



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.63	inches	**Normalized Macroetch Weld Width:**	282	% of pipe wall thickness

Seam Type Determination

[ ]	**Submerged Arc Welded (SAW)**	[X]	**ERW [calculated percent probability below]**
[ ]	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
[ ]	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
[ ]	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

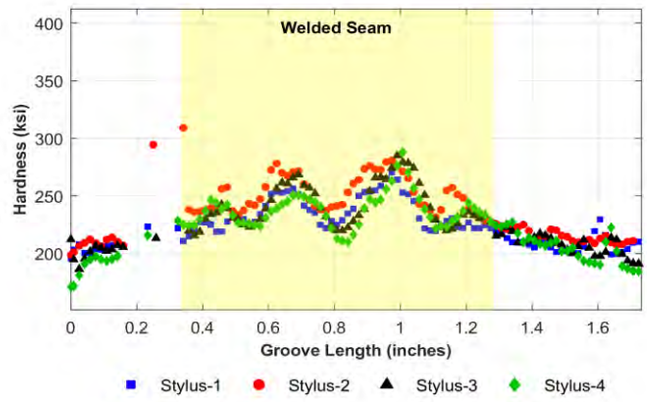
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509130623	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:06	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	35	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	35-Q1_WD-01_5002-EB5002_190509130623			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000 Grit			LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133 in/min			Stylus-1 Serial No.	103-190412	
Travel Distance	2 in			Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16 in/min			Stylus-3 Serial No.	109-190520	
Sampling Rate	1600 Hz			Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	235.3	208.7	26.6	12.7
Stylus-2	252.4	216.5	36.0	16.6
Stylus-3	241.6	206.8	34.9	16.9
Stylus-4	237.4	204.2	33.1	16.2



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.20	inches	**Normalized Macroetch Weld Width:**	79	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	☒	**ERW [calculated percent probability below]**
☐	**Flash**	72 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	28 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Approved: Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

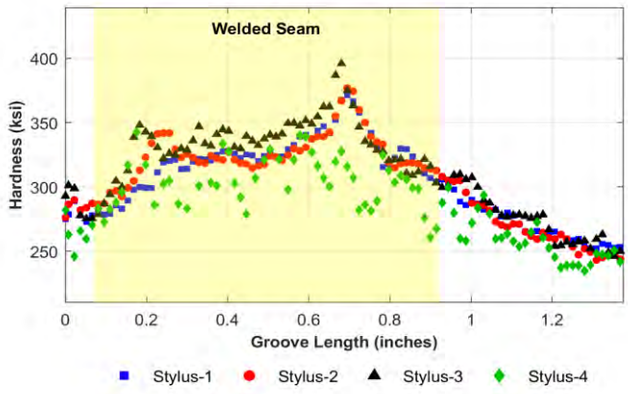
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523095312	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	9:53	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	43	Pipe Size	20 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	43-Q1_WD-01_7001-EB7001_190523095312			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	322.3	271.2	51.1	18.8
Stylus-2	325.4	268.8	56.6	21.1
Stylus-3	333.8	275.2	58.6	21.3
Stylus-4	303.8	258.7	45.1	17.4



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.31	inches	**Normalized Macroetch Weld Width:**	124	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521112328 REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:23
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002
Sample ID	107	Pipe Size	6 OD x 0.24 WT (in)	Operator Initials	RP
Test Name	107-Q1_WD-01_5002-EB5002_190521112328			Sample Type	Cutout
Sample Description					

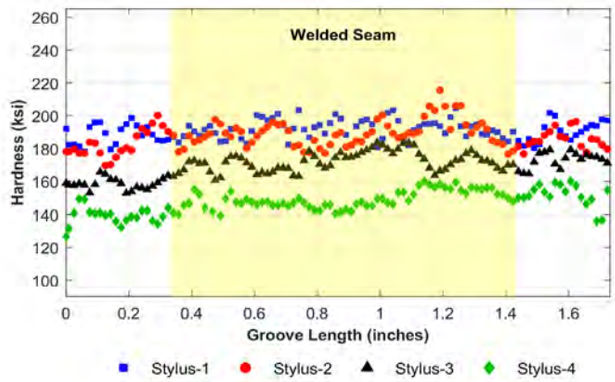
Surface Finish	2000	Grit	LVDT-1 Serial No.	L01-190107
HSD Core Speed	0.133	in/min	LVDT-2 Serial No.	L02-190107
Travel Distance	2	in	Stylus-1 Serial No.	103-190412
Profiler Speed	2.16	in/min	Stylus-2 Serial No.	105-190412
Sampling Rate	1600	Hz	Stylus-3 Serial No.	109-190520
			Stylus-4 Serial No.	118-190520

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	191.9	189.7	2.3	1.2
Stylus-2	189.4	184.5	4.9	2.7
Stylus-3	172.0	165.7	6.3	3.8
Stylus-4	149.0	145.8	3.2	2.2



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width: 1.00 inches | **Normalized Macroetch Weld Width:** 415 % of pipe wall thickness

Seam Type Determination

[ ]	**Submerged Arc Welded (SAW)**	[X]	**ERW [calculated percent probability below]**
[ ]	**Flash**	X %	**Low Frequency ERW (LF-ERW)**
[ ]	**Lap-Welded**	___ %	**High Frequency ERW (HF-ERW)**
[ ]	**See Comments**	___ %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

There was no presence of a HAZ due to the quality of the seam etch and image for this sample. However, it was classified as LF based on the Yield strength measurement of 33.8 ksi, which matched the characteristics of low strength pipeline steels manufactured pre 1940s[1]. This predicted vintage is before the emergence of HF technology, when LF was the main welding process for ERW seams.

[1] Switzner et al., "An Approach to Establishing Manufacturing Process and Vintage of Line Pipe Using In-Situ Nondestructive Examination and Historical Manufacturing Data", Proceedings of the 13th International Pipeline Conference, 2020.

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

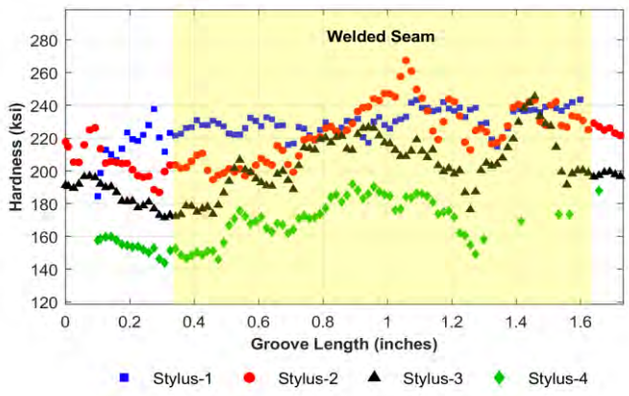
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520170244	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:02	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	111	Pipe Size	4 OD x 0.24 WT (in)	Operator Initials	JJ	
Test Name	111-Q1_WD-01_5001-EB5001_190520170244			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	230.4	215.4	15.0	7.0
Stylus-2	224.0	204.4	19.6	9.6
Stylus-3	205.1	184.3	20.9	11.3
Stylus-4	170.6	153.8	16.8	10.9



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	1.00	inches	Normalized Macroetch Weld Width:	408	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

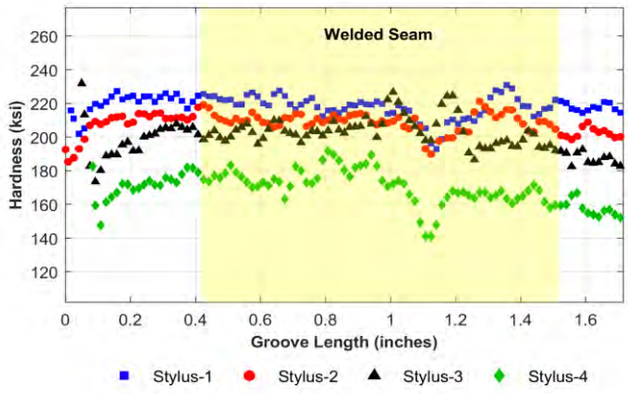
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530154646	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:46	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	112	Pipe Size	4 OD x 0.25 WT (in)	Operator Initials	JJ	
Test Name	112-Q1_WD-01_5001-EB5001_190530154646			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	217.6	220.3	-2.8	-1.3
Stylus-2	209.2	209.1	0.1	0.1
Stylus-3	203.5	198.6	4.8	2.4
Stylus-4	170.8	171.3	-0.5	-0.3



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	1.00	inches	Normalized Macroetch Weld Width:	400	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

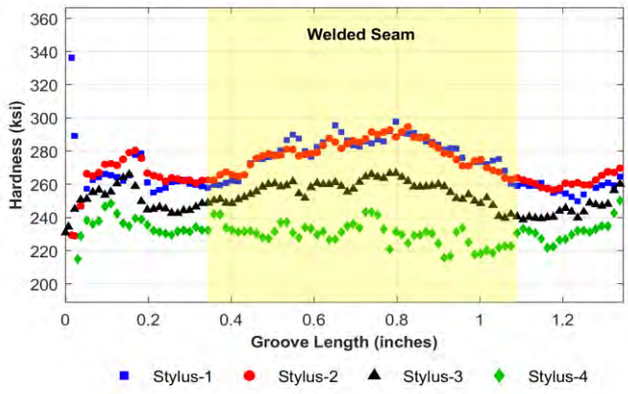
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506162145	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	113	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	113-Q1_WD-01_7001-EB7001_190506162145			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	278.8	262.8	16.0	6.1
Stylus-2	278.1	262.7	15.3	5.8
Stylus-3	255.8	247.4	8.4	3.4
Stylus-4	229.8	233.5	-3.6	-1.5



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.75	inches	Normalized Macroetch Weld Width:	286	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

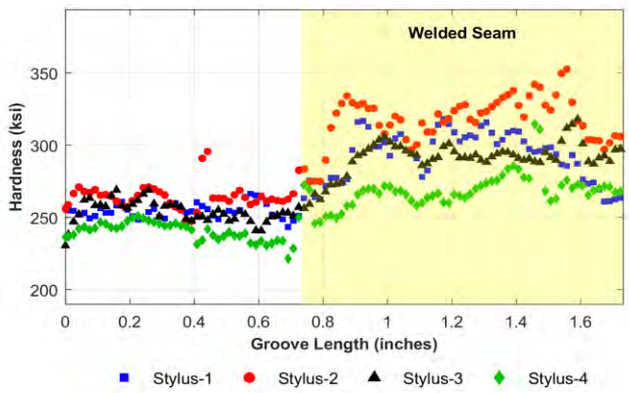
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507144827	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:48	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	114	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	114-Q1_WD-01_5002-EB5002_190507144827			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	292.6	254.4	38.2	15.0
Stylus-2	317.5	264.6	52.8	20.0
Stylus-3	290.9	254.7	36.2	14.2
Stylus-4	268.5	240.2	28.3	11.8



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.20	inches	Normalized Macroetch Weld Width:	81	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

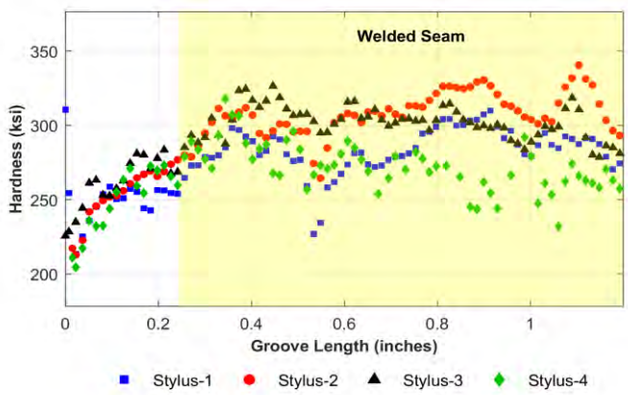
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507163125	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:31	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	115	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	115-Q1_WD-02_7001-EB7001_190507163125			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	283.5	251.1	32.4	12.9
Stylus-2	307.8	260.3	47.5	18.2
Stylus-3	301.7	268.2	33.5	12.5
Stylus-4	272.4	256.3	16.0	6.3



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.20	inches	**Normalized Macroetch Weld Width:**	79	% of pipe wall thickness

Seam Type Determination

[ ]	**Submerged Arc Welded (SAW)**	[X]	**ERW [calculated percent probability below]**
[ ]	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
[ ]	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
[ ]	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

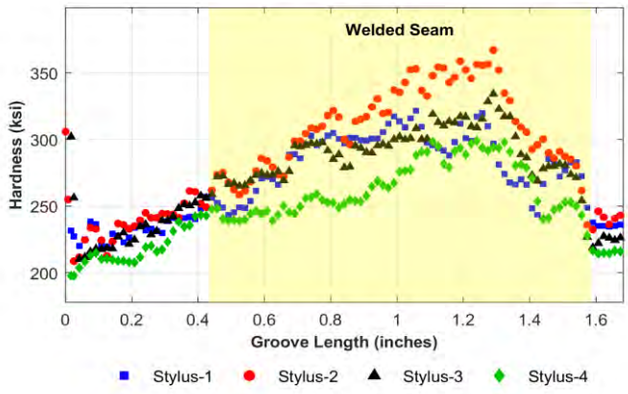
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507131912	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	13:19	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	116	Pipe Size	8 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	116-Q1_WD-01_5001-EB5001_190507131912			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	285.2	234.7	50.5	21.5
Stylus-2	309.9	240.3	69.5	28.9
Stylus-3	290.1	232.8	57.3	24.6
Stylus-4	263.5	220.2	43.3	19.7



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.23	inches	**Normalized Macroetch Weld Width:**	92	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	72 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	28 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

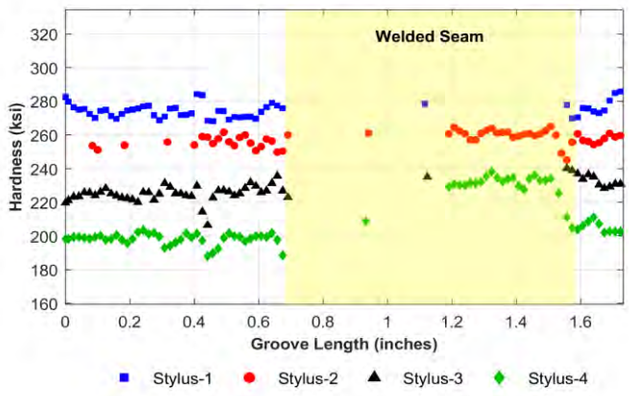
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506160545	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:05	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	119	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	RP	
Test Name	119-Q1_WD-01_5002-EB5002_190506160545			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	275.4	273.6	1.7	0.6
Stylus-2	259.7	255.3	4.4	1.7
Stylus-3	234.2	225.3	9.0	4.0
Stylus-4	229.2	198.1	31.1	15.7



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	1.00	inches	**Normalized Macroetch Weld Width:**	372	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

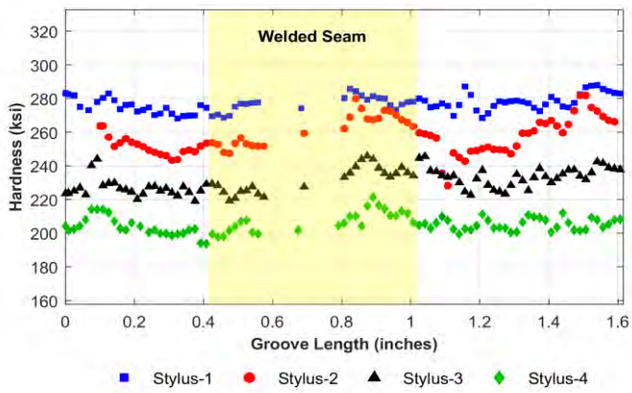
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506163610	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:36	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	119	Pipe Size	10 OD x 0.27 WT (in)	Operator Initials	RP	
Test Name	119-Q1_WD-02_5002-EB5002_190506163610			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	277.0	276.9	0.1	0.0
Stylus-2	261.7	255.7	6.0	2.3
Stylus-3	232.0	231.0	0.9	0.4
Stylus-4	207.2	204.7	2.5	1.2



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	1.00	inches	Normalized Macroetch Weld Width:	372	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

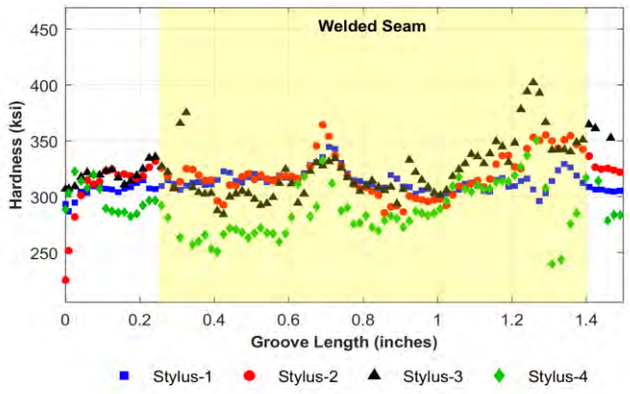
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506151543	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	15:15	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	122	Pipe Size	10 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	122-Q2_WD-01_5001-EB5001_190506151543			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	314.5	308.4	6.1	2.0
Stylus-2	319.2	322.2	-2.9	-0.9
Stylus-3	324.1	322.6	1.5	0.5
Stylus-4	287.2	289.1	-1.9	-0.7



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.90	inches	**Normalized Macroetch Weld Width:**	357	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

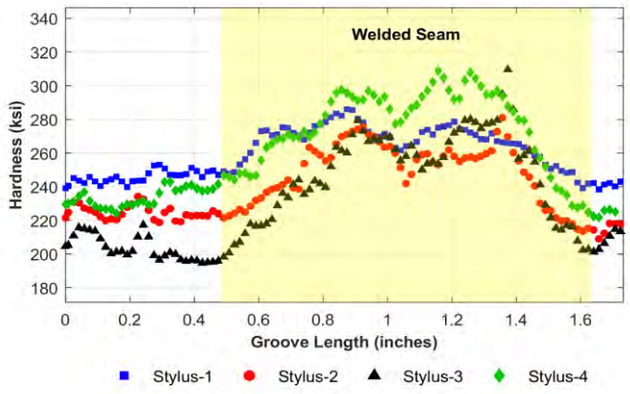
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520145329	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:53	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	124	Pipe Size	6 OD x 0.16 WT (in)	Operator Initials	RP	
Test Name	124-Q1_WD-01_5002-EB5002_190520145329			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	266.7	245.2	21.4	8.7
Stylus-2	248.5	222.7	25.8	11.6
Stylus-3	248.0	203.8	44.3	21.7
Stylus-4	275.1	232.4	42.7	18.4



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.44	inches	Normalized Macroetch Weld Width:	280	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

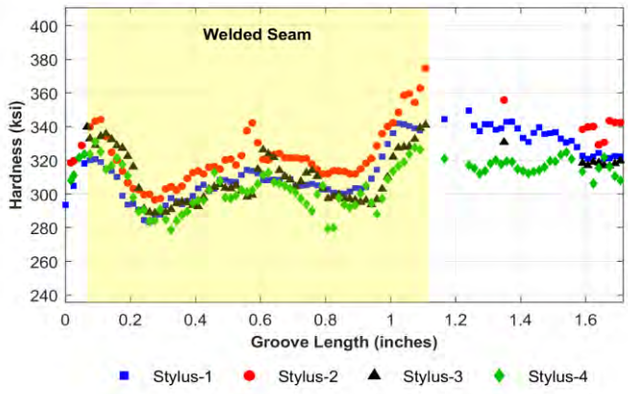
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508165340	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	16:53	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	125	Pipe Size	10 OD x 0.22 WT (in)	Operator Initials	RP	
Test Name	125-Q1_WD-01_5002-EB5002_190508165340			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	308.1	333.5	-25.5	-7.6
Stylus-2	322.2	340.3	-18.0	-5.3
Stylus-3	309.0	319.5	-10.5	-3.3
Stylus-4	302.0	316.3	-14.3	-4.5



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	1.00	inches	**Normalized Macroetch Weld Width:**	463	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

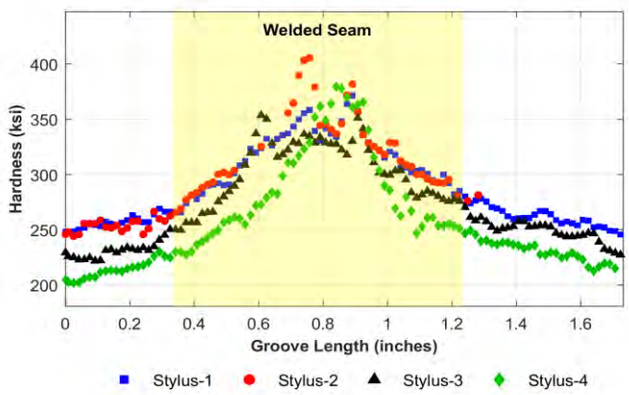
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529200440	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	20:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	130	Pipe Size	4 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	130-Q1_WD-01_5002-EB5002_190529200440			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000 Grit			LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133 in/min			Stylus-1 Serial No.	103-190412	
Travel Distance	2 in			Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16 in/min			Stylus-3 Serial No.	109-190520	
Sampling Rate	1600 Hz			Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	315.1	260.5	54.7	21.0
Stylus-2	321.5	257.2	64.3	25.0
Stylus-3	302.2	242.5	59.7	24.6
Stylus-4	287.2	224.8	62.4	27.8



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.25	inches	**Normalized Macroetch Weld Width:**	123	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

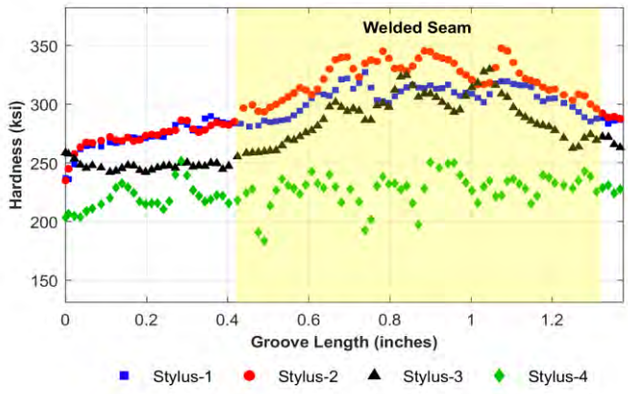
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506173031	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:30	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	133	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	133-Q1_WD-01_7001-EB7001_190506173031			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000 Grit			LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117 in/min			Stylus-1 Serial No.	103-190412	
Travel Distance	2 in			Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8 in/min			Stylus-3 Serial No.	109-190520	
Sampling Rate	1600 Hz			Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	305.2	274.4	30.8	11.2
Stylus-2	322.1	274.8	47.3	17.2
Stylus-3	289.7	246.8	43.0	17.4
Stylus-4	227.5	221.0	6.5	3.0



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.44	inches	**Normalized Macroetch Weld Width:**	171	% of pipe wall thickness

Seam Type Determination

[ ]	**Submerged Arc Welded (SAW)**	[X]	**ERW [calculated percent probability below]**
[ ]	**Flash**	98 %	**Low Frequency ERW (LF-ERW)**
[ ]	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
[ ]	**See Comments**	2 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

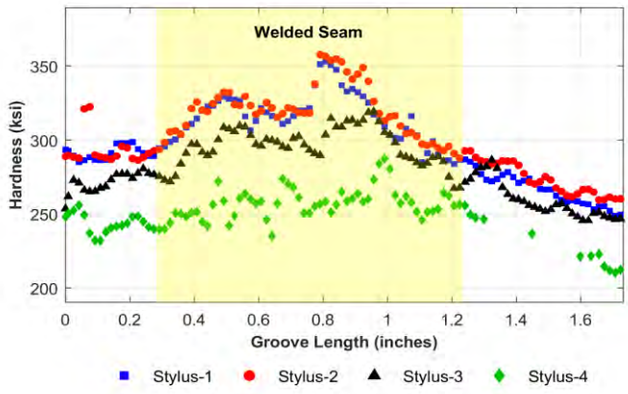
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507125915	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:59	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	134	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	RP	
Test Name	134-Q1_WD-01_5002-EB5002_190507125915			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	314.9	274.6	40.2	14.7
Stylus-2	319.9	280.5	39.4	14.1
Stylus-3	296.0	263.9	32.1	12.2
Stylus-4	257.1	236.5	20.6	8.7



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.19	inches	Normalized Macroetch Weld Width:	74	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

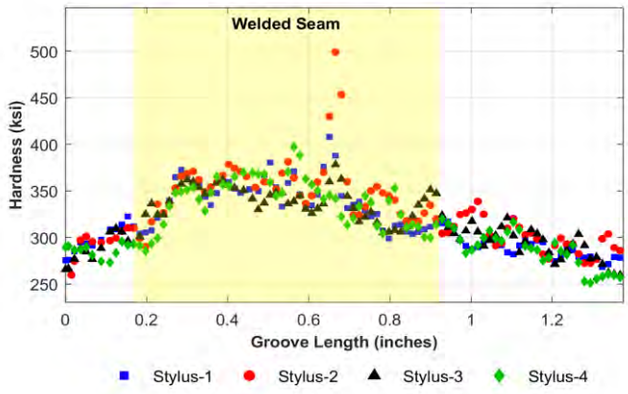
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521181409	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:14	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	137	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	137-Q1_WD-01_7001-EB7001_190521181409			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.8	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	339.5	292.2	47.3	16.2
Stylus-2	353.2	300.1	53.1	17.7
Stylus-3	337.9	293.2	44.7	15.2
Stylus-4	338.3	286.1	52.2	18.2



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.70	inches	Normalized Macroetch Weld Width:	372	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

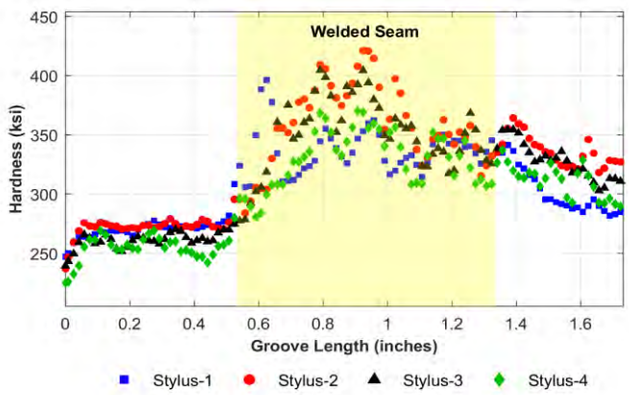
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509121335	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	12:13	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	140	Pipe Size	8 OD x 0.18 WT (in)	Operator Initials	JJ	
Test Name	140-Q1_WD-01_5001-EB5001_190509121335			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	336.8	285.7	51.1	17.9
Stylus-2	358.0	301.6	56.4	18.7
Stylus-3	350.1	291.5	58.6	20.1
Stylus-4	329.5	281.0	48.5	17.3



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.30	inches	Normalized Macroetch Weld Width:	163	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	100 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	0 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

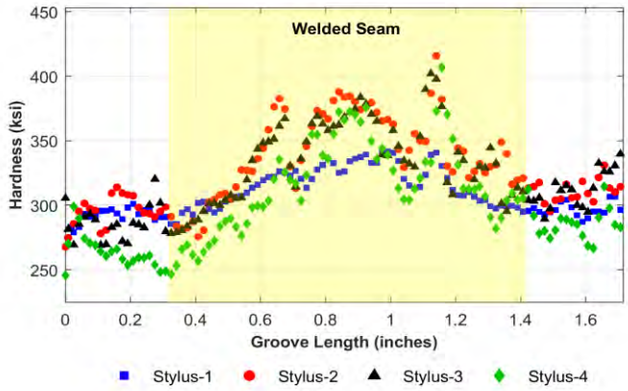
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509114427	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	11:44	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	141	Pipe Size	8 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	141-Q2_WD-01_5001-EB5001_190509114427			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	315.7	294.6	21.1	7.2
Stylus-2	340.9	304.2	36.6	12.0
Stylus-3	335.0	298.6	36.4	12.2
Stylus-4	316.2	275.2	40.9	14.9



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.90	inches	Normalized Macroetch Weld Width:	481	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	1 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	99 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

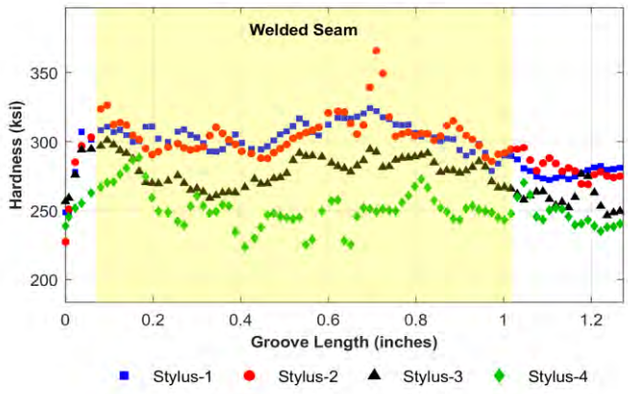
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521172639	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	17:26	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	142	Pipe Size	6 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	142-Q1_WD-01_7001-EB7001_190521172639			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.117	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.80002	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	304.3	277.8	26.5	9.5
Stylus-2	305.4	280.3	25.1	8.9
Stylus-3	279.0	258.8	20.2	7.8
Stylus-4	251.7	246.6	5.1	2.0



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.40	inches	**Normalized Macroetch Weld Width:**	200	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

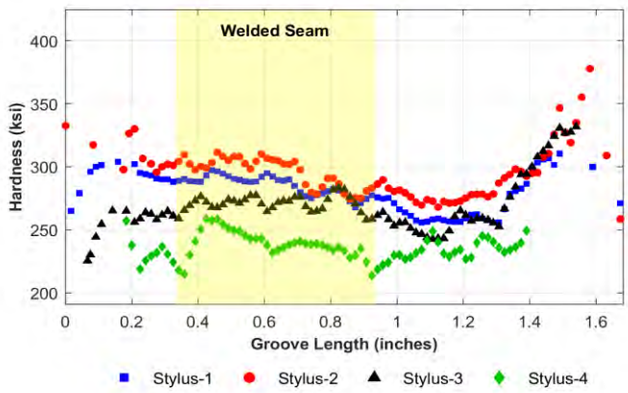
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523182552	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	18:25	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	143	Pipe Size	4 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	143-Q1_WD-01_5002-EB5002_190523182552			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	285.2	261.6	23.6	9.0
Stylus-2	296.0	277.5	18.5	6.7
Stylus-3	270.8	254.6	16.2	6.4
Stylus-4	238.6	233.1	5.5	2.4



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.40	inches	**Normalized Macroetch Weld Width:**	213	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

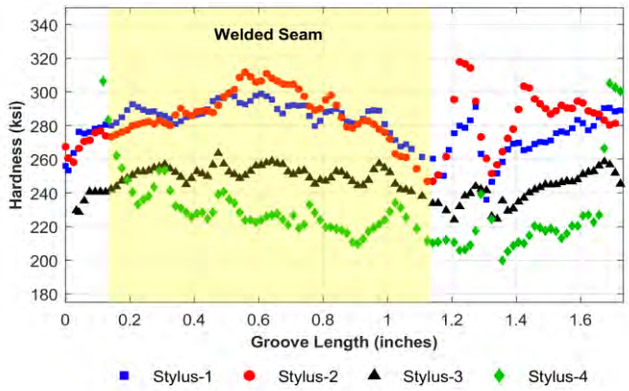
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190524095011	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	9:50	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	143	Pipe Size	4 OD x 0.19 WT (in)	Operator Initials	RP	
Test Name	143-Q1_WD-03_5002-EB5002_190524095011			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000	Grit		LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133	in/min		Stylus-1 Serial No.	103-190412	
Travel Distance	2	in		Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16	in/min		Stylus-3 Serial No.	109-190520	
Sampling Rate	1600	Hz		Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	286.7	274.9	11.7	4.3
Stylus-2	287.3	286.5	0.8	0.3
Stylus-3	250.9	244.3	6.6	2.7
Stylus-4	228.7	230.0	-1.3	-0.5



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.40	inches	Normalized Macroetch Weld Width:	213	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

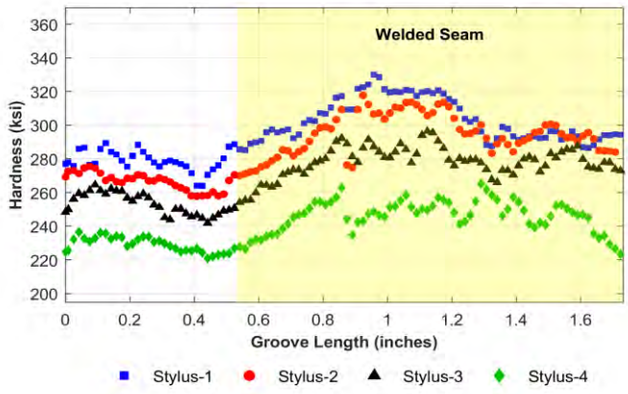
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530142658	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Planes, IL 60018			Test Time	14:26	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	144	Pipe Size	12 OD x 0.29 WT (in)	Operator Initials	JJ	
Test Name	144-Q2_WD-01_5002-EB5002_190530142658			Sample Type	Cutout	
Sample Description						
				LVDT-1 Serial No.	L01-190107	
Surface Finish	2000 Grit			LVDT-2 Serial No.	L02-190107	
HSD Core Speed	0.133 in/min			Stylus-1 Serial No.	103-190412	
Travel Distance	2 in			Stylus-2 Serial No.	105-190412	
Profiler Speed	2.16 in/min			Stylus-3 Serial No.	109-190520	
Sampling Rate	1600 Hz			Stylus-4 Serial No.	118-190520	

Measurements

Post-Processing Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔHs (ksi)	Normalized ΔHs (%)
Stylus-1	302.9	279.1	23.8	8.5
Stylus-2	294.6	266.1	28.5	10.7
Stylus-3	278.0	253.1	24.9	9.8
Stylus-4	246.0	229.2	16.8	7.3



ΔHs: Average change in hardness between base metal and weld regions.

Normalized ΔHs: ΔHs normalized by base metal average hardness

Results

Macroetch Weld Width:	0.75	inches	**Normalized Macroetch Weld Width:**	261	% of pipe wall thickness

Seam Type Determination

☐	**Submerged Arc Welded (SAW)**	☒ X	**ERW [calculated percent probability below]**
☐	**Flash**	0 %	**Low Frequency ERW (LF-ERW)**
☐	**Lap-Welded**	0 %	**High Frequency ERW (HF-ERW)**
☐	**See Comments**	100 %	**High Frequency Normalized ERW (HFN-ERW)**

Classification Model Version: v200406-cSVM

ERW seam classification percent probability determined with a classification model trained to a database of 56 ERW pipes.

Comments

Prepared: Yasamin Salamat, PhD **Approved:** Steven Palkovic, PhD