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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.

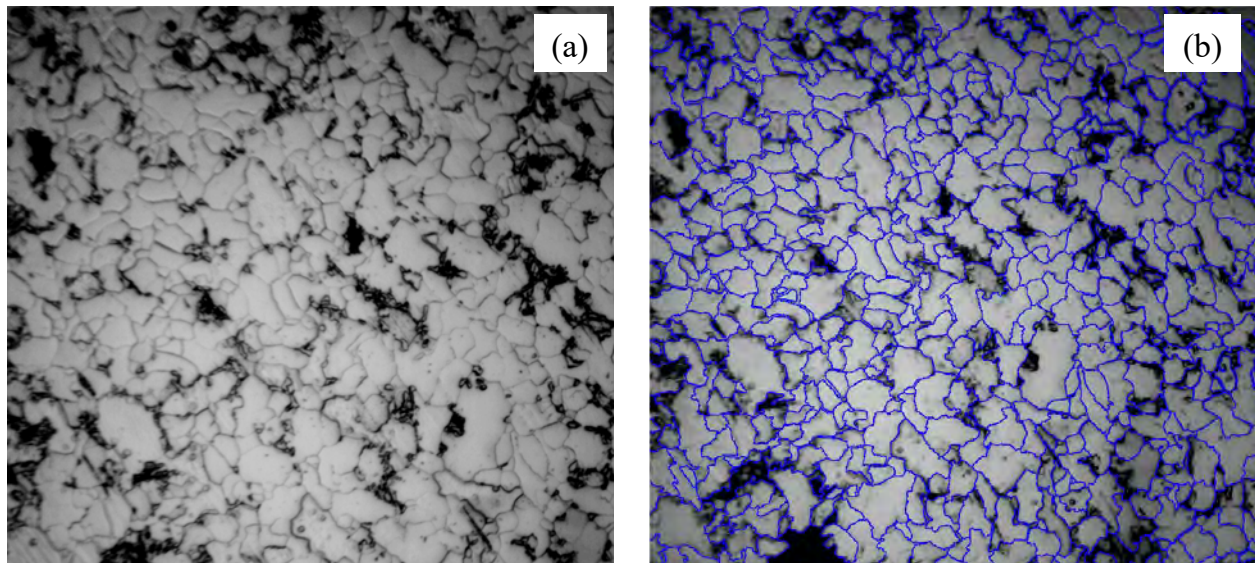


Fig. 1: (a) Imaged etched steel microstructure and (b) the segmented grain boundaries used to determine the average mean-linear-intercept grain size.

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} .

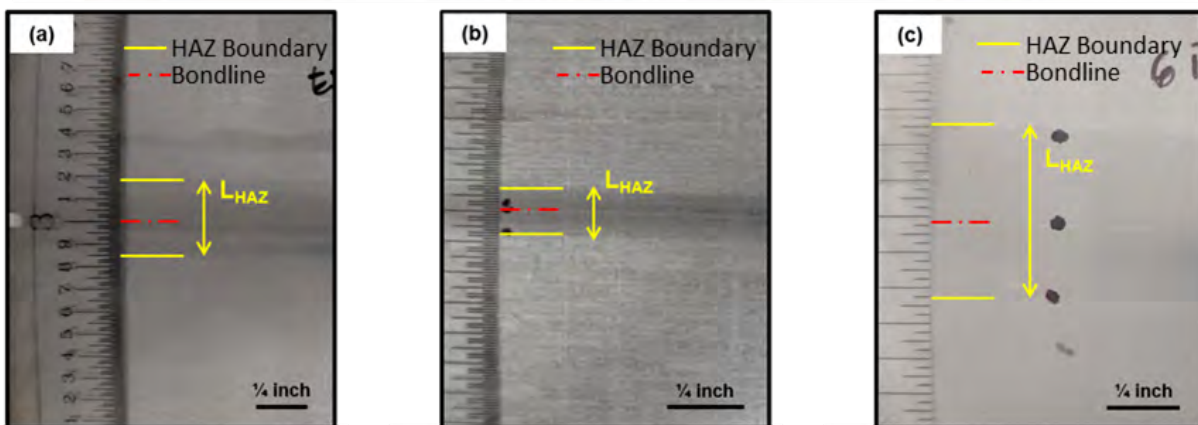


Fig. 2: Representative etched welded seams for (a) LF-ERW, (b) HF-ERW, and (c) HFN-ERW.

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.

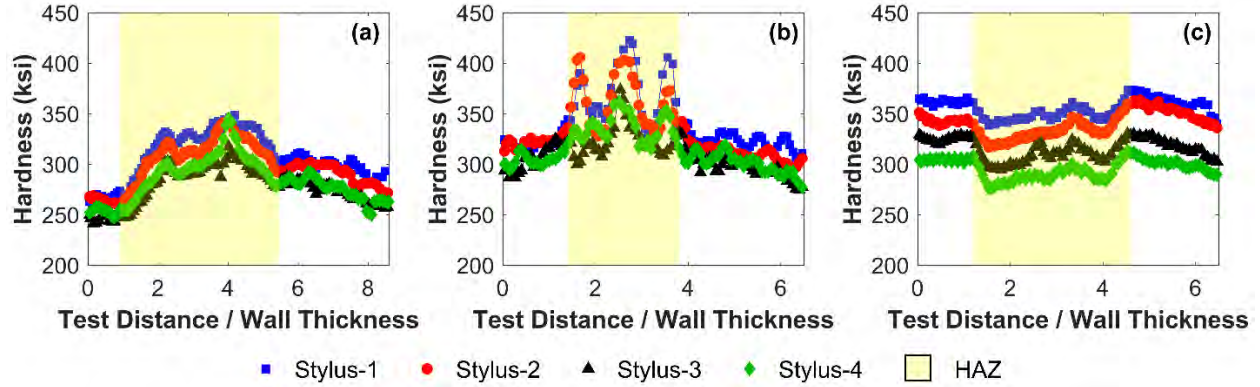


Fig. 3: Hardness measured along the length of HSD weld tests performed on (a) LF-ERW, (b) HF-ERW, and (c) HFN-ERW pipe joints. The heat-affected-zones (HAZ) are shown by the shaded region.

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,

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

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,

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

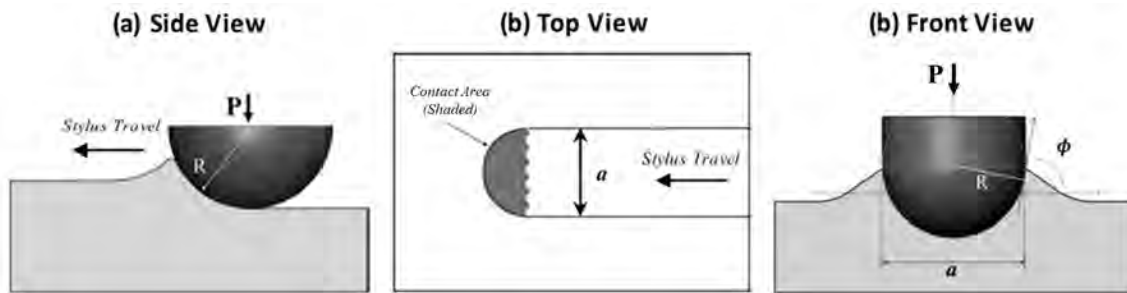


Fig. 4: Schematic views of a spherical stylus engaging with a substrate under load to create a shallow groove as it travels along the surface.

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],

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

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.

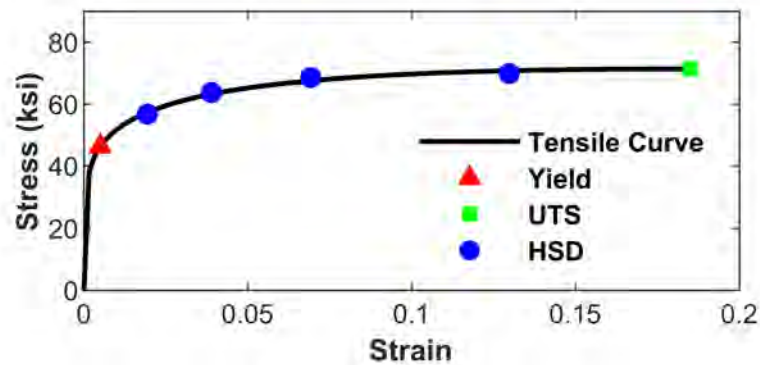


Fig. 5: Engineering stress-strain curve obtained from a power-law fit to 4 stylus measurements collected with the HSD. The predicted tensile yield and UTS are also shown.

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.

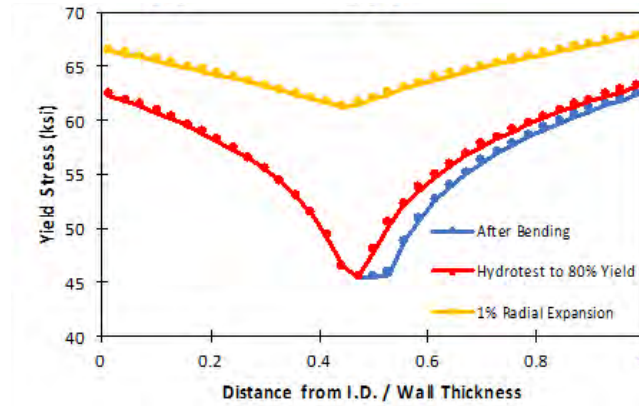


Fig. 6: Calculated yield strength distributions through the pipe wall at different stages of manufacturing.

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.

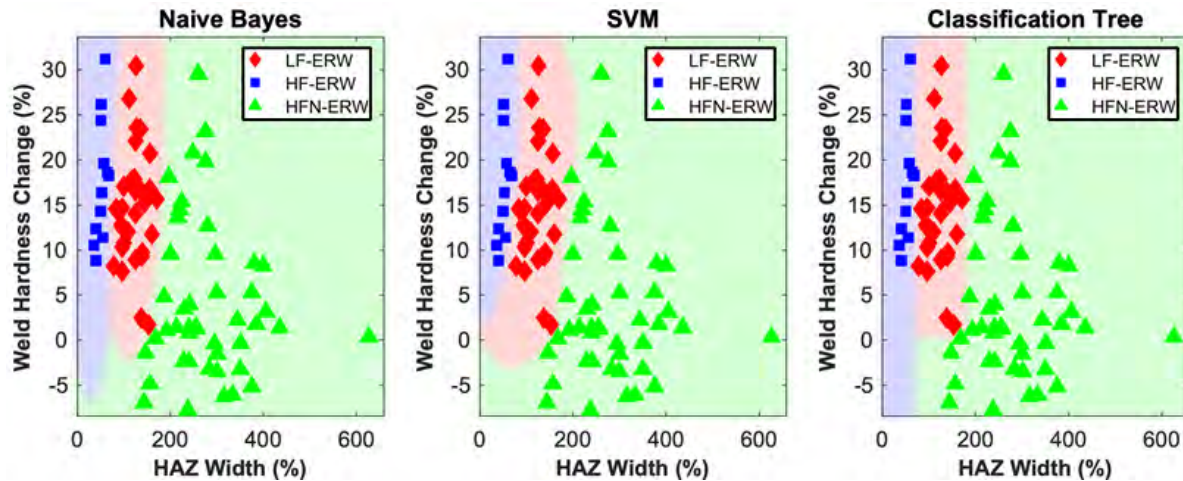


Fig. 7: Seam classification models generated from MMT database of 87 unique ERW pipe samples. Blue indicates HF-ERW, red indicates LF-ERW, and green indicates HFN-ERW.

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.

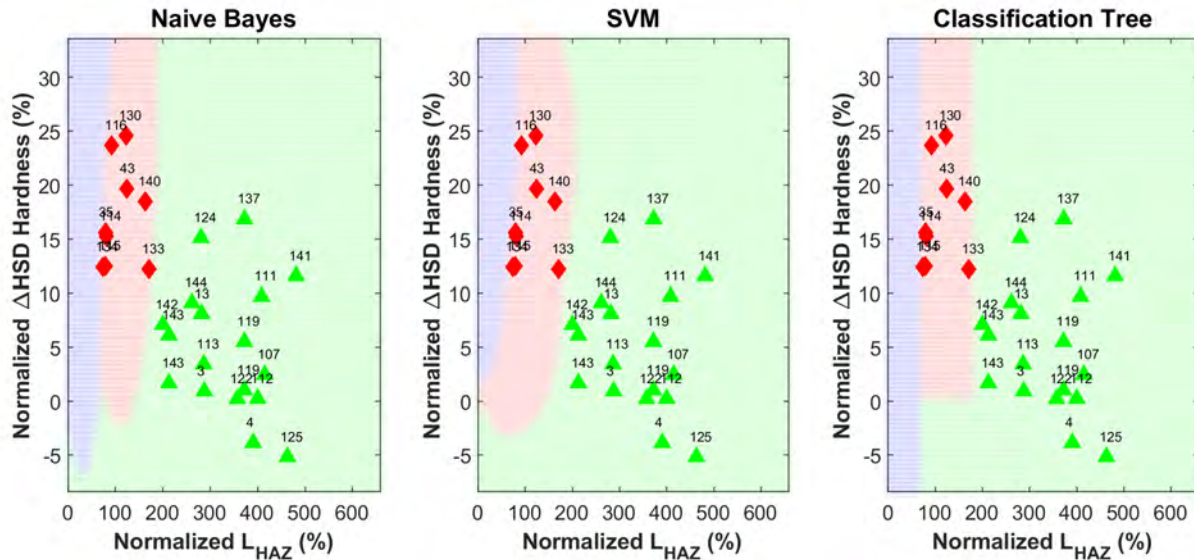


Fig. 8: Seam classification from three different classification models for 25 GTI ERW pipe joints. Blue indicates HF-ERW, red indicates LF-ERW, and green indicates HFN-ERW. The sample number is indicated near the point.

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.

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.

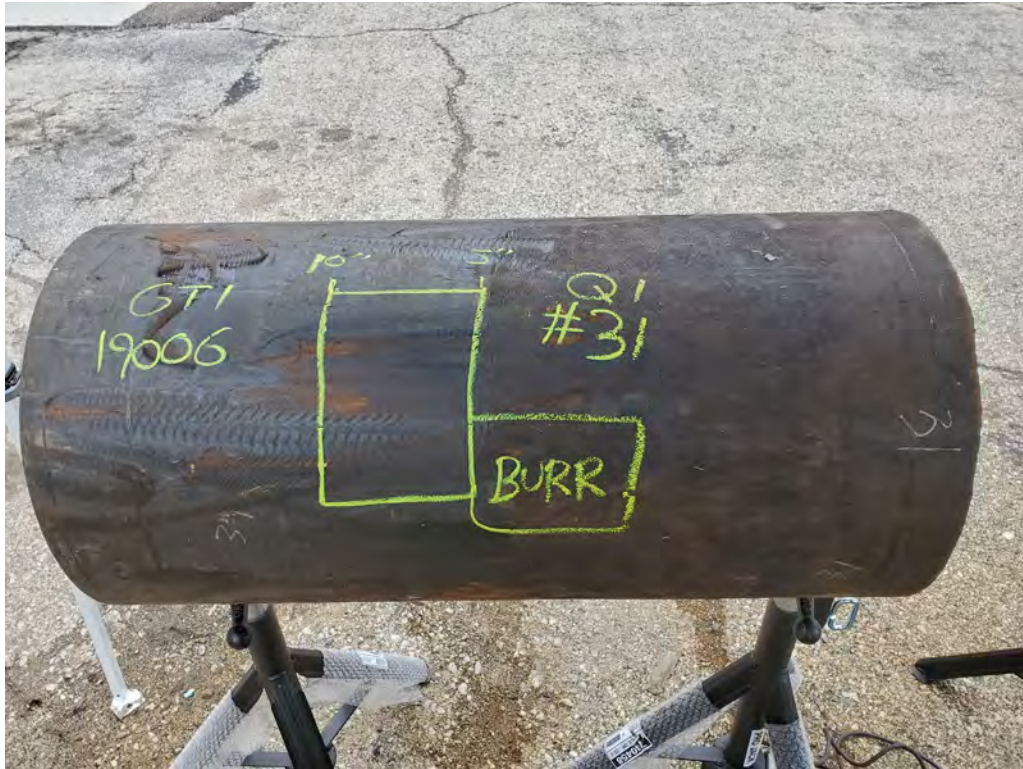


Figure 15: Test locations and overview of Sample 031.



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.

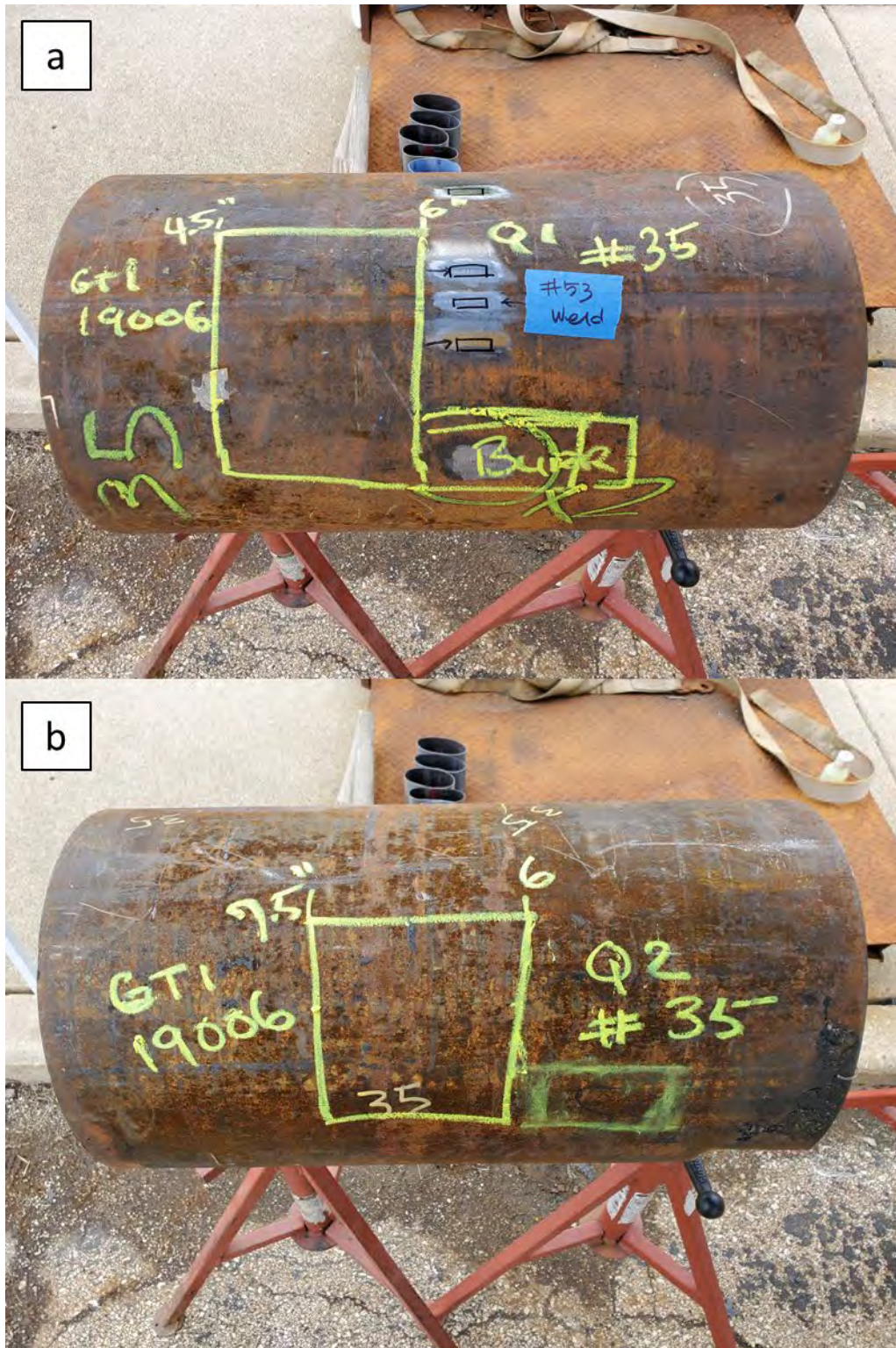


Figure 19: (a) Test location Q1 on ERW seam and overview of Sample 035; (b) Test location Q2 and overview of Sample 035.

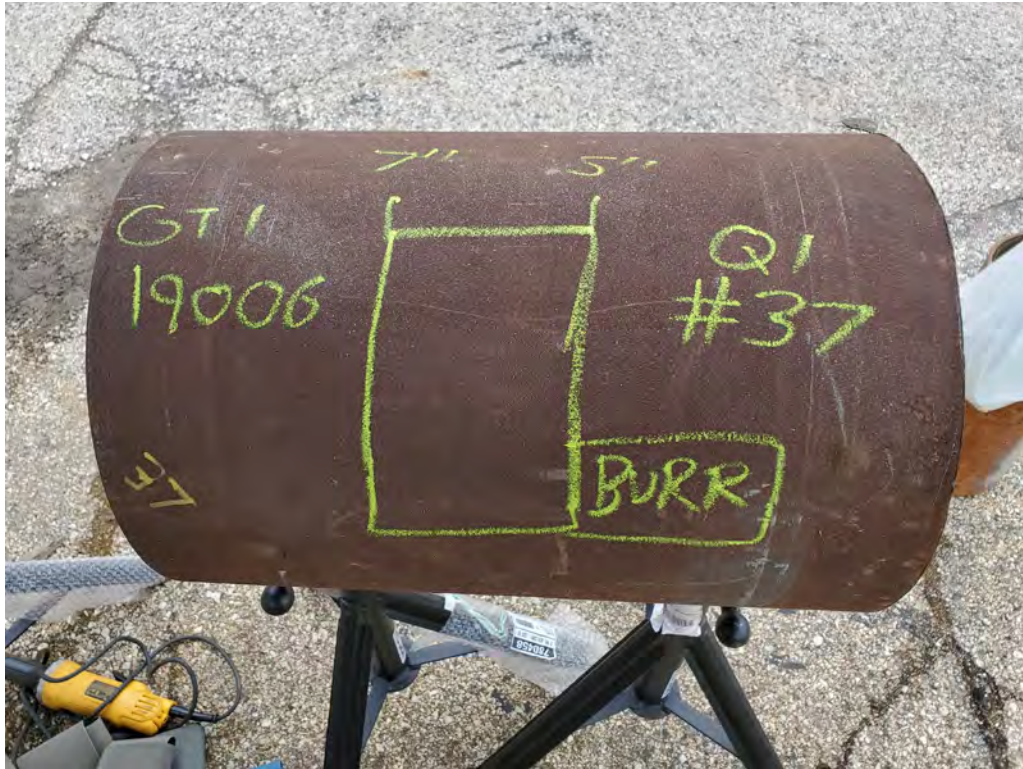


Figure 20: Test locations and overview of Sample 037.



Figure 21: Test locations and overview of Sample 040.



Figure 22: Test locations and overview of Sample 042.

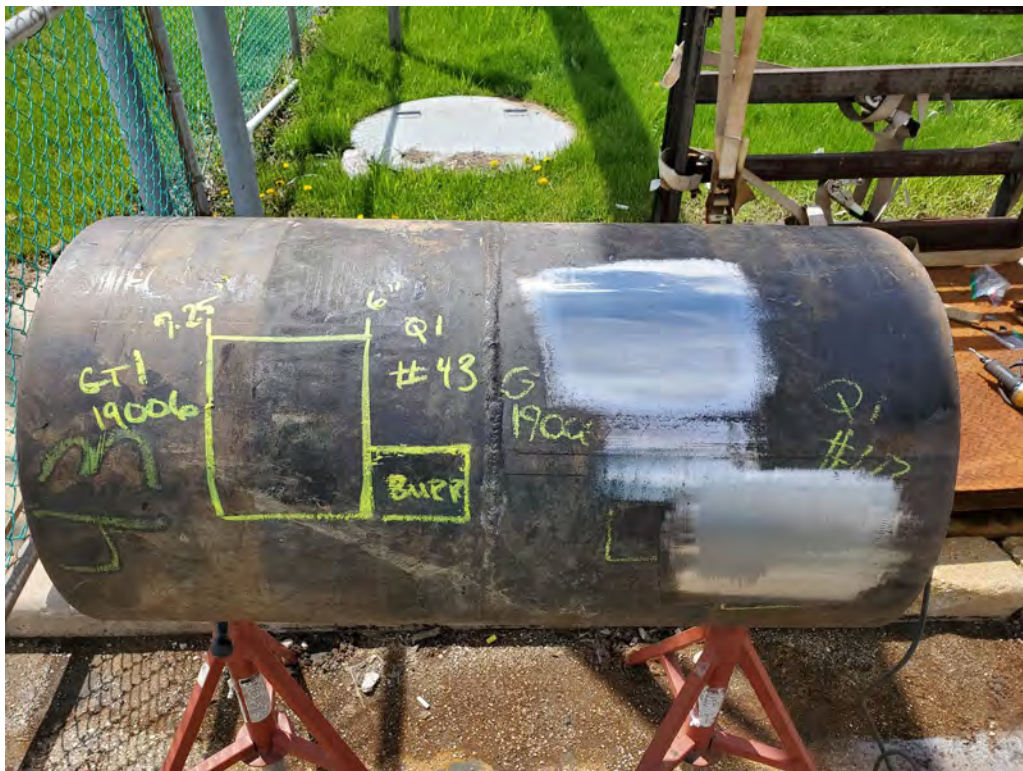


Figure 23: Test locations and overview of Sample 043.



Figure 24: Test locations and overview of Sample 044.

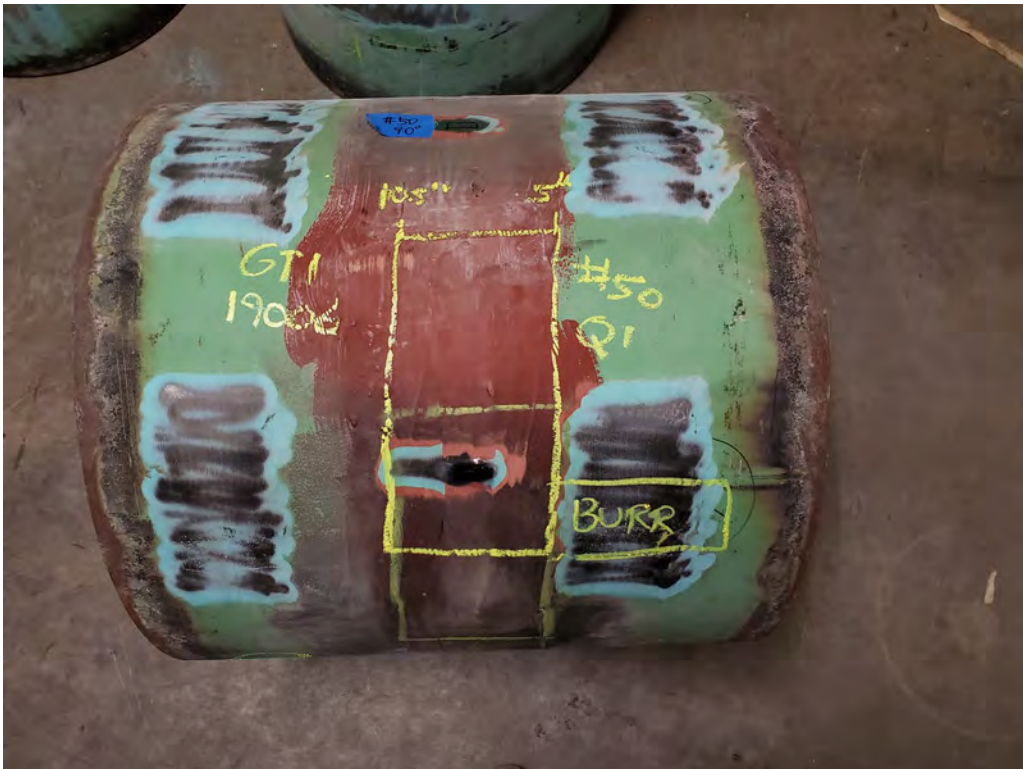


Figure 25: Test locations and overview of Sample 050.



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.

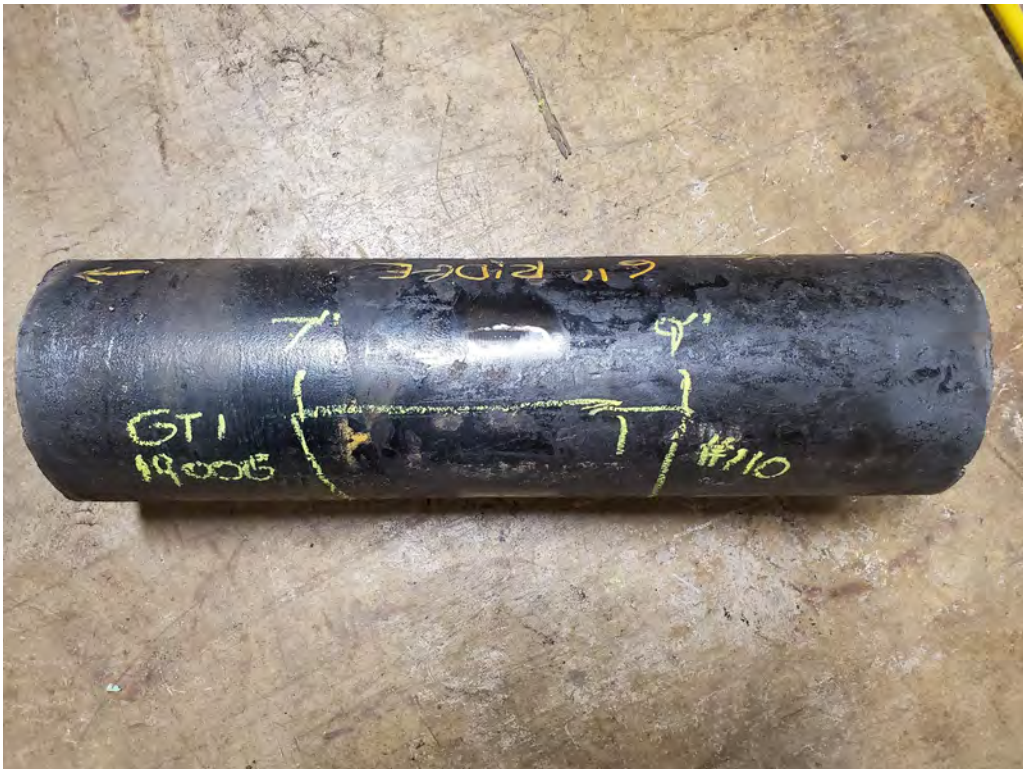


Figure 29: Test locations and overview of Sample 110.



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.

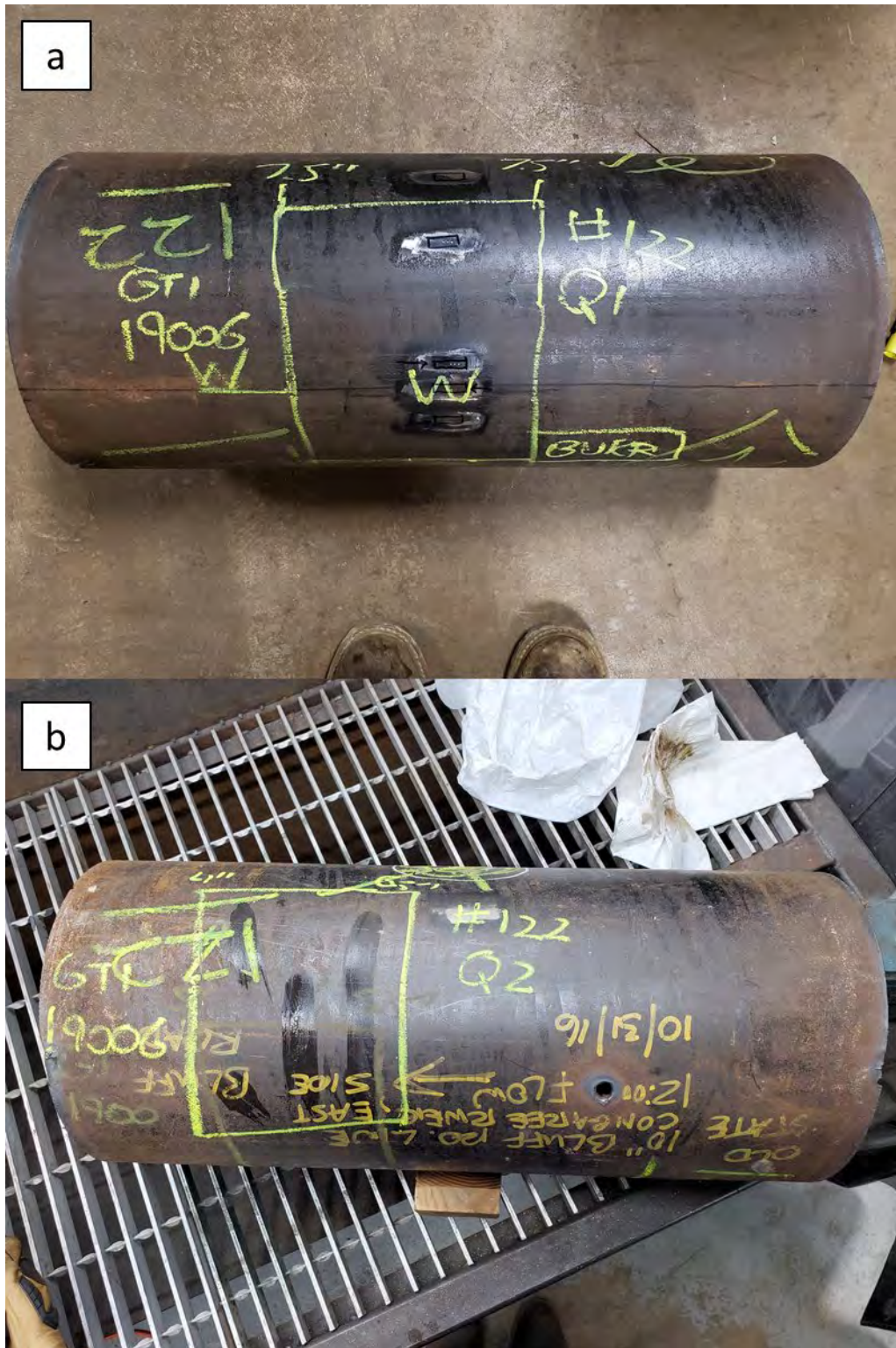


Figure 40: (a) Test location Q1 on ERW seam and overview of Sample 122; (b) Test location Q2 and overview of Sample 122.



Figure 41: Test locations and overview of Sample 123.



Figure 42: Test locations and overview of Sample 124.

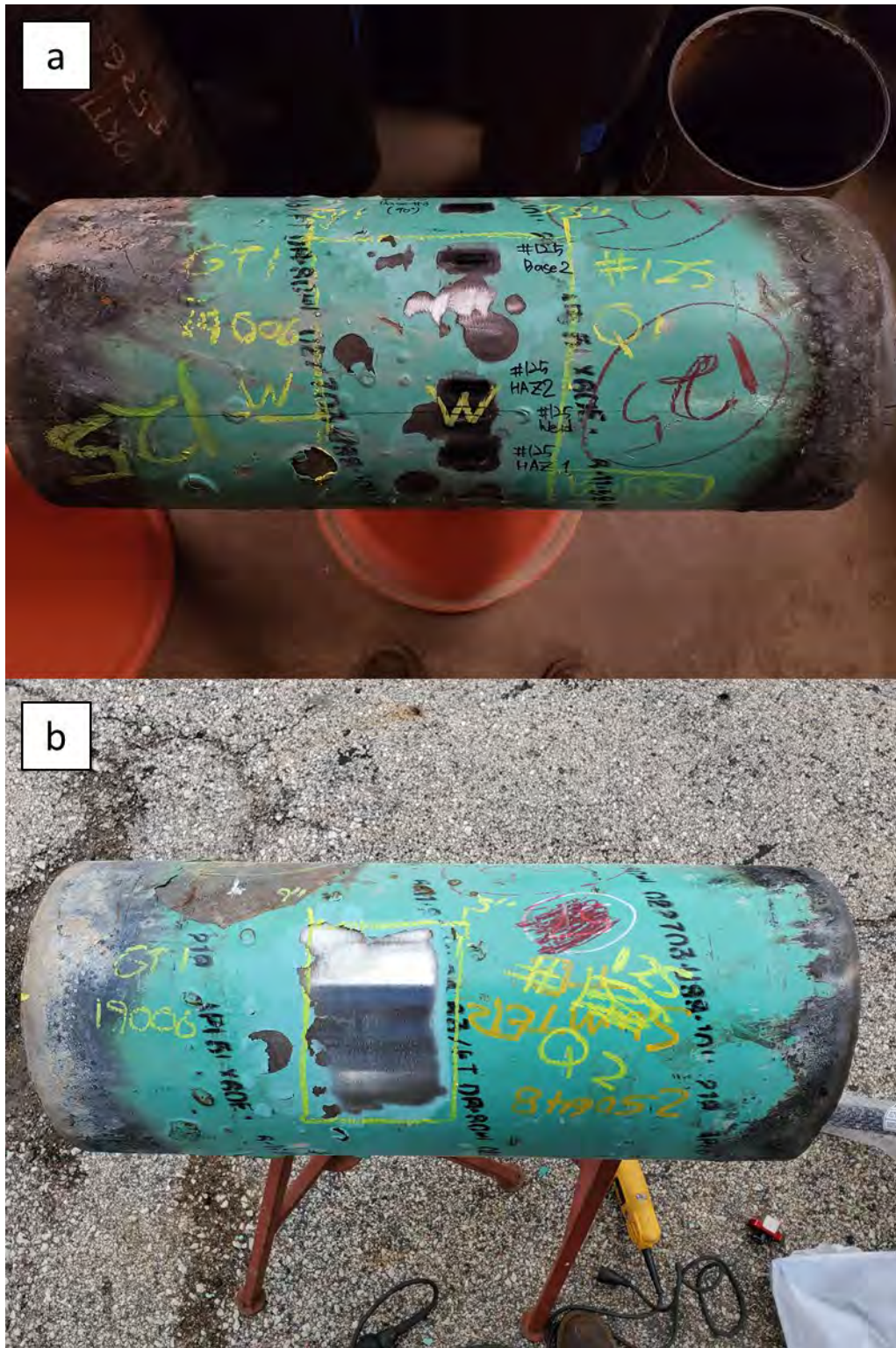


Figure 43: (a) Test location Q1 on ERW seam and overview of Sample 125; (b) Test location Q2 and overview of Sample 125.



Figure 44: Test locations and overview of Sample 126.

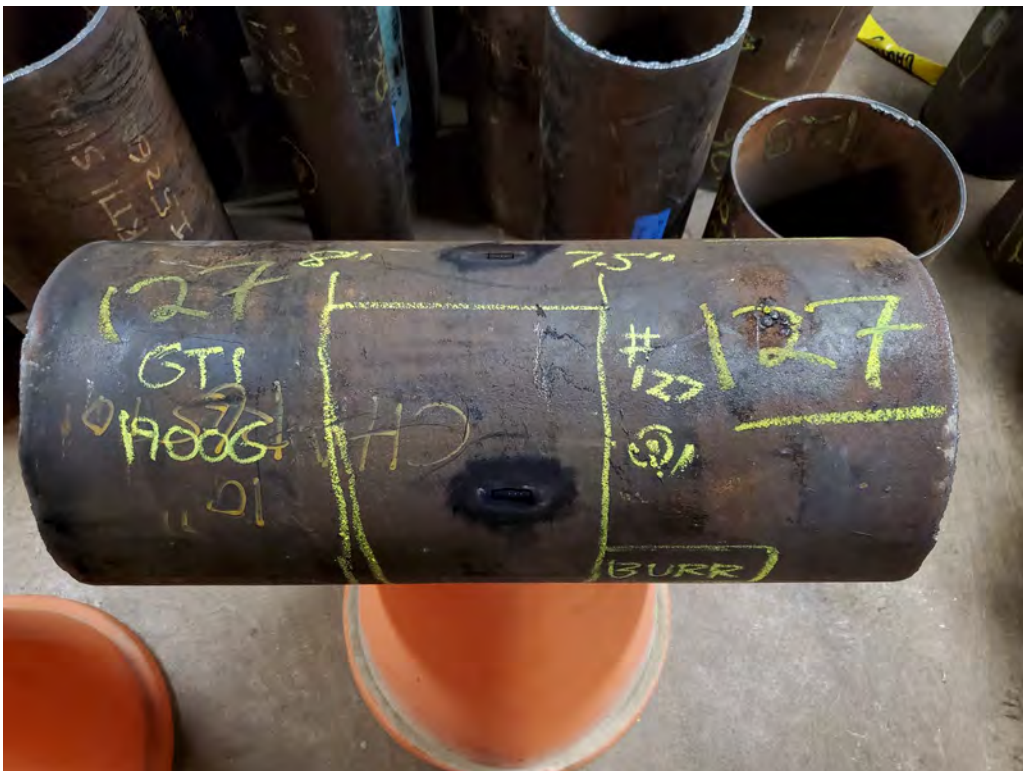


Figure 45: Test locations and overview of Sample 127.



Figure 46: Test locations and overview of Sample 130.

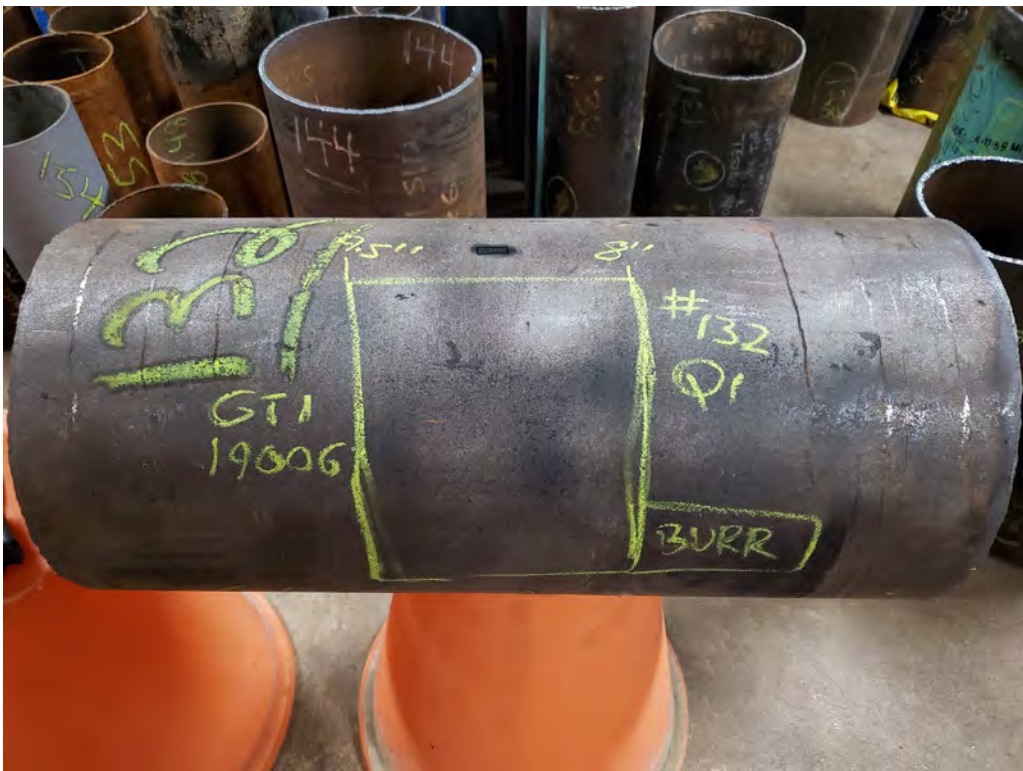


Figure 47: Test locations and overview of Sample 132.

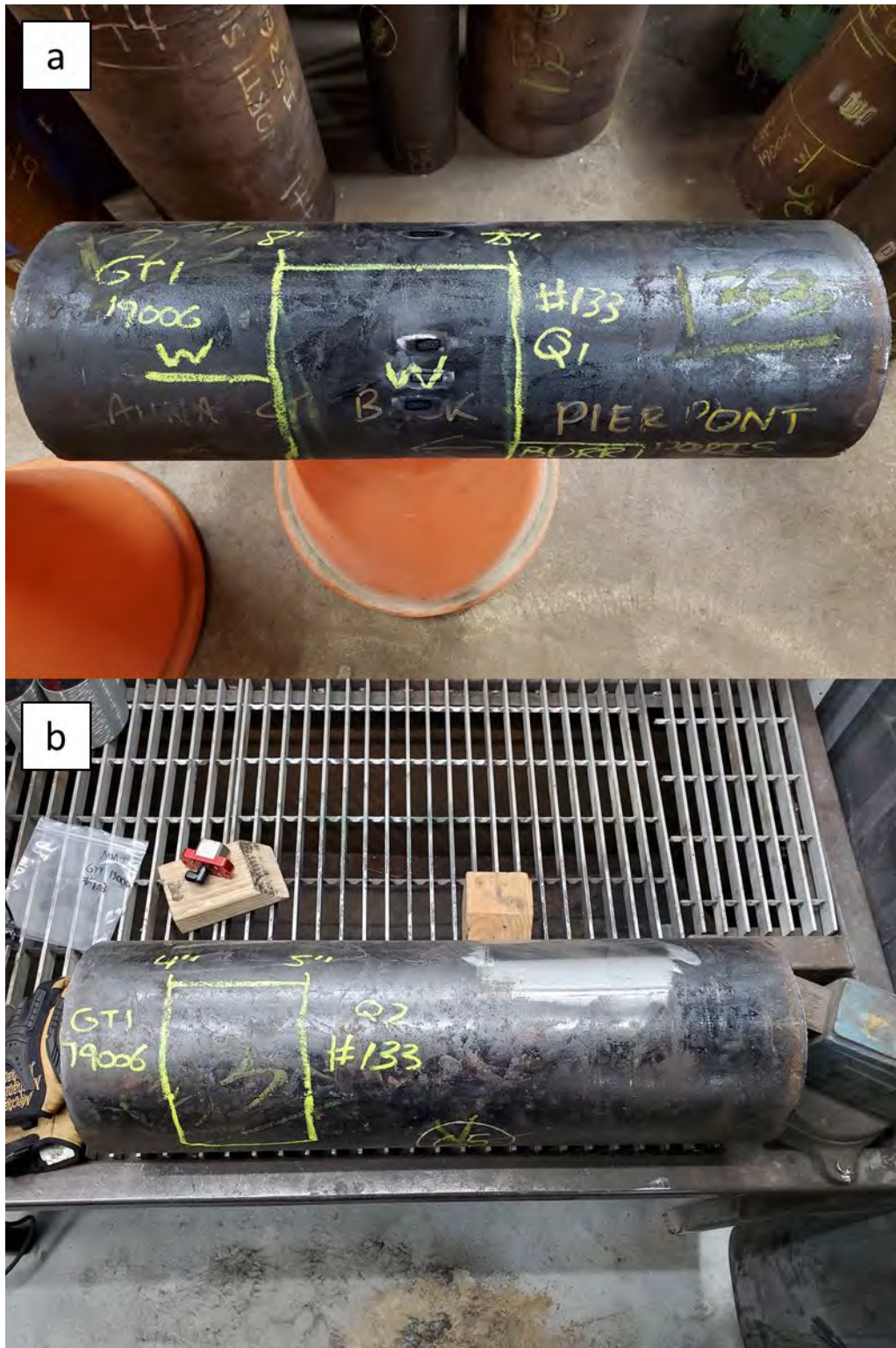


Figure 48: (a) Test location Q1 on ERW seam and overview of Sample 133; (b) Test location Q2 and overview of Sample 133.

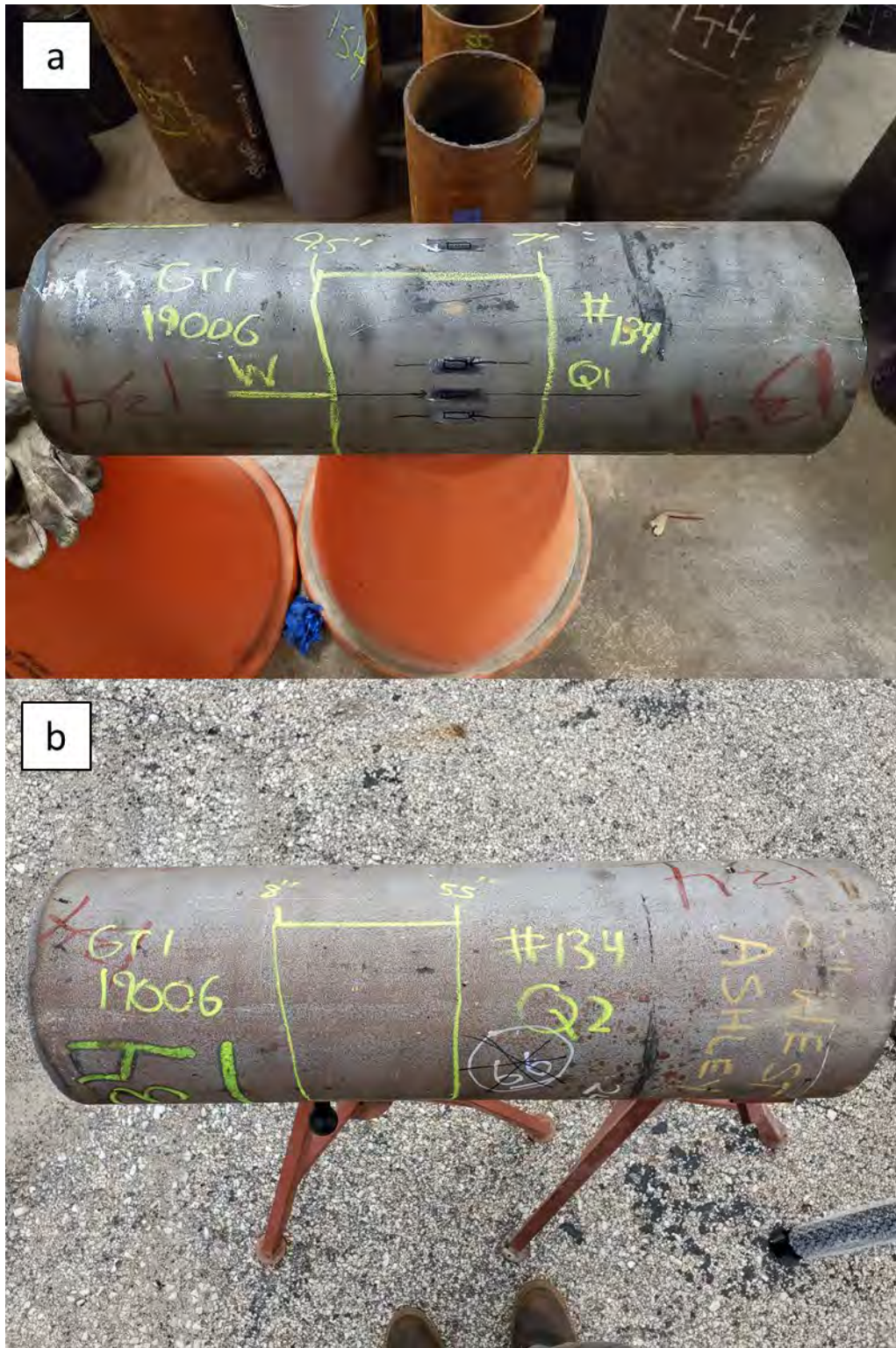


Figure 49: (a) Test location Q1 on ERW seam and overview of Sample 134; (b) Test location Q2 and overview of Sample 134.



Figure 50: Test locations and overview of Sample 136.

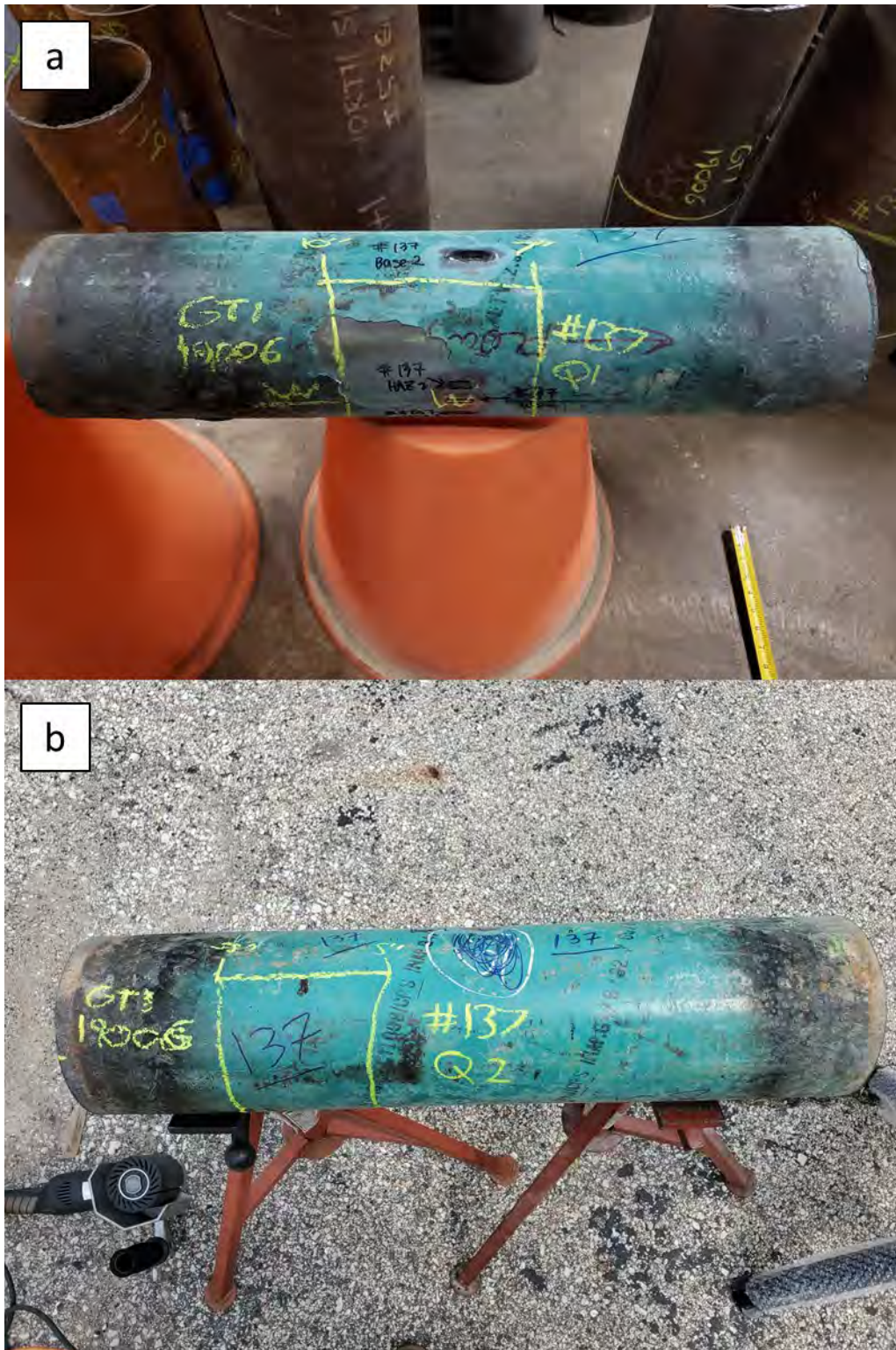


Figure 51: (a) Test location Q1 on ERW seam and overview of Sample 137; (b) Test location Q2 and overview of Sample 137.



Figure 52: Test locations and overview of Sample 138.



Figure 53: Test locations and overview of Sample 139.

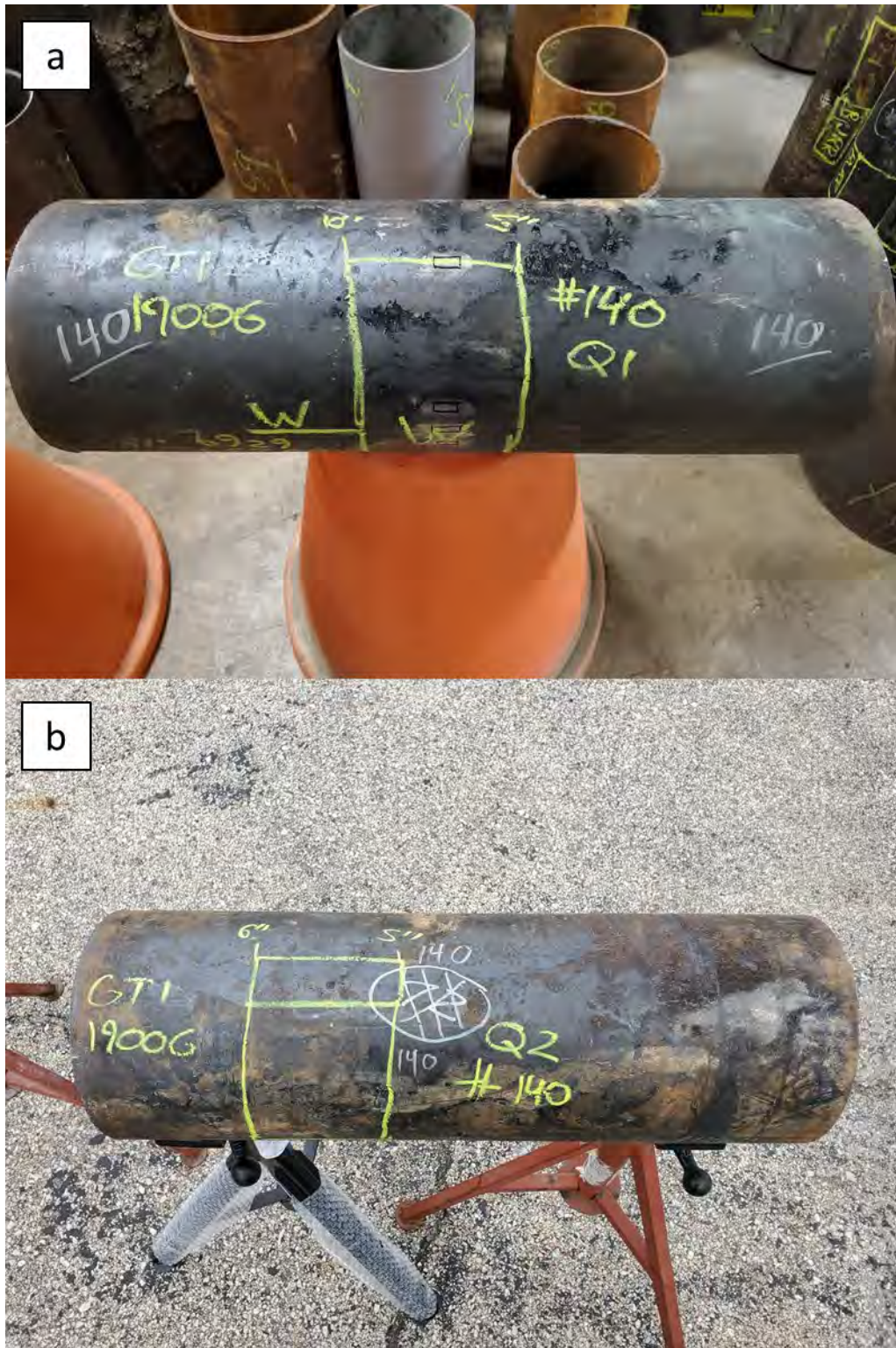


Figure 54: (a) Test location Q1 on ERW seam and overview of Sample 140; (b) Test location Q2 and overview of Sample 140.

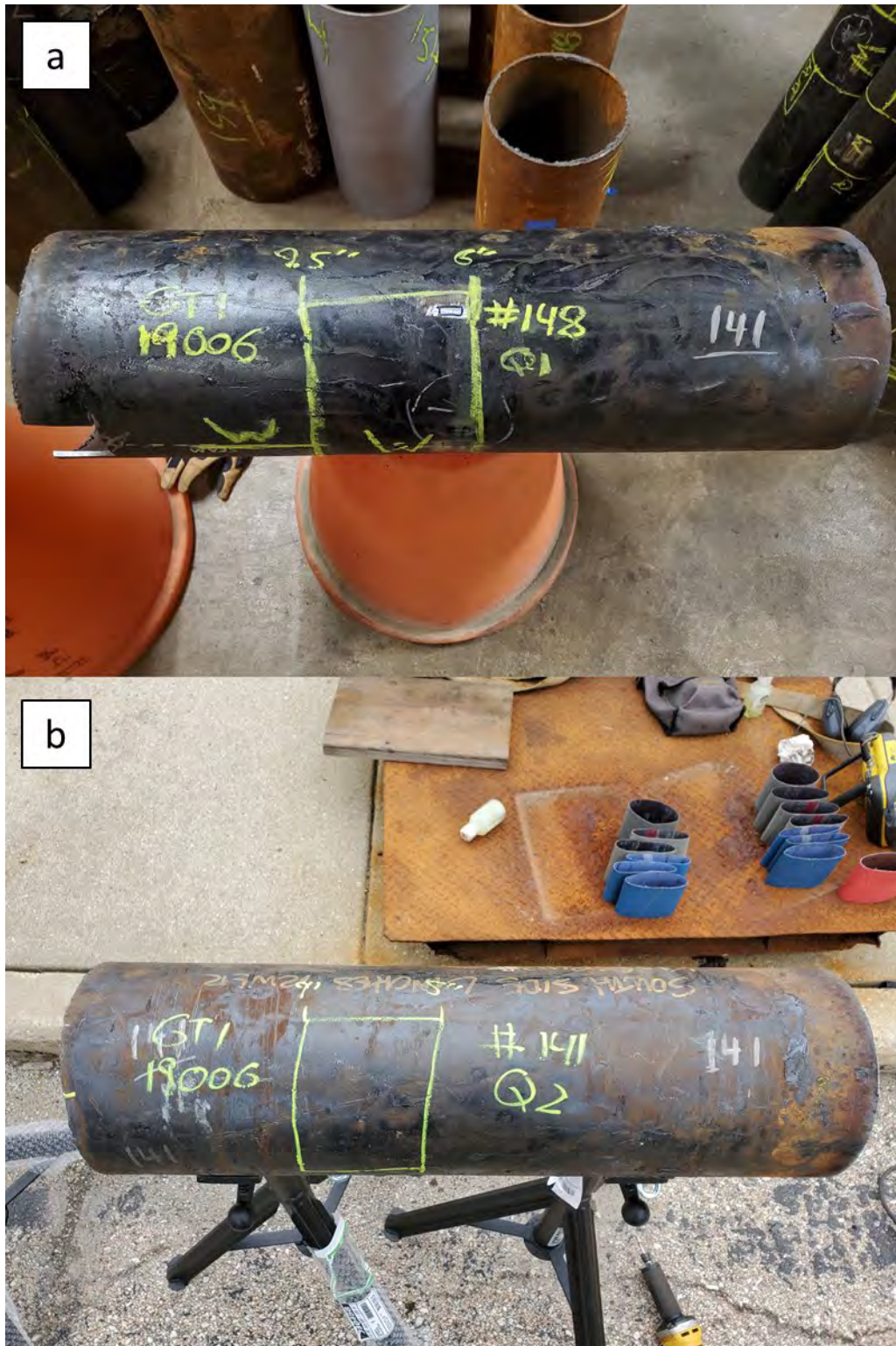


Figure 55: (a) Test location Q1 on ERW seam and overview of Sample 141; (b) Test location Q2 and overview of Sample 141.

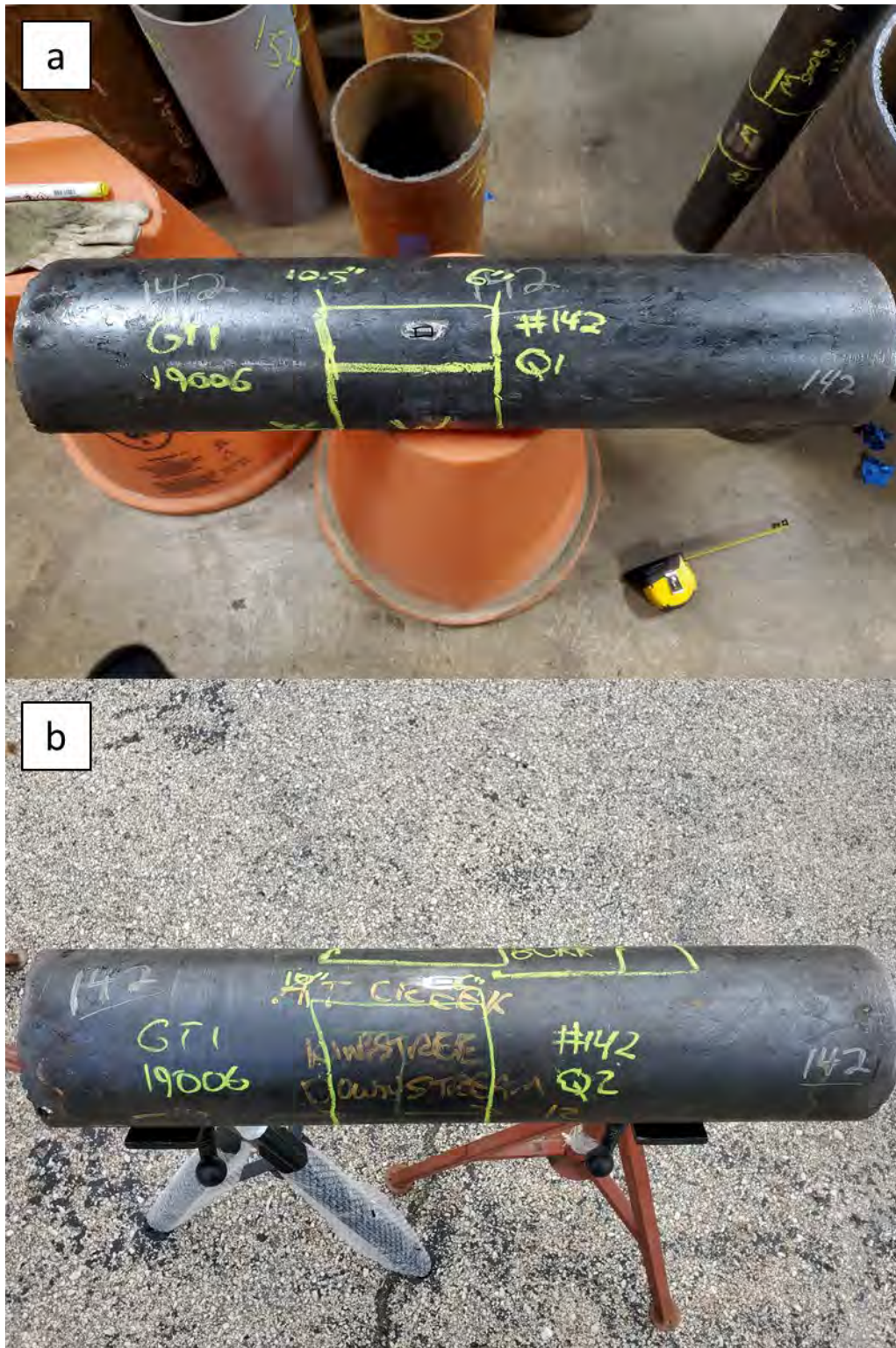


Figure 56: (a) Test location Q1 on ERW seam and overview of Sample 142; (b) Test location Q2 and overview of Sample 142.



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

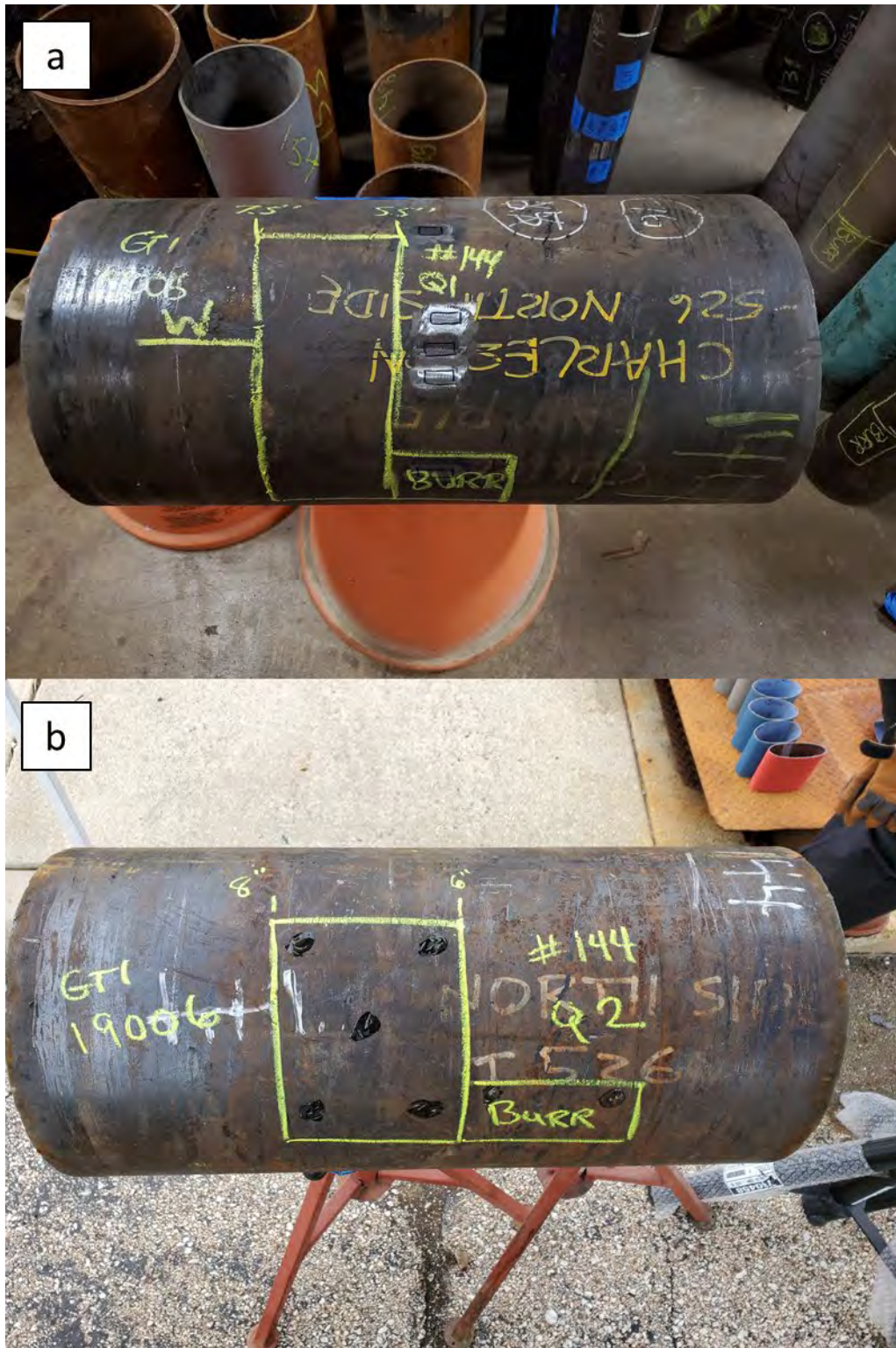


Figure 58: (a) Test location Q1 on ERW seam and overview of Sample 144; (b) Test location Q2 and overview of Sample 144.

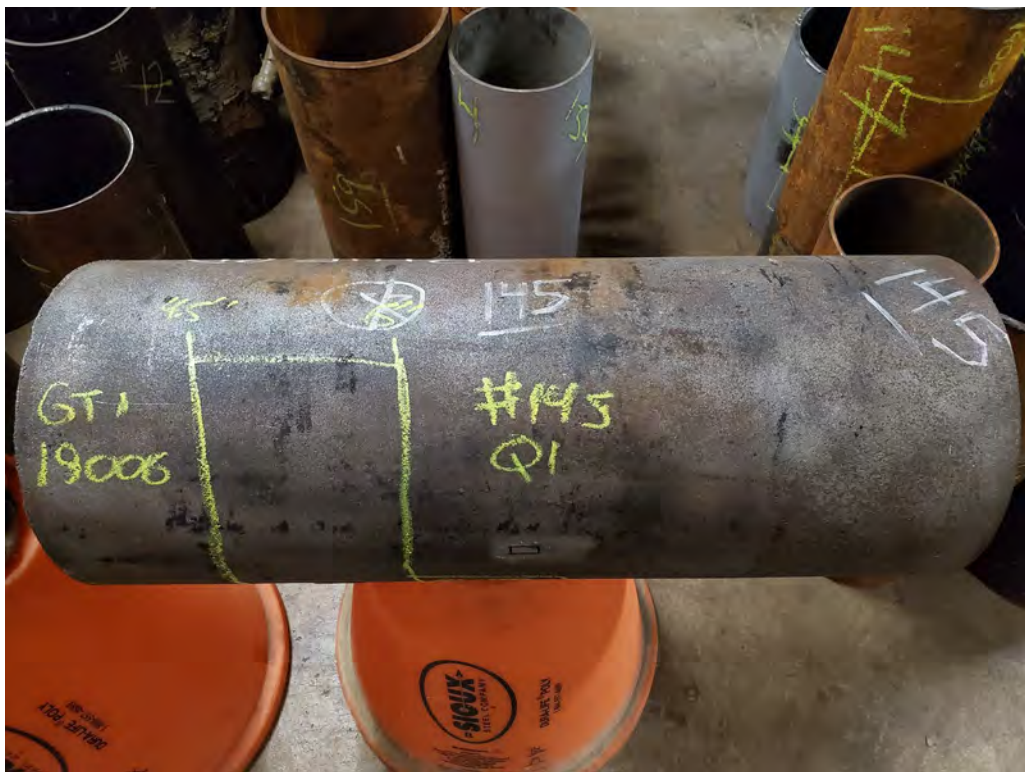


Figure 59: Test locations and overview of Sample 145.



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.

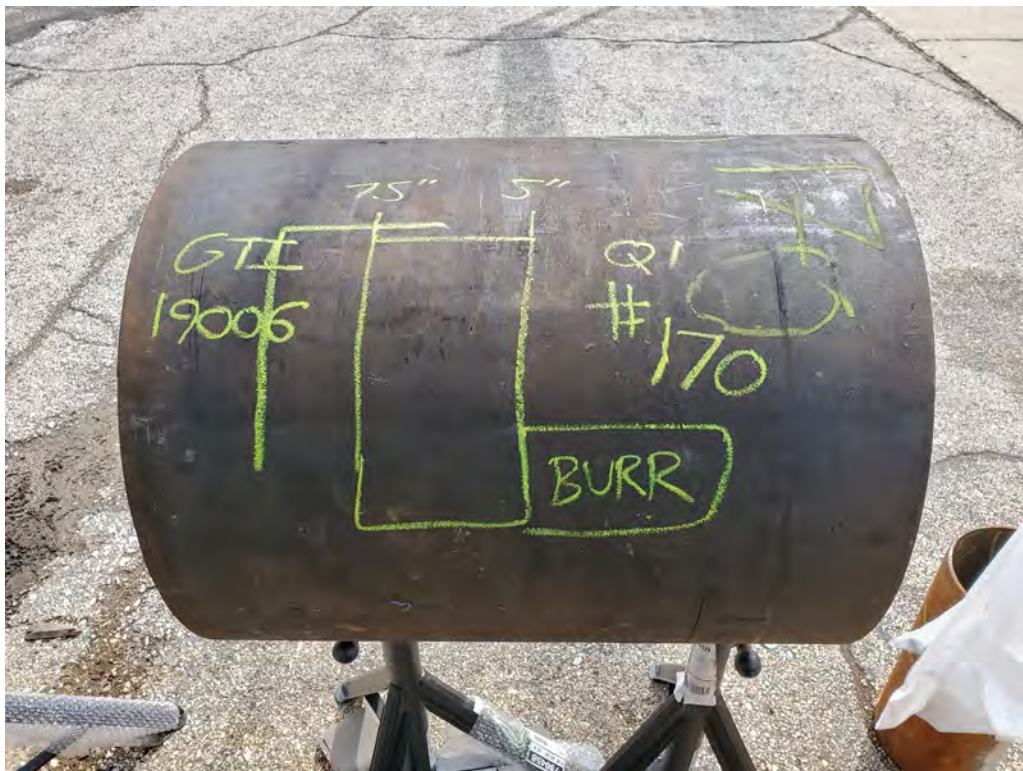


Figure 70: Test locations and overview of Sample 170.

Customer: Gas Technology Institute

Project ID: MMT Project GTI19006

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

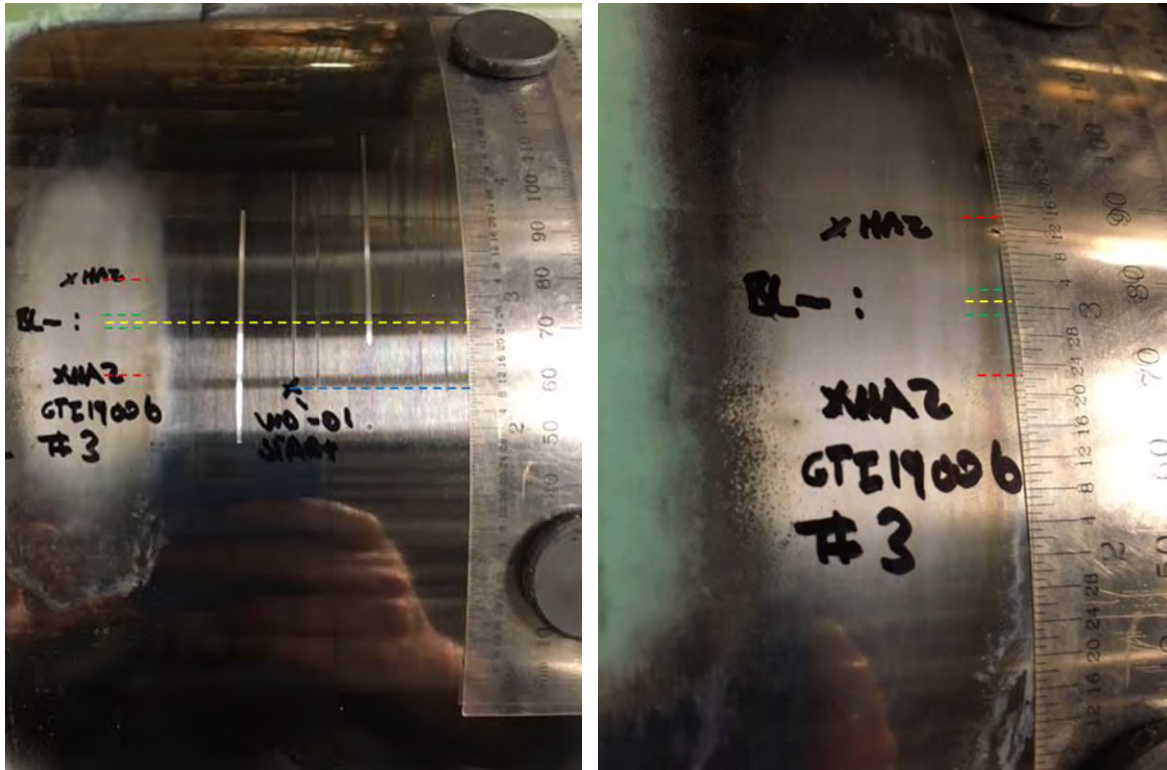


Figure 1: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 003. The boundaries of the etched HAZ are shown in dashed red lines, the bondline is shown by the dashed yellow line, and the edges of the inner hourglass HAZ surrounding the bondline is shown by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

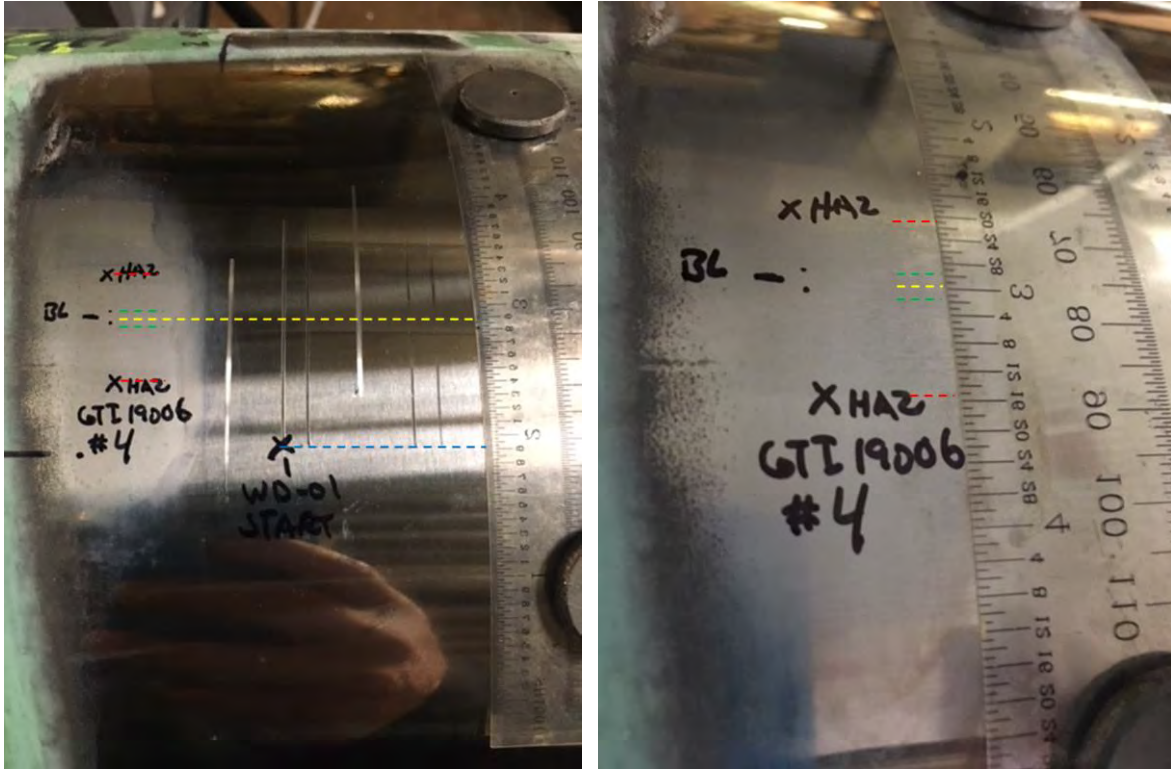


Figure 2: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 004. The boundaries of the etched HAZ are shown in dashed red lines, the bondline is shown by the dashed yellow line, and the edges of the inner hourglass HAZ surrounding the bondline is shown by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

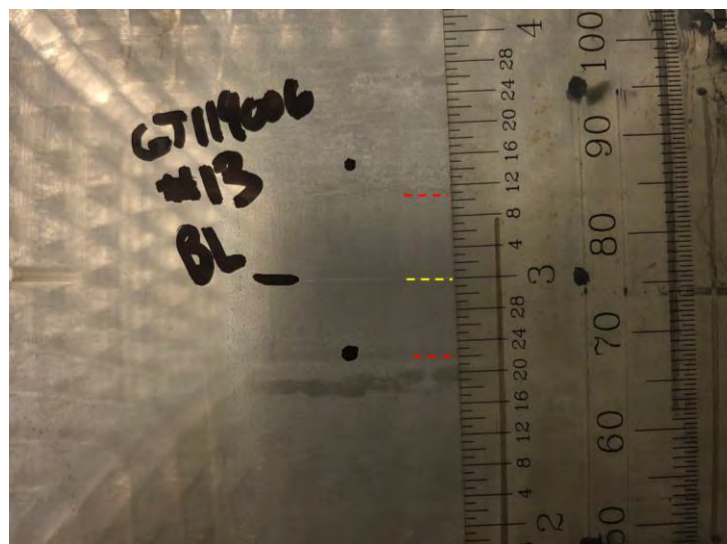


Figure 3: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 013. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

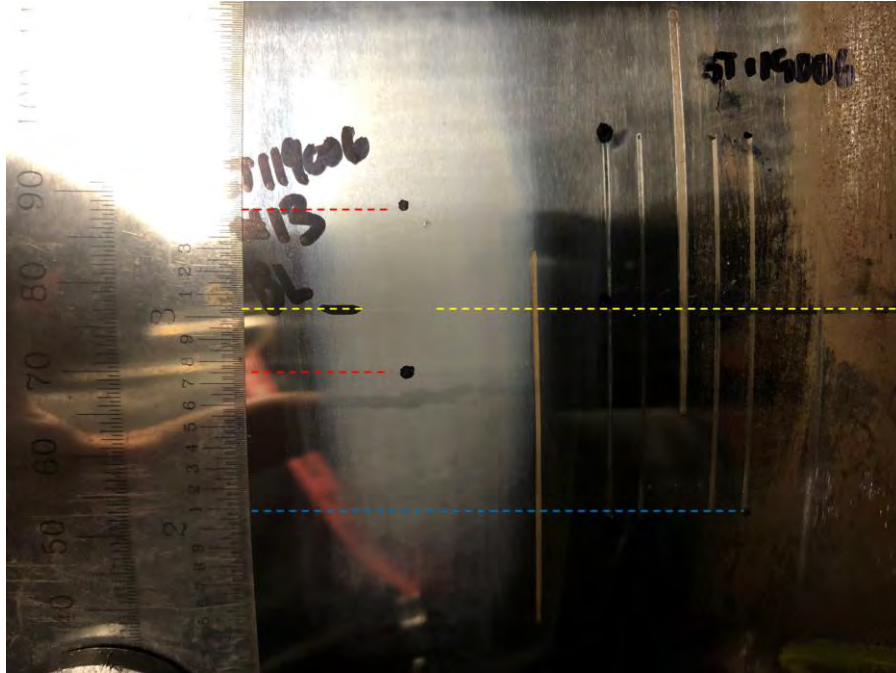


Figure 4: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 013. The bondline is located approximately 0.95 inches from the start of the HSD test.



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 $0.20 \text{ in} / 0.25 \text{ in} = 80\%$.

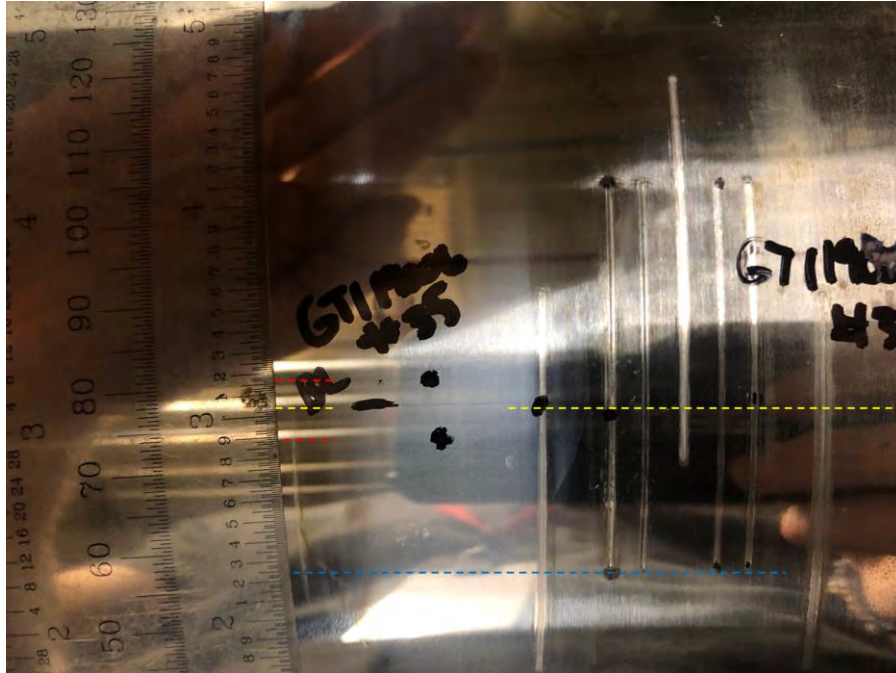


Figure 6: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 035. The bondline is located approximately 0.8 inches from the start of the HSD test.

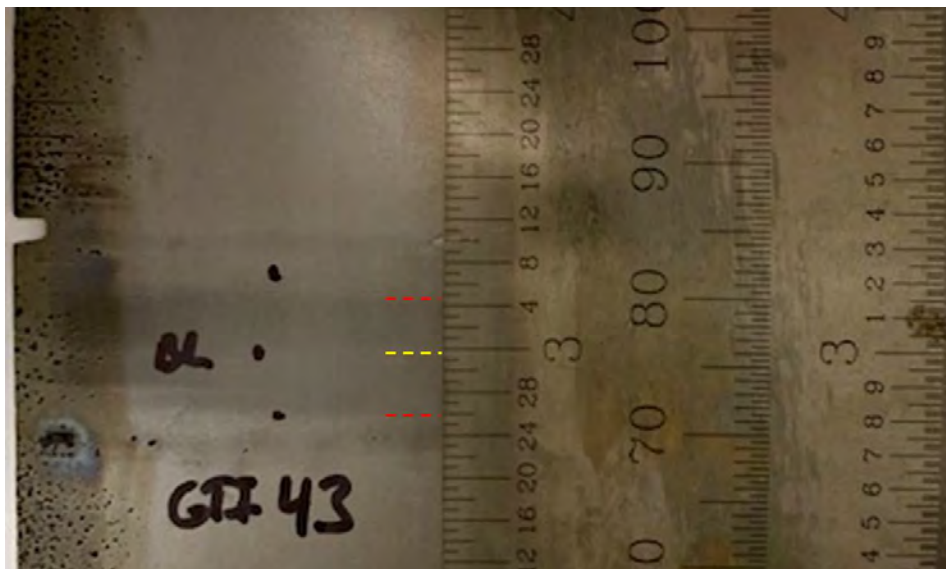


Figure 7: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 043. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width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



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.

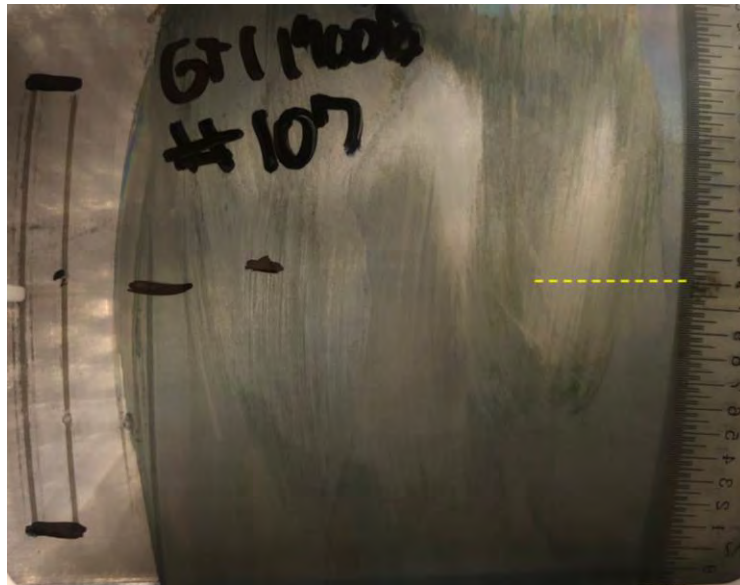


Figure 9: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 107. The bondline is shown by the dashed yellow line. There was no presence of a HAZ due to the quality of the seam etch and image.



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.

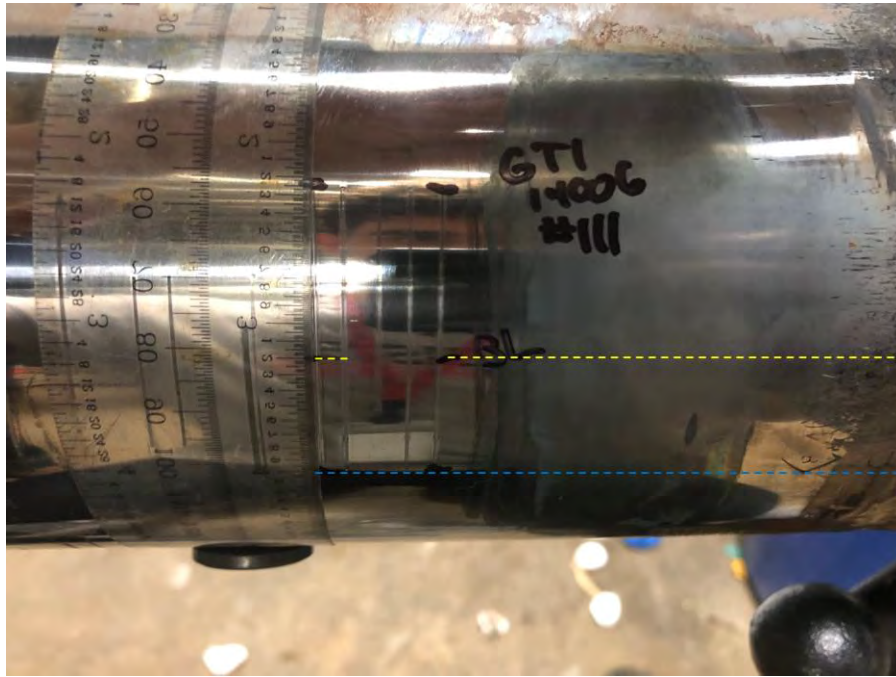


Figure 12: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 111. The bondline is located approximately 0.8 inches from the start of the HSD test.

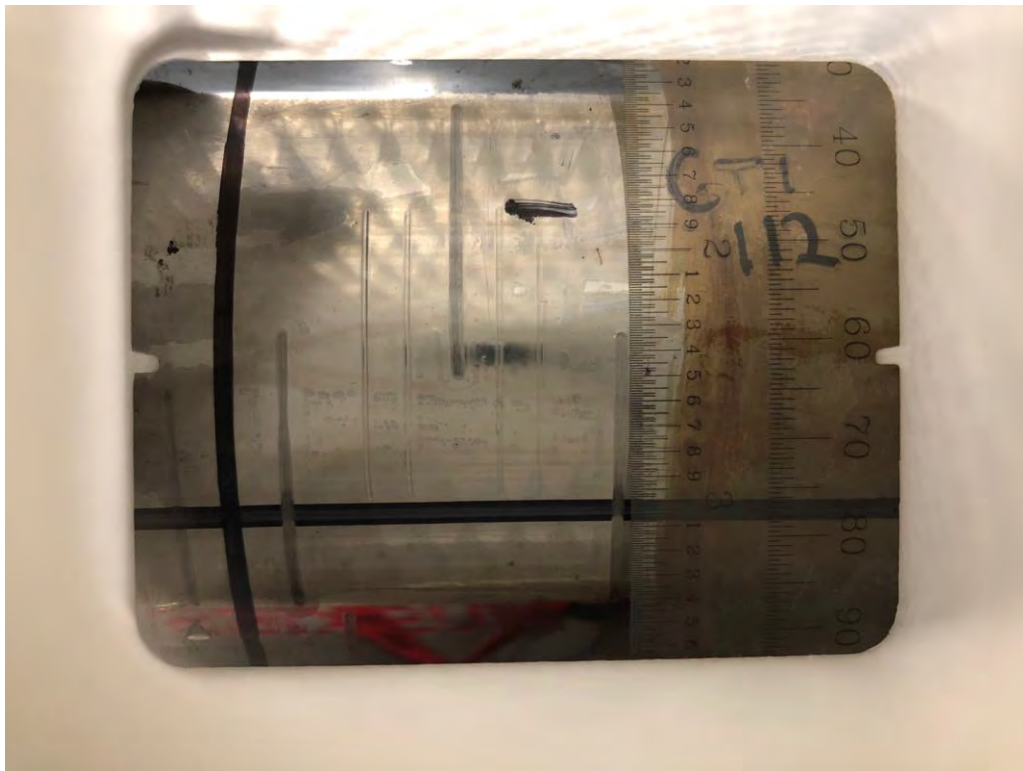


Figure 13: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 112. A HAZ and the bondline were not made visible by the macro-etch procedure. MMT technicians centered the weld test on the seam via visual inspection of the pipe ID and UT thickness mapping.

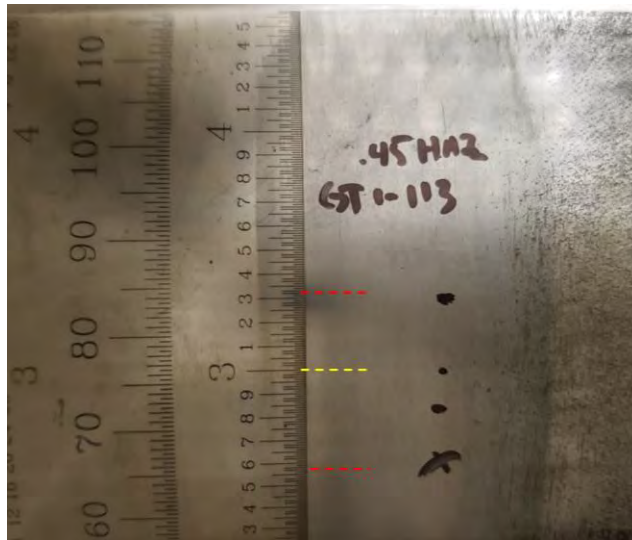


Figure 14: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 113. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

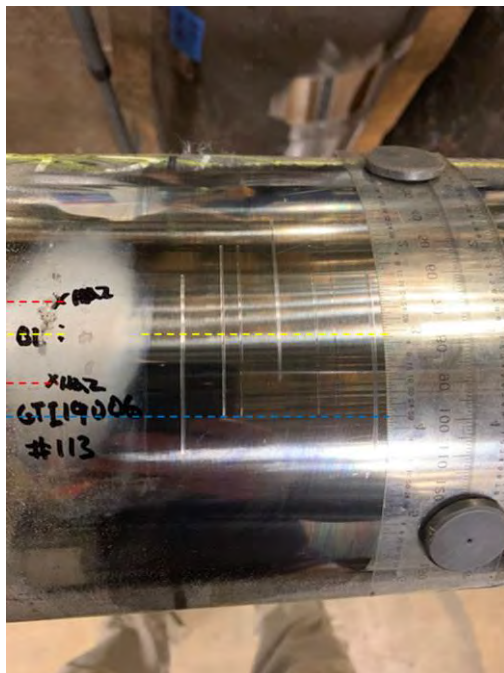


Figure 15: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 113. The bondline is located approximately 0.8 inches from the start of the HSD test.

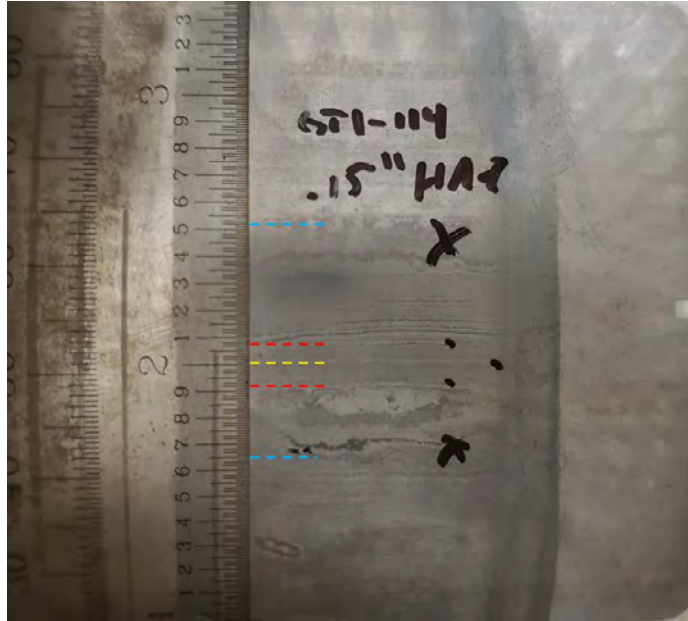


Figure 16: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 114. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width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



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.

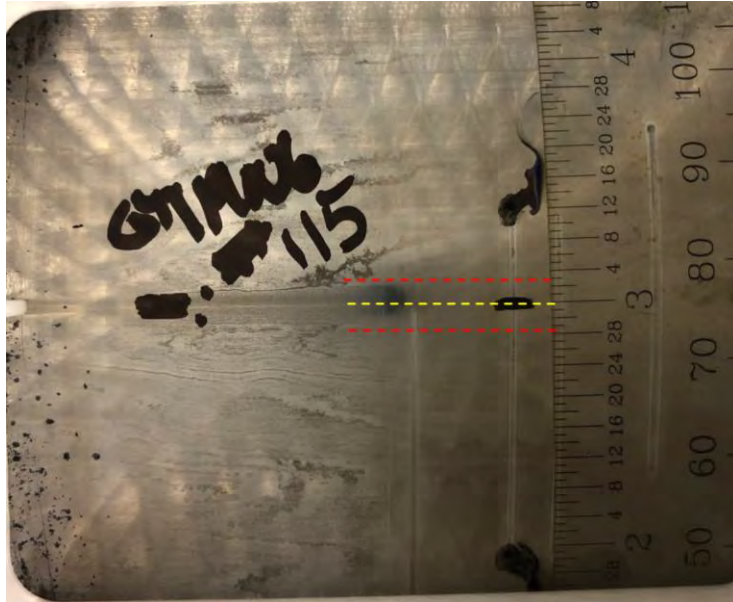


Figure 18: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 115. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

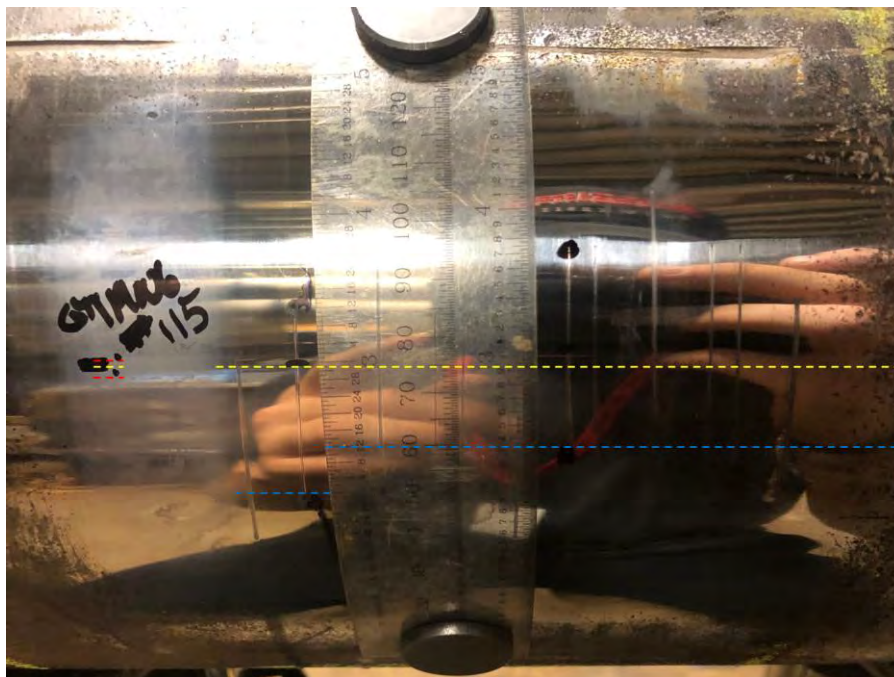


Figure 19: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 115. The bondline is located approximately 0.6 inches from the start of the HSD test.

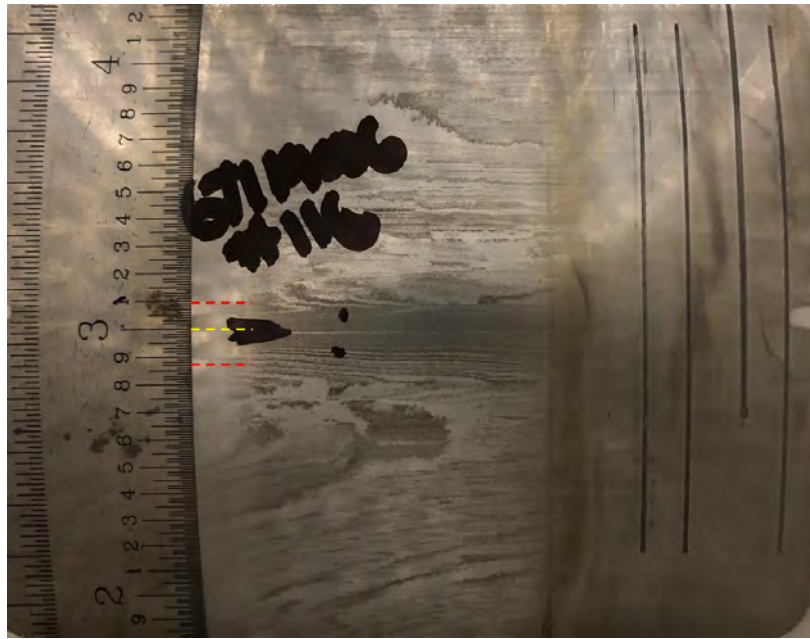


Figure 20: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 116. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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



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.

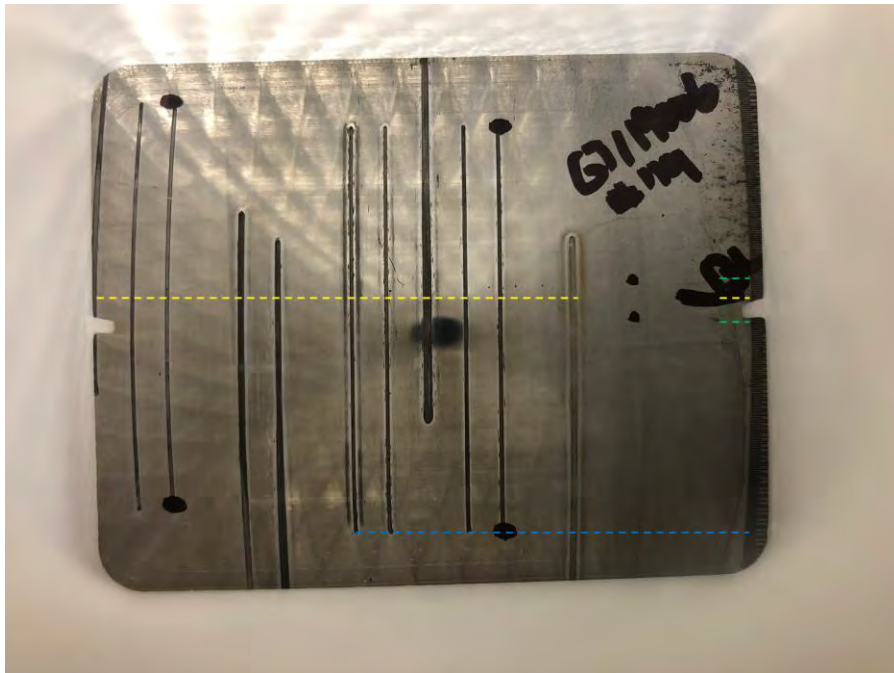


Figure 23: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 119. The bondline is located approximately 1.1 inches from the start of the HSD test.



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 $0.90 \text{ in} / 0.25 \text{ in} = 357\%$.



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.

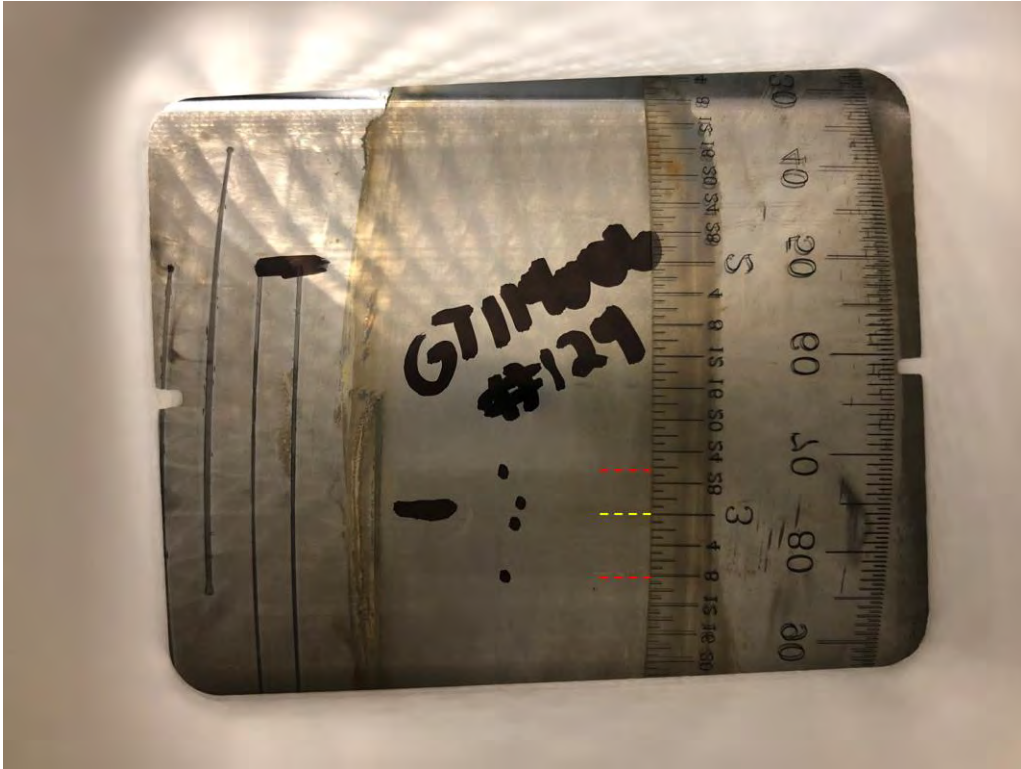


Figure 26: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 124. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

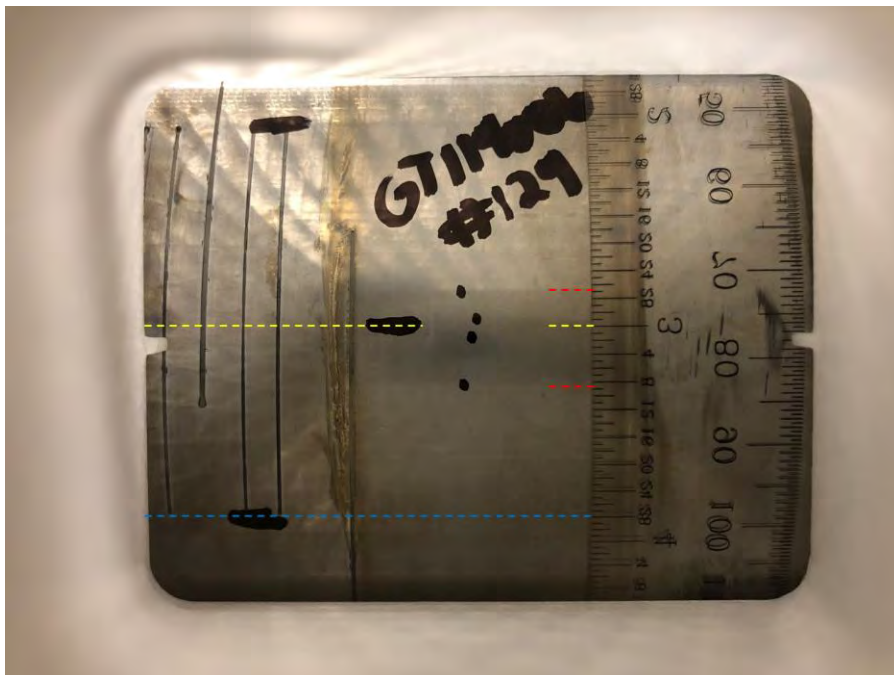


Figure 27: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 124. The bondline is located approximately 0.875 inches from the start of the HSD test.



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.

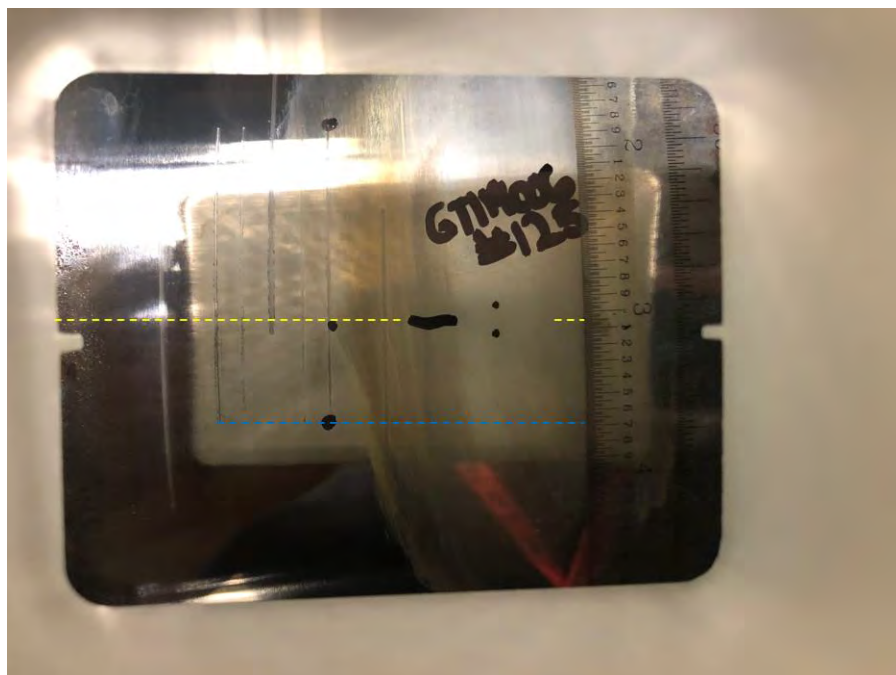


Figure 29: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 125. The bondline is located approximately 0.6 inches from the start of the HSD test.



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 $0.25 \text{ in} / 0.20 \text{ in} = 125\%$.



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.

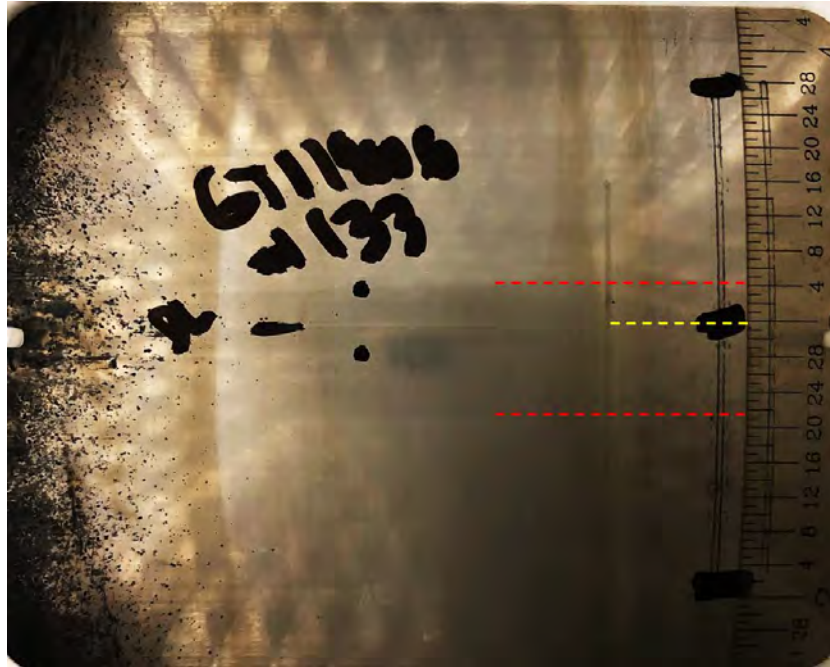


Figure 32: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 133. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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



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 $0.1875 \text{ in} / 0.26 \text{ in} = 72\%$. The bondline is located approximately 0.6875 inches from the start of the HSD test.

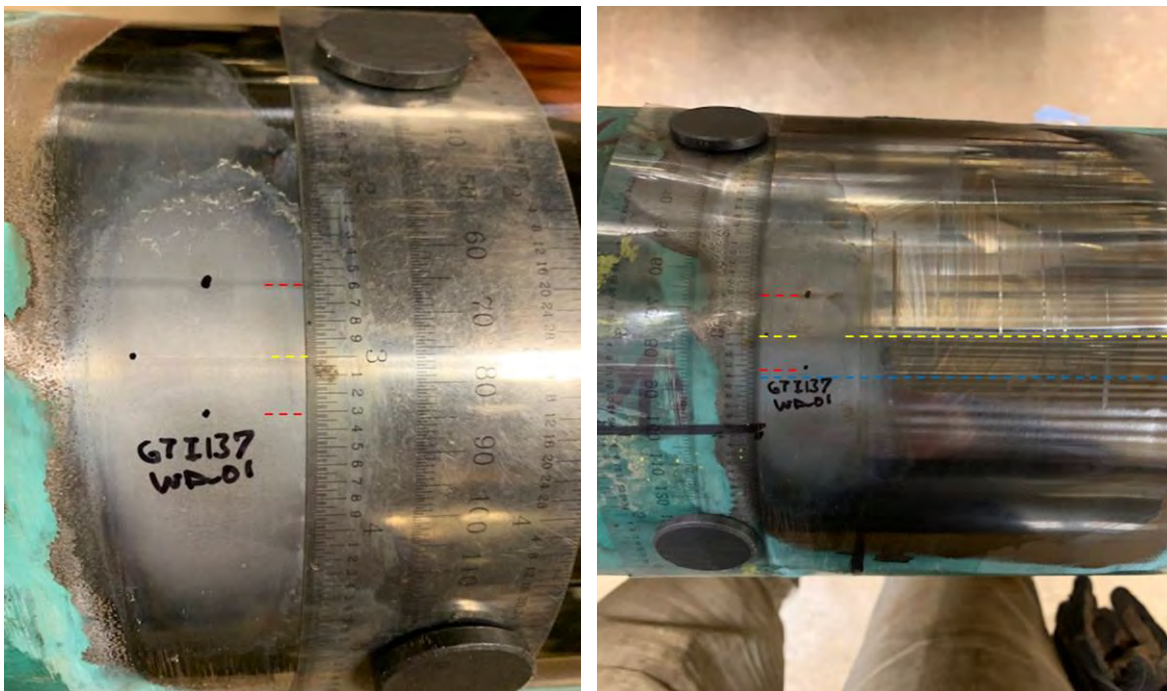


Figure 35: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 137. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

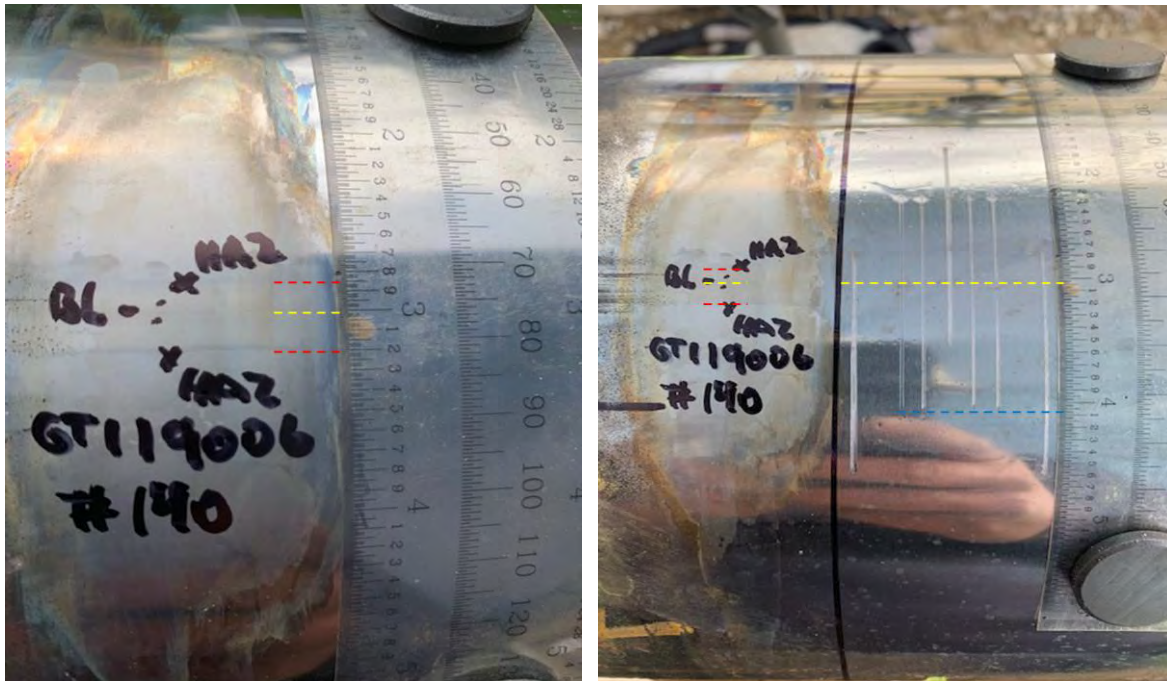


Figure 36: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 140. The boundaries of the etched HAZ, which blends into the contact lines, are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width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

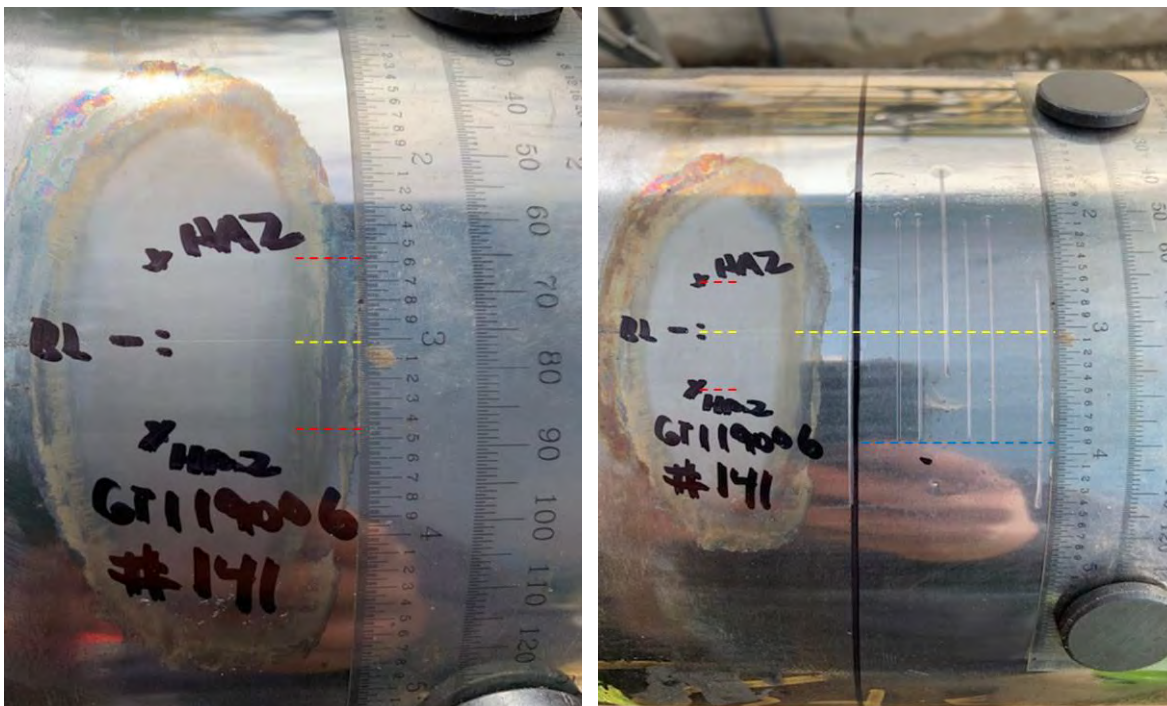


Figure 37: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 141. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

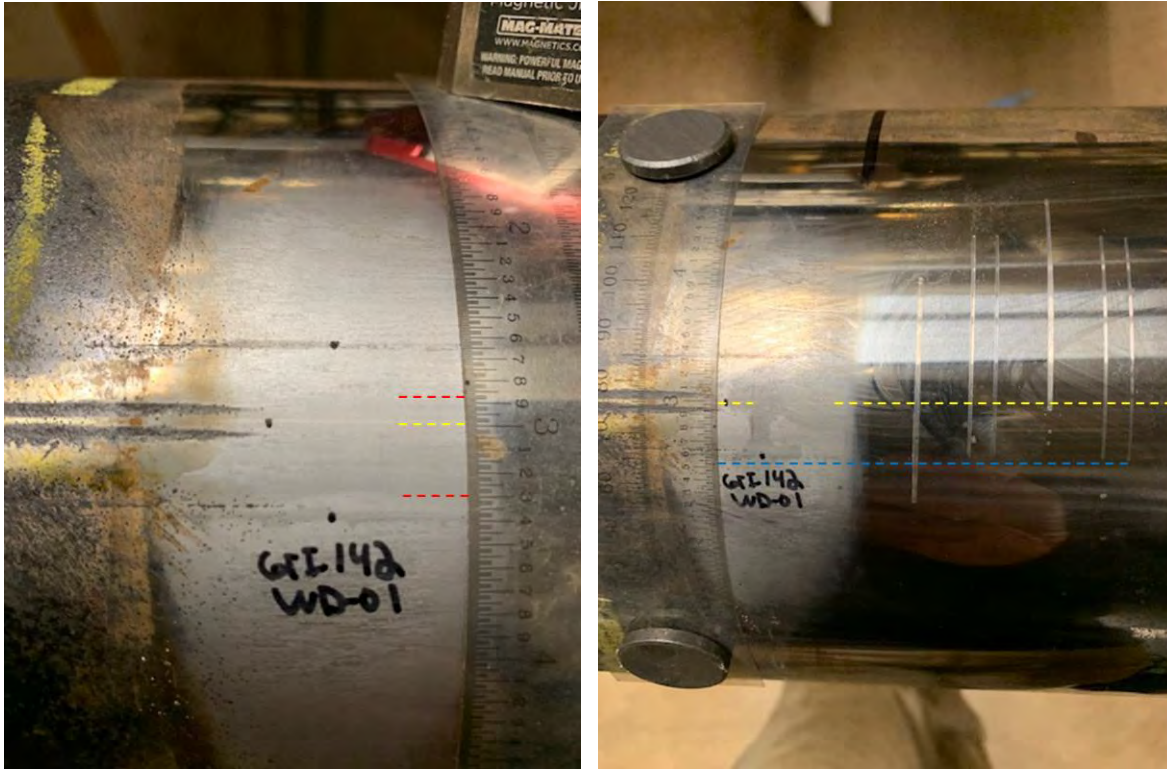


Figure 38: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 142. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

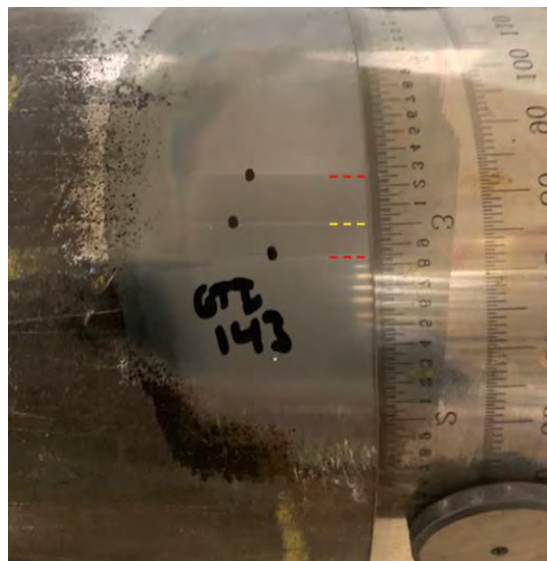


Figure 39: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 143. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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

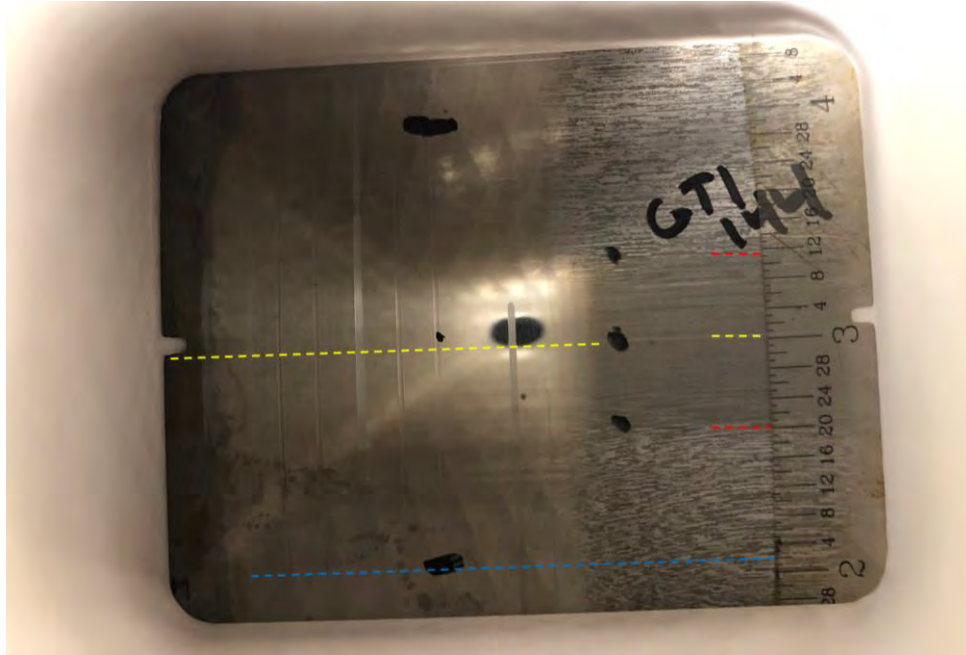


Figure 40: Examination of etched heat-affected-zone (HAZ) on the outer surface of the ERW seam for Sample 144. The boundaries of the etched HAZ are shown in dashed red lines and the bondline is shown by the dashed yellow line. The normalized HAZ width (measured width / wall thickness) is approximately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



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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 Plaines, 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						
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	2.80002	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	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)

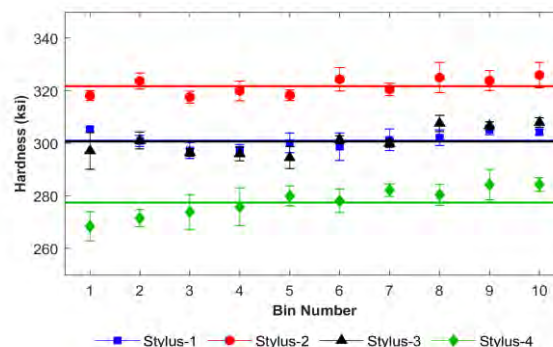
Base Metal Chemical Composition (wt. %)

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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	305	318	298	268
2	302	325	301	272
3	298	318	297	274
4	298	320	297	276
5	300	318	296	280
6	300	325	300	278
7	300	320	300	282
8	305	325	308	281
9	305	325	306	284
10	305	325	308	284

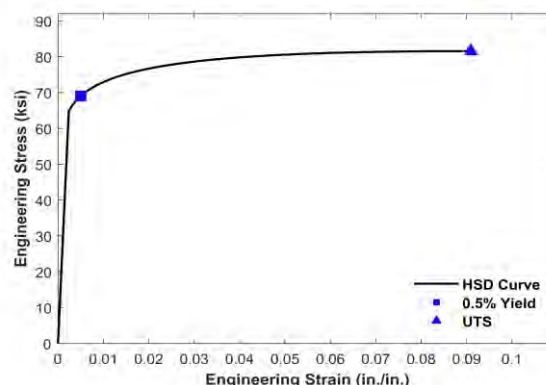


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10. The x-axis ranges from 0 to 0.1 in increments of 0.01. A black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off. A blue square marks the 0.5% Yield point at approximately (0.005, 70). A blue triangle marks the UTS (Ultimate Tensile Strength) point at approximately (0.09, 82).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~70
UTS	~0.09	~82



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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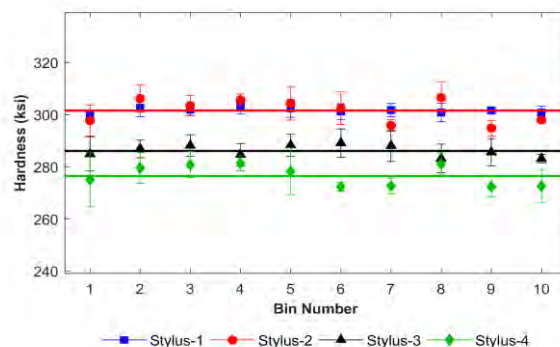
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522130524	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

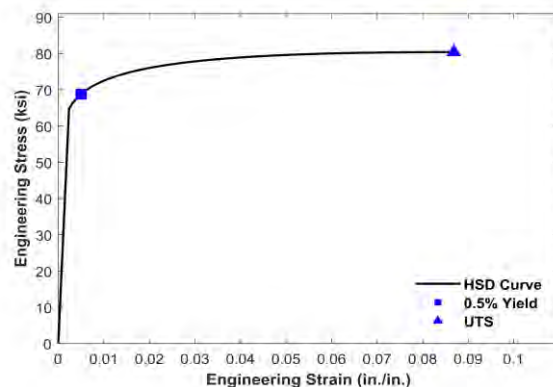
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	301.6	2.60
Stylus-2	301.6	5.98
Stylus-3	286.1	4.83
Stylus-4	276.5	6.64
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.10	1.06	0.010
S	Cr	Nb
0.008	0.03	0.02
Cu	Al	Mo
0.07	0.03	0.01
Ni	Si	Ti
0.02	0.21	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	68.8	69.2
UTS (ksi)	80.4	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).		
Engineering Stress (ksi) vs Engineering Strain (in./in.)		
HSD Curve, 0.5% Yield, UTS		



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.	190523125325	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

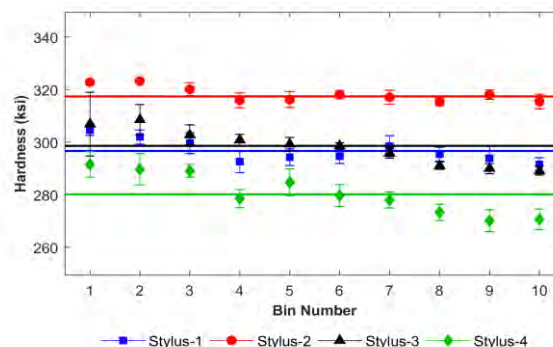
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size 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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	305	323	307	291
2	303	324	310	287
3	301	319	304	289
4	293	316	302	279
5	298	317	300	284
6	297	318	299	280
7	296	317	297	279
8	295	315	292	274
9	293	318	291	270
10	292	316	289	271

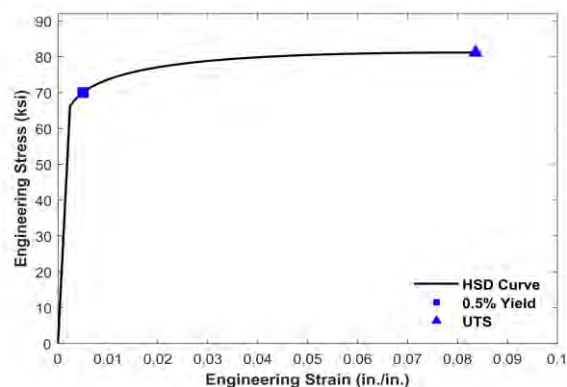


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 ksi in increments of 10, and the x-axis ranges from 0 to 0.1 in./in. in increments of 0.01. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.005 strain and 70 ksi. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.085 strain and 81 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	70.0
UTS	~0.085	81.2



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.	190531120821	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

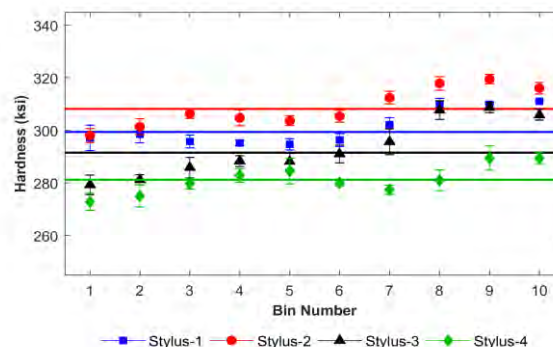
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	298.5	300.0	280.0	275.0
2	299.0	302.0	282.0	276.0
3	298.0	306.0	285.0	280.0
4	297.0	305.0	288.0	283.0
5	297.5	304.0	287.0	281.0
6	298.5	305.0	290.0	280.0
7	300.0	313.0	295.0	278.0
8	310.0	318.0	308.0	282.0
9	310.0	320.0	309.0	288.0
10	311.0	316.0	307.0	288.0



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

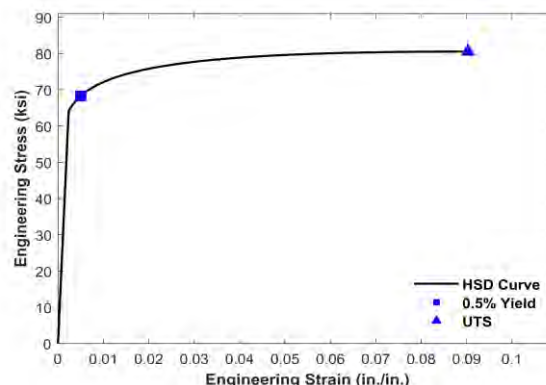
Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend:

- HSD Curve
- 0.5% Yield
- UTS

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	68.3
UTS	0.088	80.5
End of Curve (UTS)	0.09	82.1



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.	190529142708	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	2.80002	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	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

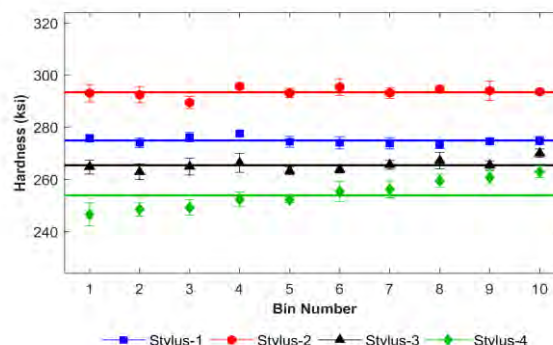
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	275.0	293.5	265.4	253.9
2	274.9	293.5	265.4	253.9
3	274.9	293.5	265.4	253.9
4	274.9	293.5	265.4	253.9
5	274.9	293.5	265.4	253.9
6	274.9	293.5	265.4	253.9
7	274.9	293.5	265.4	253.9
8	274.9	293.5	265.4	253.9
9	274.9	293.5	265.4	253.9
10	274.9	293.5	265.4	253.9

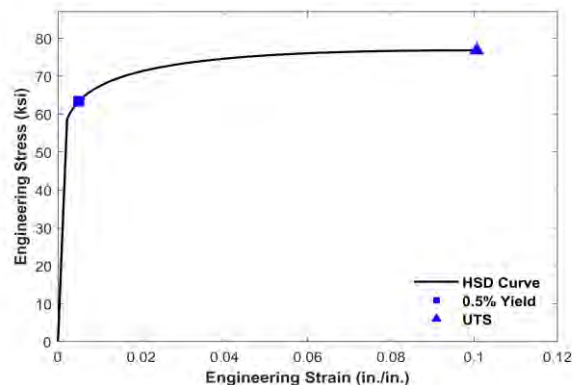


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>63.4</u>	<u>61.9</u>	<u>63.1</u>	<u>64.9</u>
UTS (ksi)	<u>76.8</u>	<u>76.5</u>	<u>76.9</u>	<u>77.0</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.12 in./in. The HSD Curve (black line) starts at the origin, rises steeply to the 0.5% Yield point (blue square at approx 0.005 strain, 63.4 ksi), and then continues to rise more gradually, reaching the UTS point (blue triangle at 0.1 strain, 76.8 ksi). The legend indicates the HSD Curve, 0.5% Yield, and UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	63.4
UTS	0.1	76.8



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.	190521100831	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

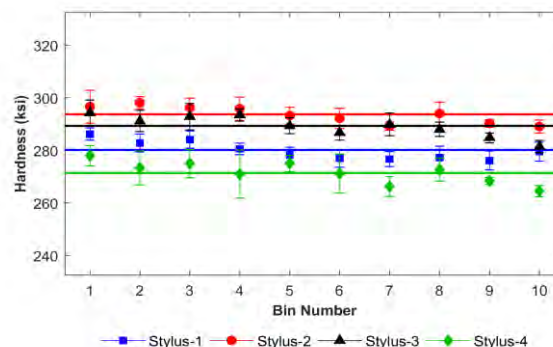
Base Metal Chemical Composition (wt. %)

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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	285	295	292	278
2	284	298	293	273
3	285	296	292	275
4	282	294	293	271
5	288	292	290	272
6	277	292	288	272
7	277	290	290	268
8	276	294	289	272
9	275	290	286	270
10	280	288	282	266

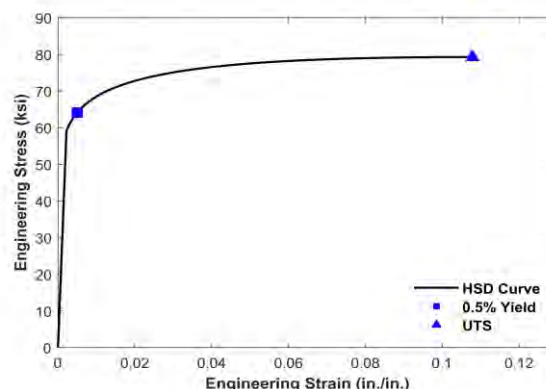


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 90) versus Engineering Strain (in./in.) on the x-axis (0 to 0.12). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 64.1). The UTS point is marked with a blue triangle at approximately (0.105, 79.2).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	64.1
UTS	0.105	79.2



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.	190524105236	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

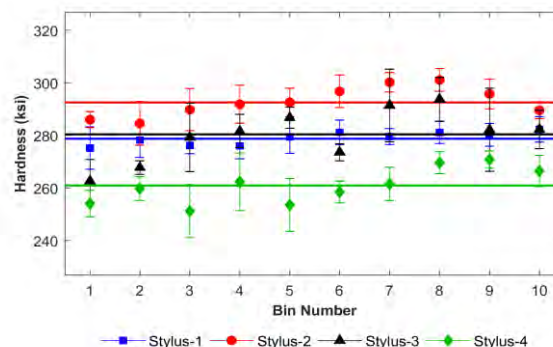
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	9.3

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	275	285	262	252
2	272	284	270	260
3	278	290	278	251
4	277	292	282	262
5	280	293	287	254
6	281	297	275	259
7	280	300	290	261
8	281	301	295	270
9	281	296	282	271
10	280	289	283	265

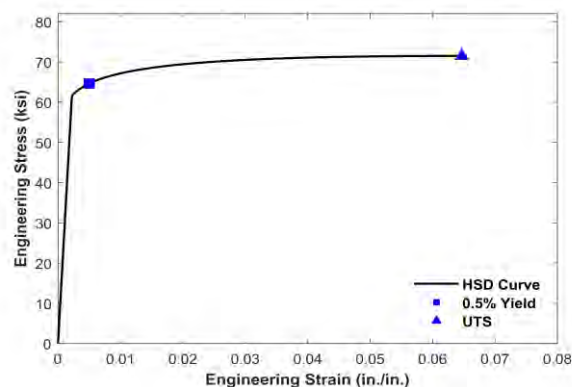


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.08 in./in. in increments of 0.01. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.005 strain and 64.6 ksi. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.065 strain and 71.5 ksi. The curve shows a rapid initial increase in stress, followed by a plateau and then a gradual increase towards the UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	64.6
UTS	~0.065	71.5



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.	190524112228	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

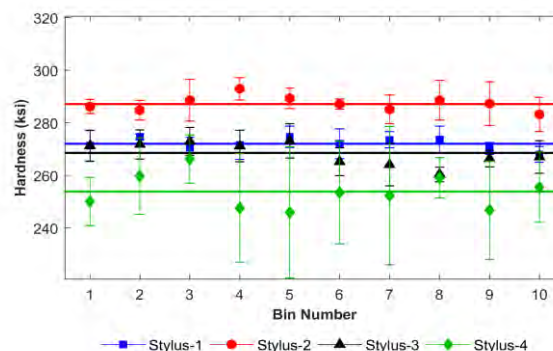
Base Metal Chemical Composition (wt. %)

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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	272.1	287.1	268.6	253.7
2	272.1	287.1	268.6	253.7
3	272.1	287.1	268.6	253.7
4	272.1	287.1	268.6	253.7
5	272.1	287.1	268.6	253.7
6	272.1	287.1	268.6	253.7
7	272.1	287.1	268.6	253.7
8	272.1	287.1	268.6	253.7
9	272.1	287.1	268.6	253.7
10	272.1	287.1	268.6	253.7

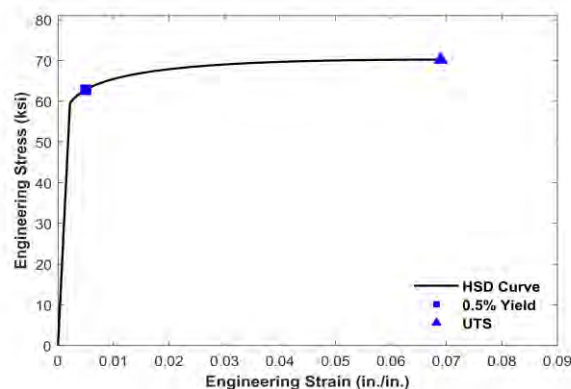


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.09 in./in. in increments of 0.01. A black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off. A blue square marks the 0.5% Yield point at approximately 0.005 strain and 62.8 ksi. A blue triangle marks the UTS (Ultimate Tensile Strength) point at approximately 0.068 strain and 70.2 ksi. The legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	62.8
UTS	~0.068	70.2



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.	190524120114	REV --
Test Location	Gas Technology Institute			Test Date	5/24/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

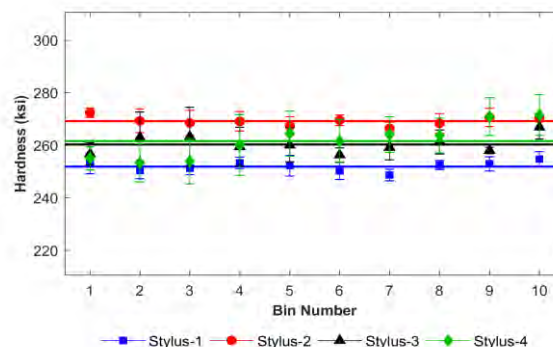
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	9.3

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	252.0	272.0	255.0	255.0
2	251.0	270.0	255.0	252.0
3	252.0	270.0	255.0	253.0
4	252.0	270.0	255.0	253.0
5	252.0	270.0	255.0	253.0
6	251.0	270.0	255.0	253.0
7	250.0	268.0	255.0	253.0
8	252.0	268.0	255.0	253.0
9	253.0	268.0	255.0	253.0
10	253.0	268.0	255.0	253.0

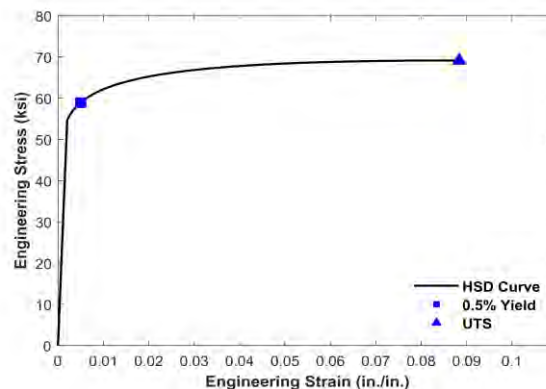


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.1 in increments of 0.01. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point at approximately (0.005, 58.9), and then gradually levels off, reaching a peak at approximately (0.085, 69.1) before slightly declining. A blue square marker is placed on the curve at the yield point. A blue triangle marker is placed at the peak of the curve, representing the UTS. A yellow shaded region highlights the area around the UTS point, extending from approximately 0.08 to 0.09 on the x-axis and 68 to 70 on the y-axis. The legend in the bottom right corner identifies the HSD Curve, 0.5% Yield, and UTS.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	58.9
UTS	0.085	69.1



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.	190530114931	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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. %)

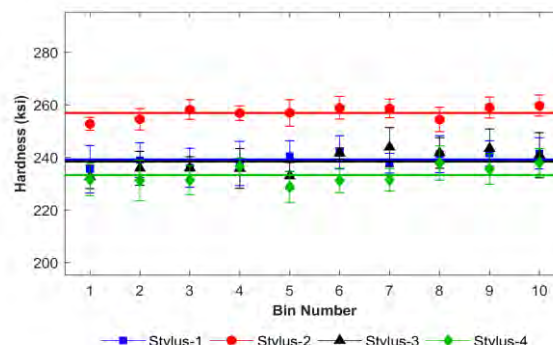
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.63	0.010	< 0.005	0.02	0.01	0.01	0.05	< 0.01	< 0.01	0.25	0.01	< 0.01	< 0.0005

Grain Size mli (μm)

9.5

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	237	253	235	232
2	238	255	237	233
3	240	258	236	232
4	239	257	238	233
5	240	257	237	232
6	240	260	242	233
7	240	259	243	233
8	240	255	241	233
9	241	259	243	233
10	240	260	241	233

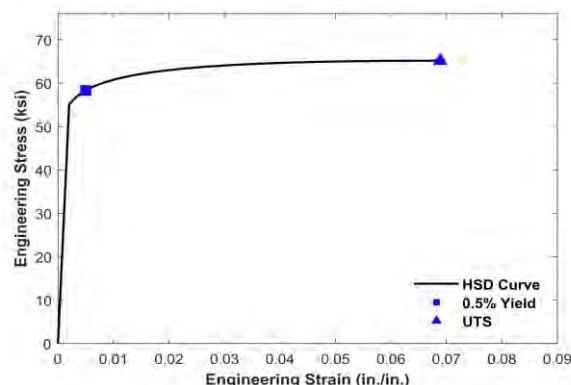


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.09 in./in. The HSD Curve (black line) shows a rapid increase in stress up to the 0.5% Yield point, followed by a gradual increase to the UTS point. The 0.5% Yield point is marked with a blue square at approximately 0.005 strain and 58.3 ksi. The UTS point is marked with a blue triangle at approximately 0.068 strain and 65.2 ksi. A yellow circle is also present at approximately 0.07 strain and 65.5 ksi.

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	58.3	0.005
UTS	65.2	0.068



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.	190523180341	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

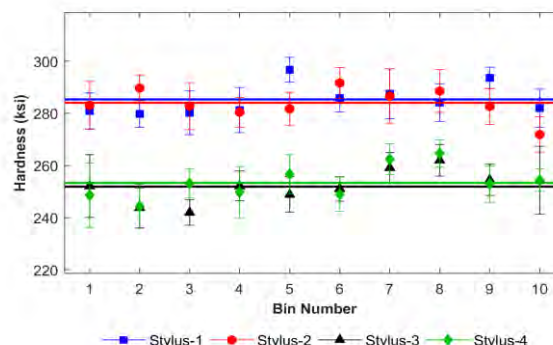
Base Metal Chemical Composition (wt. %)

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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	282	281	248	248
2	279	291	244	244
3	281	281	242	254
4	280	280	250	251
5	296	281	248	257
6	285	291	249	250
7	285	285	260	263
8	284	285	264	264
9	293	282	254	254
10	281	272	254	254

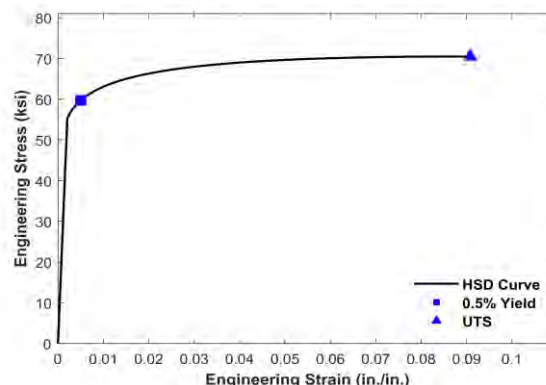


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.1 in./in. in increments of 0.01. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually increases to a peak before leveling off. A blue square marker indicates the 0.5% Yield point at approximately 60 ksi and 0.005 in./in. strain. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 71 ksi and 0.09 in./in. strain.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~60
UTS	~0.09	~71



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.	190523185038	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

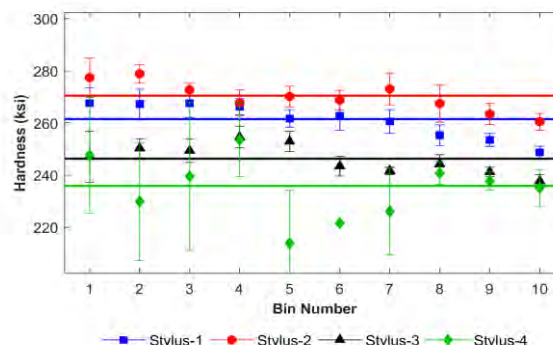
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

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



Base Metal Chemical Composition (wt. %)

Grain Size

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
0.07	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.

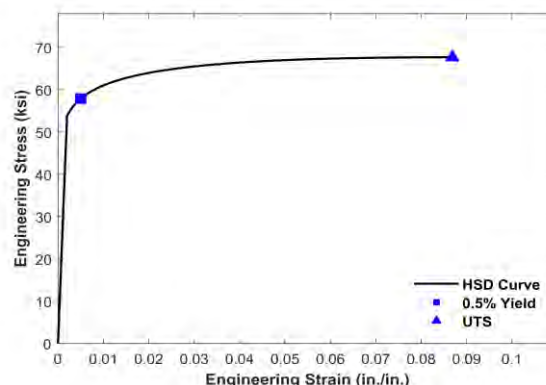
Results

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

Tensile Properties	Overall	Subset-1	Subset-2	Subset-3
0.5% EUL Yield (ksi)	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

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.	190424173445	REV --
Test Location	Gas Technology Institute			Test Date	4/24/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	248	228	208	178
2	245	224	212	180
3	244	226	210	175
4	248	226	208	175
5	242	220	210	182
6	240	220	208	175
7	238	224	209	176
8	236	222	214	179
9	232	222	215	182
10	226	220	212	184

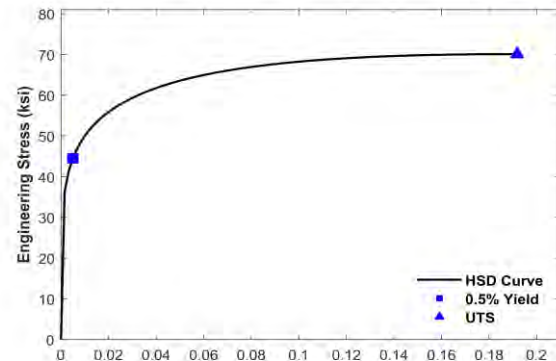
Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	6.5

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

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				



The graph displays the HSD Curve, which plots Engineering Stress (ksi) on the y-axis (0 to 80) against Engineering Strain (in./in.) on the x-axis (0 to 0.2). The curve starts at the origin, rises steeply, and then levels off, reaching a plateau around 70 ksi. Two specific points are highlighted: the 0.5% Yield point (blue square) at approximately (0.01, 44.5) and the UTS point (blue triangle) at approximately (0.19, 70.1).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	44.5
UTS	0.19	70.1

Comments

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

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Approved:

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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 Plaines, 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						
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	257.2	4.26	51
Stylus-2	270.9	6.70	52
Stylus-3	243.7	4.00	52
Stylus-4	236.0	7.36	53

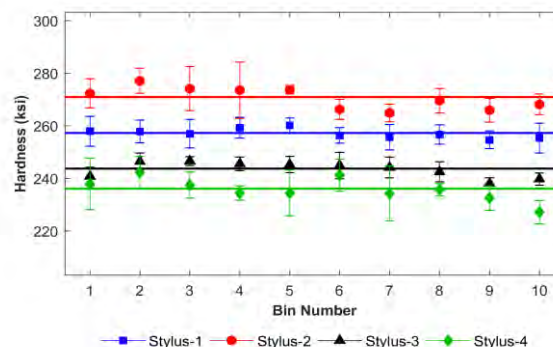
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

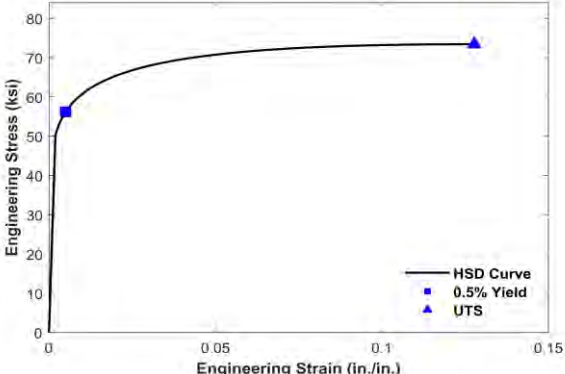
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
0.23	0.92	0.011	0.025	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	0.06	< 0.01	< 0.01	< 0.0005	10.2

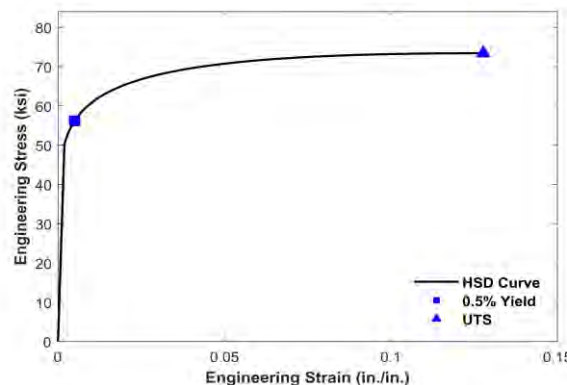
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	258	273	240	239
2	258	278	246	242
3	257	274	246	237
4	259	274	245	234
5	261	274	246	234
6	257	266	244	241
7	257	263	245	234
8	257	270	240	236
9	255	267	238	232
10	256	269	240	228



Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc																		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>																
0.5% EUL Yield (ksi)	56.2	56.7	56.5	55.9	 The stress-strain plot shows the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.15 in increments of 0.05. A solid black line represents the HSD Curve. A blue square marker at approximately (0.005, 56.2) indicates the 0.5% Yield point. A blue triangle marker at approximately (0.13, 73.4) indicates the UTS (Ultimate Tensile Strength). <table border="1"><thead><tr><th>Property</th><th>Overall</th><th>Subset-1</th><th>Subset-2</th><th>Subset-3</th></tr></thead><tbody><tr><td>0.5% EUL Yield (ksi)</td><td>56.2</td><td>56.7</td><td>56.5</td><td>55.9</td></tr><tr><td>UTS (ksi)</td><td>73.4</td><td>72.9</td><td>73.8</td><td>73.1</td></tr></tbody></table>	Property	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
Property	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																
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

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Massachusetts Materials Technologies LLC

167 Prospect Street, Unit 4

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617-502-5636

HSD@byMMT.com

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 Plaines, 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						
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	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

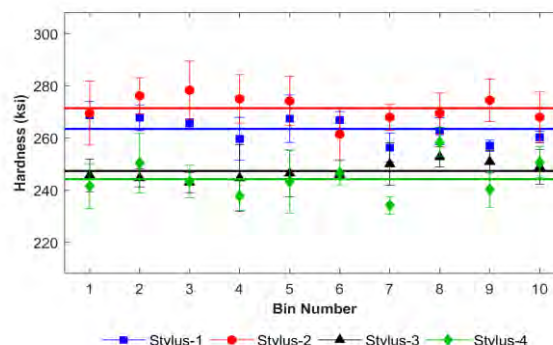
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	263.5	6.38	36
Stylus-2	271.5	9.41	40
Stylus-3	247.4	6.82	37
Stylus-4	244.2	9.20	37

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
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	10.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	268	270	246	242
2	267	276	244	250
3	266	278	244	242
4	260	275	246	237
5	268	274	246	246
6	266	262	246	246
7	257	267	251	234
8	263	270	254	258
9	257	274	252	240
10	260	267	250	250

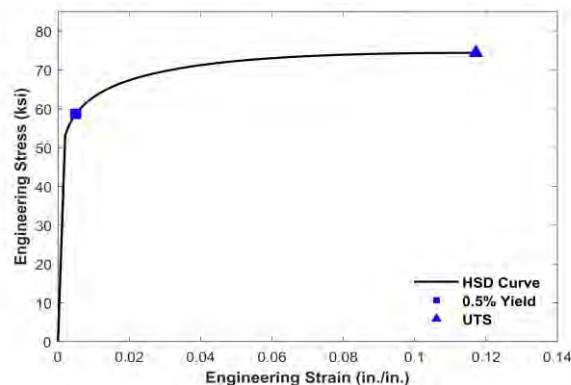


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.14 in increments of 0.02. A black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marks the 0.5% Yield point at approximately (0.005, 58.6). A blue triangle marks the UTS point at approximately (0.115, 74.4).

Point Type	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	58.6
UTS	~0.115	74.4



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.	190522190453	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

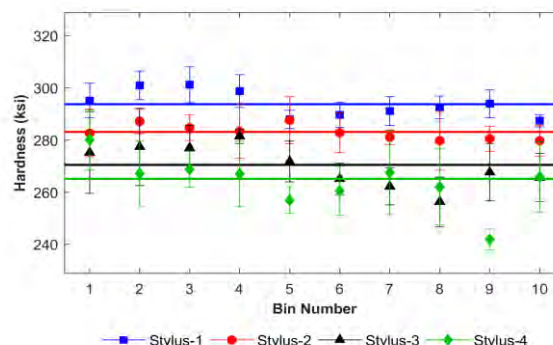
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	8.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	295	285	275	280
2	300	288	278	268
3	300	285	278	268
4	298	282	282	268
5	288	288	272	258
6	290	285	265	262
7	292	280	262	262
8	292	280	268	260
9	292	280	268	242
10	288	280	270	265

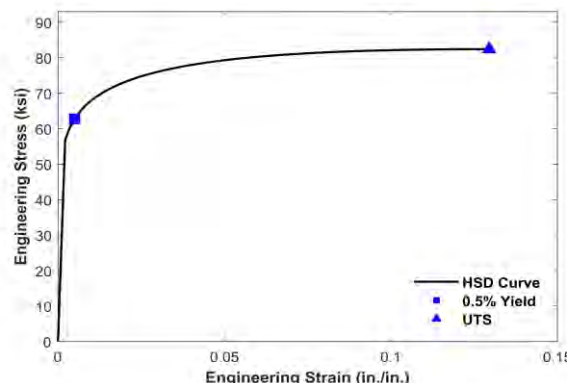


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 ksi in increments of 10. The x-axis ranges from 0 to 0.15 in./in. in increments of 0.05. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 63 ksi and 0.005 strain. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 83 ksi and 0.13 strain.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~63
UTS	~0.13	~83



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.	190529175402	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	317.0	328.9	312.3	290.9
2	317.0	328.9	312.3	290.9
3	317.0	328.9	312.3	290.9
4	317.0	328.9	312.3	290.9
5	317.0	328.9	312.3	290.9
6	317.0	328.9	312.3	290.9
7	317.0	328.9	312.3	290.9
8	317.0	328.9	312.3	290.9
9	317.0	328.9	312.3	290.9
10	317.0	328.9	312.3	290.9

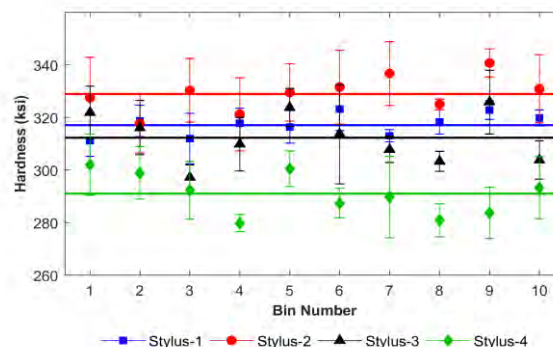
Base Metal Chemical Composition (wt. %)

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.

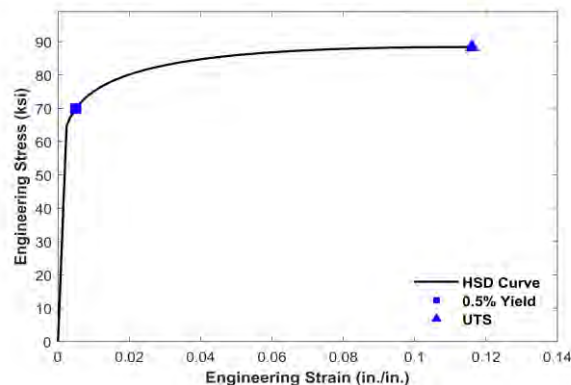


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>69.9</u>	<u>65.1</u>	<u>70.0</u>	<u>68.2</u>
UTS (ksi)	<u>88.4</u>	<u>88.3</u>	<u>88.5</u>	<u>88.6</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10. The x-axis ranges from 0 to 0.14 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point marked with a blue square at approximately (0.008, 70), and then continues to rise more gradually, reaching a peak marked with a blue triangle at approximately (0.115, 88.5). A legend in the bottom right corner identifies the HSD Curve, the 0.5% Yield point, and the UTS point.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.008	~70
UTS	~0.115	~88.5



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.	190522152433	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

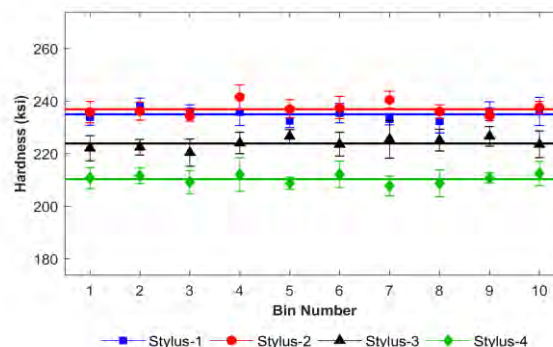
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	9.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	234.5	236.5	223.5	210.5
2	235.5	237.0	223.0	211.0
3	234.0	235.5	222.0	209.5
4	236.0	241.0	224.0	212.0
5	232.0	238.0	226.0	209.0
6	234.5	237.5	223.5	211.5
7	233.0	240.5	224.5	208.5
8	232.5	236.5	223.5	210.5
9	234.0	235.0	224.0	211.0
10	235.0	238.0	223.0	211.5

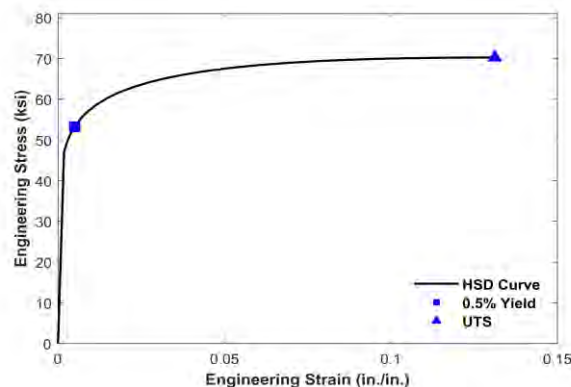


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.15 in./in. The HSD Curve is a black line showing the material's response. The 0.5% Yield point is marked with a blue square at approximately 0.005 strain and 53.2 ksi. The UTS point is marked with a blue triangle at approximately 0.13 strain and 70.2 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	53.2
UTS	~0.13	70.2



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.	190522184237	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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

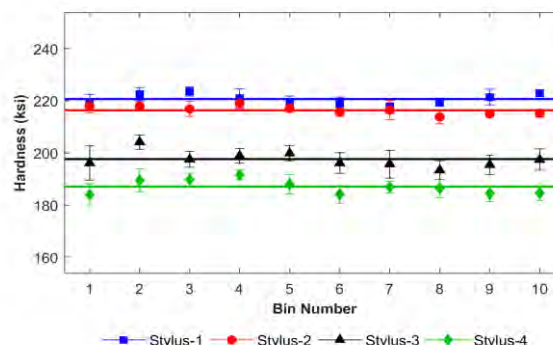
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	220.7	2.98	47
Stylus-2	216.4	2.55	47
Stylus-3	197.6	4.65	50
Stylus-4	187.1	3.83	46

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
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	9.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	221	217	198	188
2	222	218	205	190
3	223	217	199	191
4	221	219	200	192
5	220	218	201	189
6	220	217	198	185
7	219	218	198	188
8	220	215	196	187
9	222	217	198	186
10	223	217	199	186

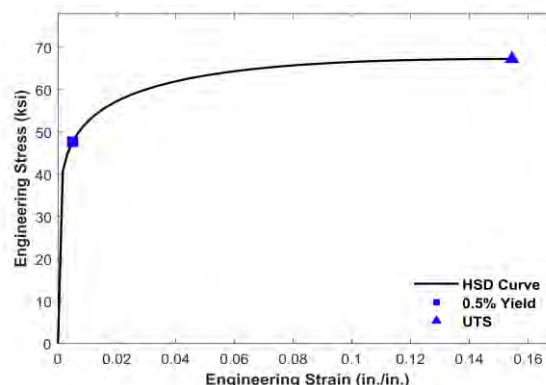


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.16 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.008, 47.7). The UTS point is marked with a blue triangle at approximately (0.15, 67.3).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.008	47.7
UTS	0.15	67.3



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.	190529190333	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

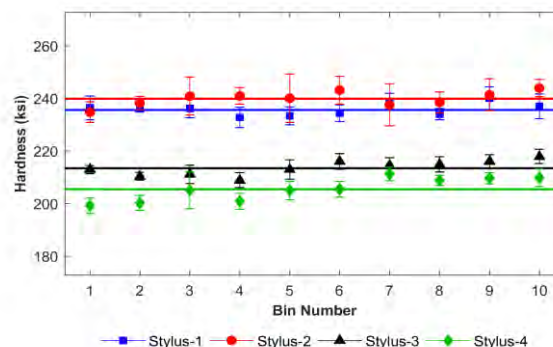
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	9.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	235.6	239.8	213.4	205.3
2	235.6	239.8	213.4	205.3
3	235.6	239.8	213.4	205.3
4	235.6	239.8	213.4	205.3
5	235.6	239.8	213.4	205.3
6	235.6	239.8	213.4	205.3
7	235.6	239.8	213.4	205.3
8	235.6	239.8	213.4	205.3
9	235.6	239.8	213.4	205.3
10	235.6	239.8	213.4	205.3

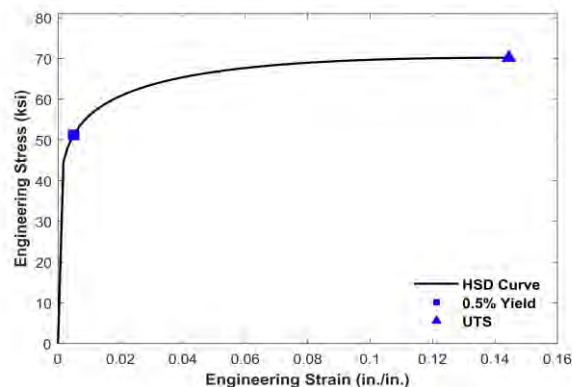


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.16 in./in. The HSD Curve (black line) shows a rapid increase in stress up to the 0.5% Yield point, followed by a gradual increase to the UTS point. The 0.5% Yield point is marked with a blue square at approximately 0.005 in./in. strain and 51.2 ksi. The UTS point is marked with a blue triangle at approximately 0.14 in./in. strain and 70.2 ksi.

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	51.2	0.005
UTS	70.2	0.14



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.	190523111909	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

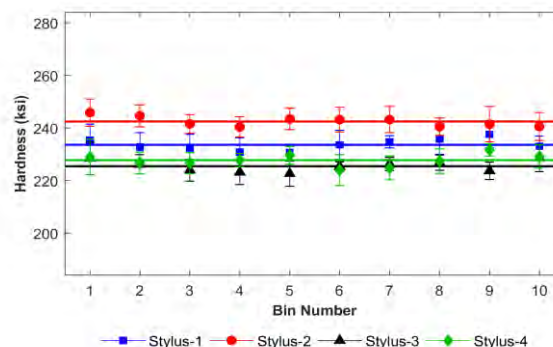
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	12.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	234.0	243.0	225.0	228.0
2	233.5	242.5	224.5	227.5
3	233.0	242.0	224.0	227.0
4	232.5	241.5	223.5	226.5
5	232.0	241.0	223.0	226.0
6	231.5	240.5	222.5	225.5
7	231.0	240.0	222.0	225.0
8	230.5	239.5	221.5	224.5
9	230.0	239.0	221.0	224.0
10	229.5	238.5	220.5	223.5

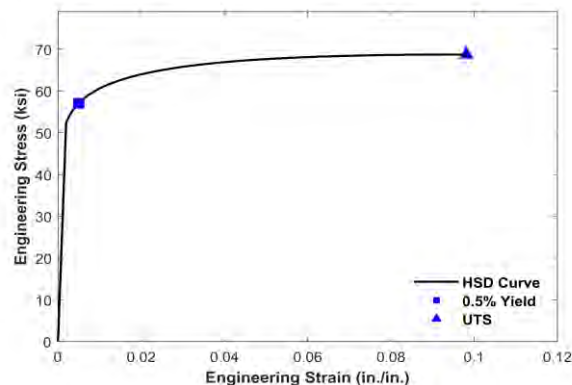


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.12 in./in. The HSD Curve is a black line showing a rapid initial increase in stress followed by a plateau. The 0.5% Yield point is marked with a blue square at approximately 0.005 strain and 57 ksi. The UTS (Ultimate Tensile Strength) is marked with a blue triangle at 0.1 strain and 68.8 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	57.1
UTS	0.1	68.8



Comments

Prepared:		Parth Patel	Approved:		Steven Palkovic, PhD
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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 Plaines, 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						
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	2.80002	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	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

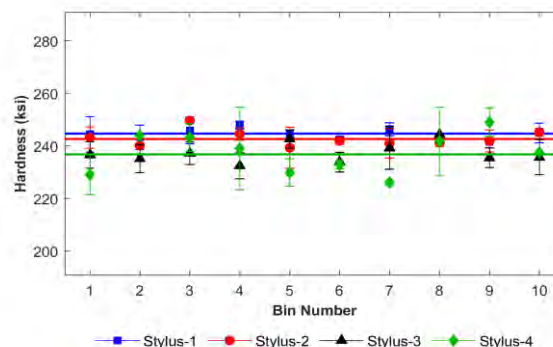
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	12.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245.0	244.0	238.0	230.0
2	244.0	243.0	237.0	245.0
3	245.0	250.0	238.0	238.0
4	246.0	244.0	232.0	240.0
5	245.0	240.0	235.0	230.0
6	244.0	242.0	238.0	233.0
7	246.0	241.0	240.0	227.0
8	244.0	243.0	244.0	242.0
9	244.0	241.0	236.0	250.0
10	245.0	245.0	237.0	238.0

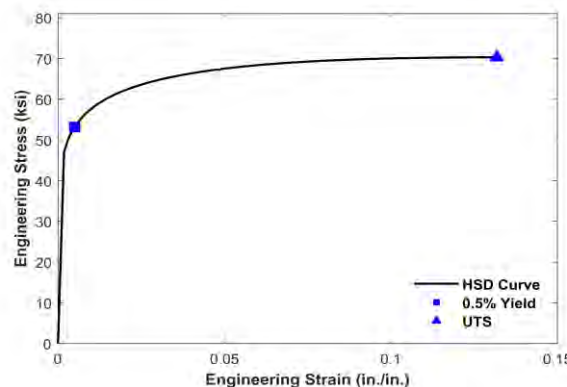


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.15 in./in. The HSD Curve (black line) shows a rapid increase in stress with strain, reaching a plateau around 70 ksi. The 0.5% Yield point (blue square) is located at approximately 0.005 in./in. strain and 53.2 ksi stress. The UTS point (blue triangle) is located at approximately 0.13 in./in. strain and 70.3 ksi stress.

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	53.2	~0.005
UTS	70.3	~0.13



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.	190425124042	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	278	268	252	230
2	278	268	248	230
3	278	265	250	232
4	275	260	252	235
5	268	265	250	232
6	268	265	248	232
7	272	265	250	232
8	275	265	252	232
9	268	265	250	232
10	272	275	248	232

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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, plotting Engineering Stress (ksi) on the y-axis (0 to 80) against Engineering Strain (in./in.) on the x-axis (0 to 0.14). The curve starts at the origin, rises steeply to a yield point marked with a blue square at approximately 60 ksi and 0.01 in./in. strain, then continues to rise more gradually to a peak marked with a blue triangle at approximately 77 ksi and 0.12 in./in. strain. The legend identifies the HSD Curve as a solid black line, the 0.5% Yield point as a blue square, and the UTS as a blue triangle.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~60
UTS	~0.12	~77

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.	190522165406	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
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	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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

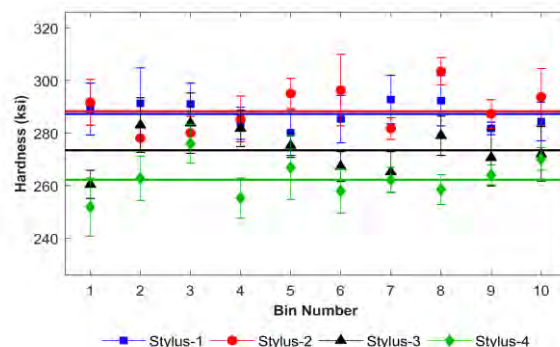
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.85	0.008	0.017	0.03	< 0.01	0.08	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

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.

Grain Size

mli (μm)
14.2



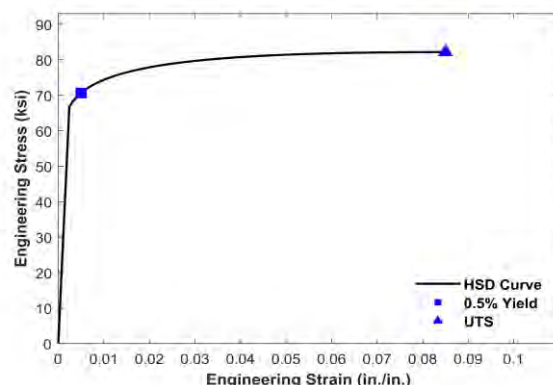
Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10. The x-axis ranges from 0 to 0.1 in increments of 0.01. A black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marks the 0.5% Yield point at approximately (0.005, 70.6). A blue triangle marks the UTS (Ultimate Tensile Strength) point at approximately (0.085, 82.2). A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.



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.	190529162259	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	268	280	267	262
2	268	280	267	262
3	268	280	267	262
4	268	280	267	262
5	268	280	267	262
6	268	280	267	262
7	268	280	267	262
8	268	280	267	262
9	268	280	267	262
10	268	280	267	262

Base Metal Chemical Composition (wt. %)

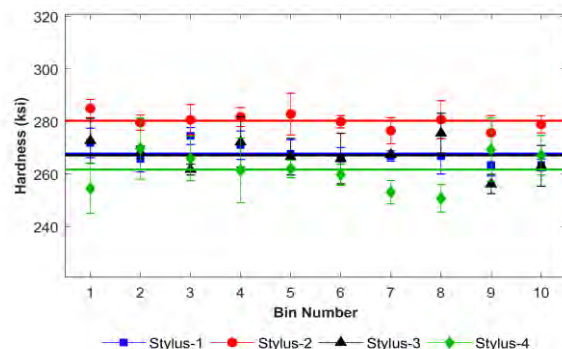
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.85	0.008	0.017	0.03	< 0.01	0.08	< 0.01	< 0.01	0.01	0.04	< 0.01	< 0.01	< 0.0005

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

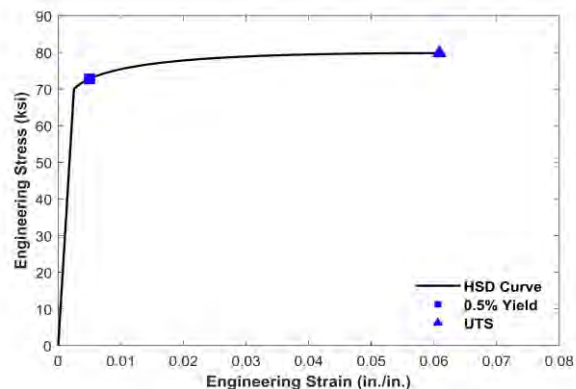
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	72.8	73.1	72.6	72.5
UTS (ksi)	79.8	80.1	79.9	79.3

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).

The graph displays the HSD Curve (black line) and the 0.5% Yield point (blue square) and UTS point (blue triangle). The x-axis represents Engineering Strain (in./in.) from 0 to 0.08, and the y-axis represents Engineering Stress (ksi) from 0 to 90. The curve shows a rapid increase in stress up to the yield point, followed by a gradual increase to the ultimate tensile strength (UTS).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~72.5
UTS	~0.06	~80.1



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.	190522183130	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

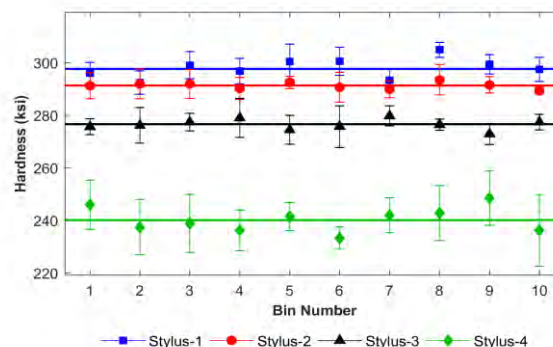
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.24	1.15	0.010	0.023	0.04	< 0.01	0.01	0.05	0.02	0.03	0.18	< 0.01	0.06	< 0.0005

Grain Size mli (μm)

10.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	297.6	291.3	276.6	246
2	297.6	291.3	276.6	238
3	297.6	291.3	276.6	240
4	297.6	291.3	276.6	236
5	297.6	291.3	276.6	242
6	297.6	291.3	276.6	233
7	297.6	291.3	276.6	242
8	297.6	291.3	276.6	243
9	297.6	291.3	276.6	249
10	297.6	291.3	276.6	237

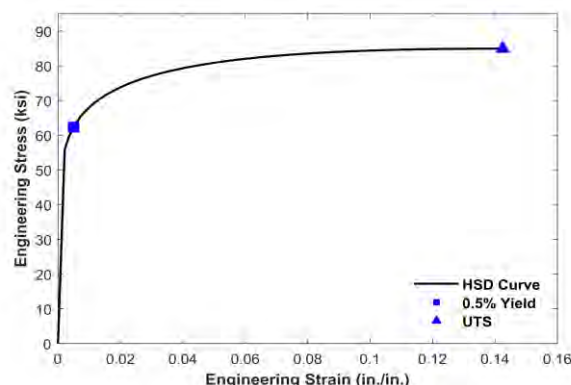


Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10. The x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.01, 62.3), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.14, 84.9), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	62.3
UTS	0.14	84.9



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

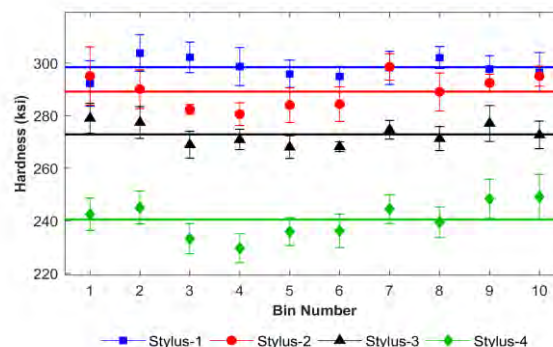
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425120349	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	12:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	26-Q1	Pipe 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						
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	1.33	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 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

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
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

mli (μm)
10.7

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

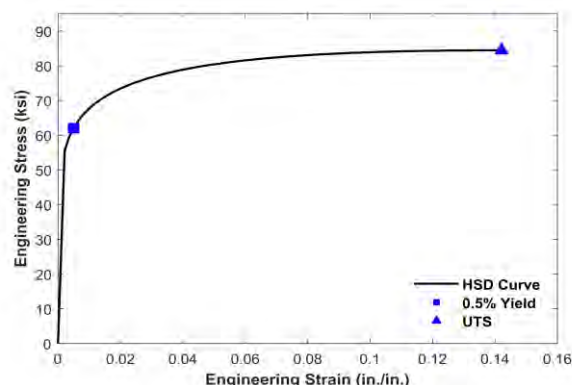
Results

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

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.	190522155253	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	320	308	288	278
2	315	308	295	250
3	320	308	285	265
4	318	308	298	265
5	315	305	288	262
6	322	308	292	268
7	315	308	290	260
8	322	308	292	272
9	320	308	290	285
10	315	305	298	262

Base Metal Chemical Composition (wt. %)

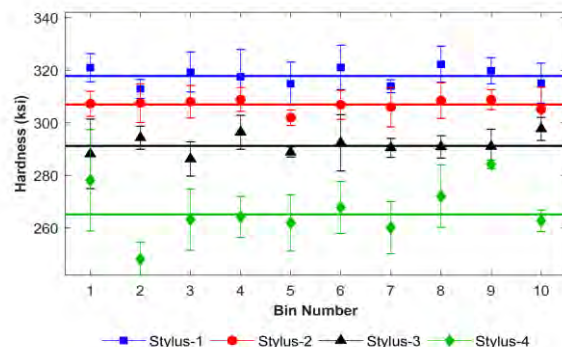
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	1.32	0.010	0.032	0.06	0.01	0.01	< 0.01	0.01	0.04	0.19	< 0.01	0.07	< 0.0005

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

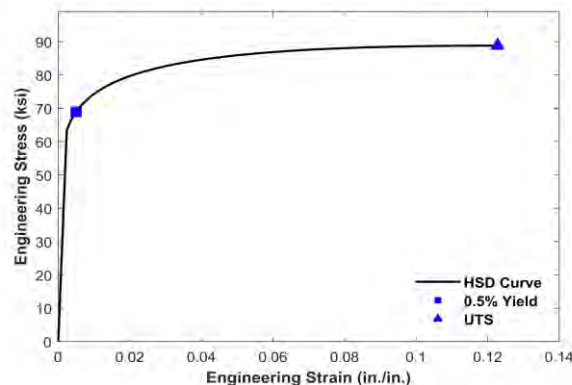
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	68.9	68.1	69.1	69.5
UTS (ksi)	88.8	88.9	88.7	88.8

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).

The plot displays Engineering Stress (ksi) on the y-axis (0 to 90) versus Engineering Strain (in./in.) on the x-axis (0 to 0.14). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 68.9). The UTS point is marked with a blue triangle at approximately (0.125, 88.8).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	68.9
UTS	0.125	88.8



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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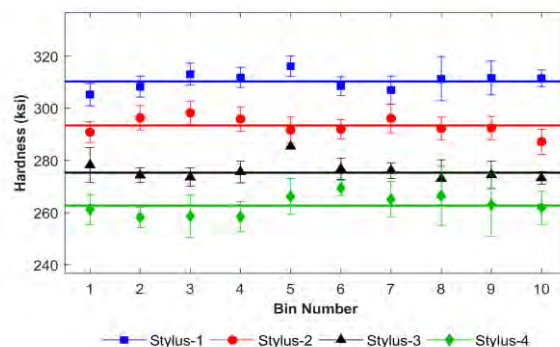
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522172140	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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)
Stylus-1	310.4	5.37
Stylus-2	293.3	5.26
Stylus-3	275.3	4.87
Stylus-4	262.7	7.69
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	1.32	0.010
S	Cr	Nb
0.032	0.06	0.01
Cu	Al	Mo
0.01	< 0.01	0.01
Ni	Si	Ti
0.04	0.19	< 0.01
V	B	
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

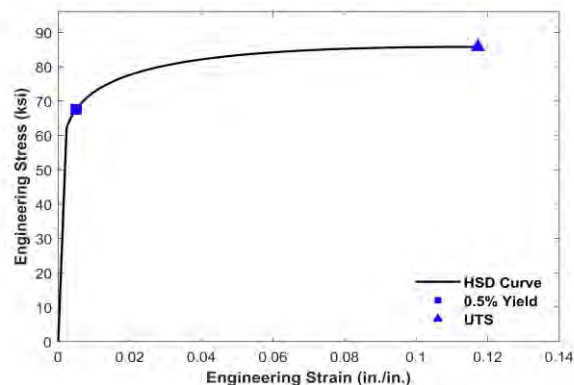
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	67.6	66.8	68.0	67.9
UTS (ksi)	85.7	85.8	86.1	85.4
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).				

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend:

- HSD Curve
- 0.5% Yield
- ▲ UTS



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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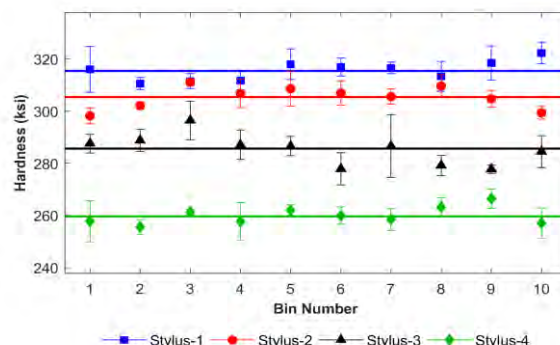
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

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 Plaines, 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						
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)
Stylus-1	315.4	5.49
Stylus-2	305.4	5.47
Stylus-3	285.7	7.66
Stylus-4	259.6	5.26
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	1.32	0.010
S	Cr	Nb
0.032	0.06	0.01
Cu	Al	Mo
0.01	< 0.01	0.01
Ni	Si	Ti
0.04	0.19	< 0.01
V	B	
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
0.5% EUL Yield (ksi)	65.2	65.3
	Subset-2	Subset-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 Plaines, 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						
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.	105-190520	
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	257.1	7.69	51
Stylus-2	253.2	7.88	52
Stylus-3	228.9	4.11	52
Stylus-4	193.9	5.48	57

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	258	262	230	195
2	255	260	232	195
3	258	260	228	192
4	255	250	228	192
5	255	250	228	192
6	255	250	230	192
7	250	250	232	200
8	255	250	228	195
9	255	248	230	195
10	255	248	228	190

Base Metal Chemical Composition (wt. %)

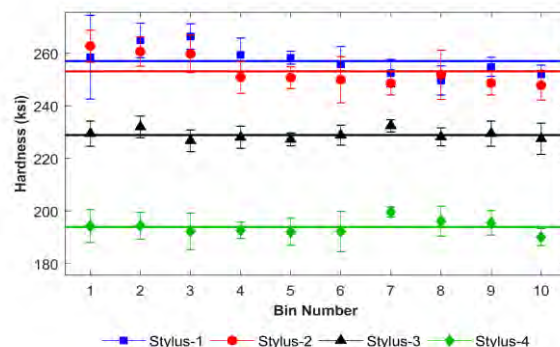
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.59	0.020	0.014	< 0.01	< 0.01	0.01	0.01	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

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

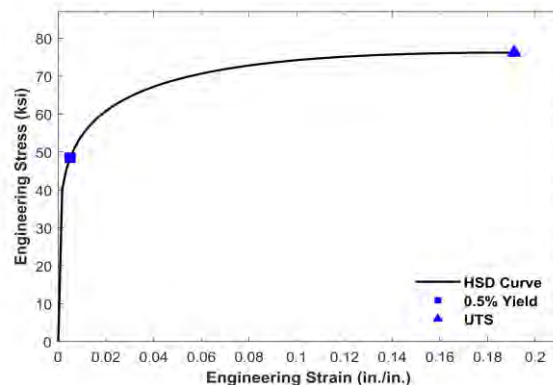
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	48.5	47.5	48.1	49.6
UTS (ksi)	76.2	78.9	75.9	74.6

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).

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.2). A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 48.5). A blue triangle marker indicates the UTS point at approximately (0.19, 76.2).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~48.5
UTS	~0.19	~76.2



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 Plaines, 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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245	230	218	195
2	245	228	216	198
3	245	226	217	195
4	244	227	215	193
5	241	226	216	198
6	240	225	212	195
7	240	226	212	195
8	242	230	216	190
9	245	229	211	188
10	239	229	212	191

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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.18). The curve starts at the origin, rises steeply to a yield point of approximately 49 ksi at 0.01 strain, then levels off to a UTS of approximately 70 ksi at 0.16 strain. Markers indicate the 0.5% Yield point (blue square) and the UTS (blue triangle).

Engineering Strain (in./in.)	Engineering Stress (ksi)	Feature
0.01	49.0	0.5% Yield
0.16	70.1	UTS

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 Plaines, 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						
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	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

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	0.53	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.

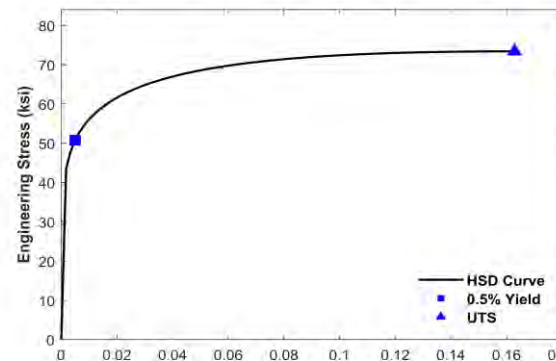
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve, which plots Engineering Stress (ksi) on the y-axis (0 to 80) against Engineering Strain (in./in.) on the x-axis (0 to 0.18). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately (0.01, 50.8), then continues to rise more gradually, reaching a peak marked by a blue triangle at approximately (0.16, 73.4). The legend identifies the black line as the HSD Curve, the blue square as the 0.5% Yield point, and the blue triangle as the UTS (Ultimate Tensile Strength) point.

Point Type	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	50.8
UTS	0.16	73.4

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 Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	240	235	212	192
2	245	238	215	188
3	238	235	206	186
4	240	232	205	182
5	238	235	206	182
6	238	235	207	185
7	238	235	205	186
8	240	232	207	184
9	242	235	206	183
10	240	235	209	185

Base Metal Chemical Composition (wt. %)

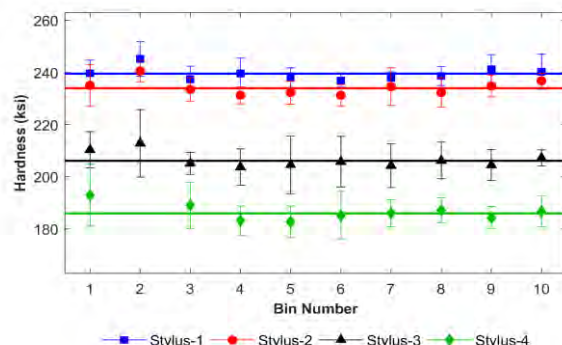
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.53	0.012	0.016	< 0.01	< 0.01	< 0.01	0.02	< 0.01	0.01	0.11	< 0.01	< 0.01	< 0.0005

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

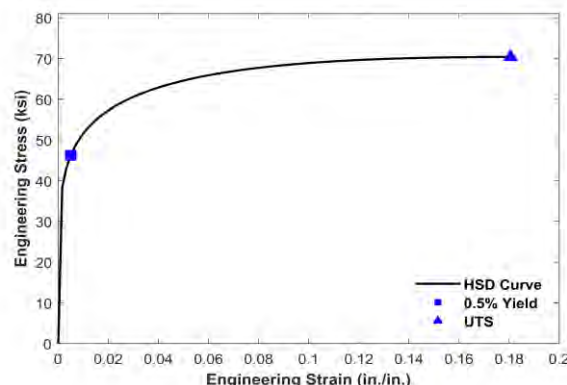
The overall results are calculated using the entire sample size.

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

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend: HSD Curve, 0.5% Yield, UTS



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 Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	266.5	273.7	263.8	259.6
2	266.5	273.7	263.8	259.6
3	266.5	273.7	263.8	259.6
4	266.5	273.7	263.8	259.6
5	266.5	273.7	263.8	259.6
6	266.5	273.7	263.8	259.6
7	266.5	273.7	263.8	259.6
8	266.5	273.7	263.8	259.6
9	266.5	273.7	263.8	259.6
10	266.5	273.7	263.8	259.6

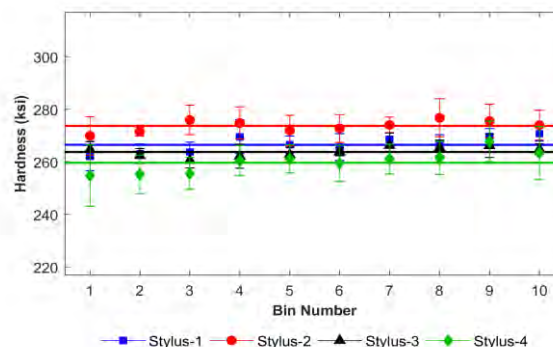
Base Metal Chemical Composition (wt. %)

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.

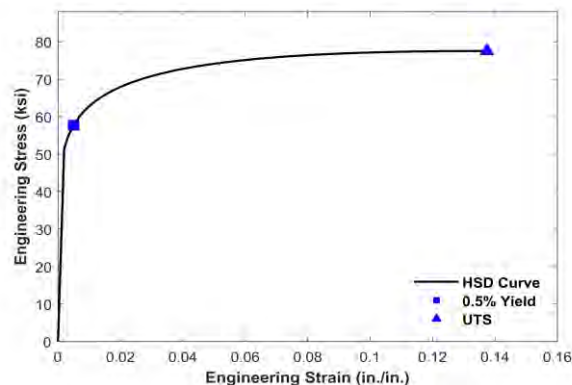


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.16 in./in. The HSD Curve is a black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.005, 58). The UTS point is marked with a blue triangle at approximately (0.135, 78).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~58
UTS	~0.135	~78



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 Plaines, 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						
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	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

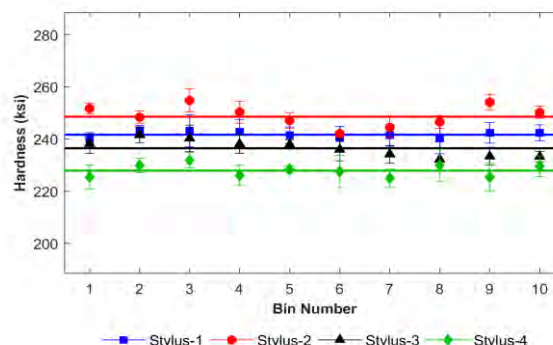
Grain Size

mli (μm)

8.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	241.6	251.0	238.0	226.0
2	242.0	249.0	239.0	230.0
3	243.0	255.0	237.0	232.0
4	242.0	250.0	238.0	228.0
5	242.0	248.0	239.0	230.0
6	242.0	243.0	237.0	227.0
7	242.0	244.0	235.0	231.0
8	242.0	247.0	234.0	229.0
9	242.0	254.0	235.0	227.0
10	242.0	250.0	234.0	229.0

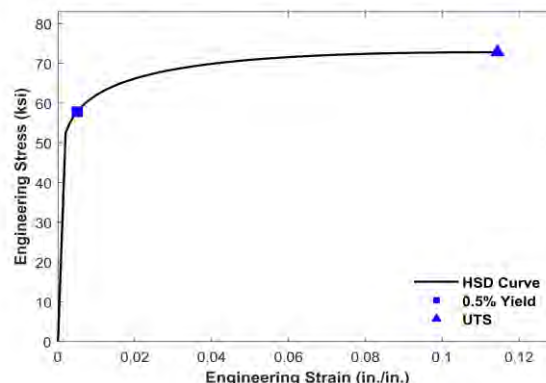


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi with increments of 10. The x-axis ranges from 0 to 0.12 in./in. with increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.005 in./in. strain and 57.8 ksi stress. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.115 in./in. strain and 72.8 ksi stress. The curve shows a rapid initial increase in stress, followed by a gradual increase that levels off as strain increases.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	57.8
UTS	~0.115	72.8



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.	190523144010	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

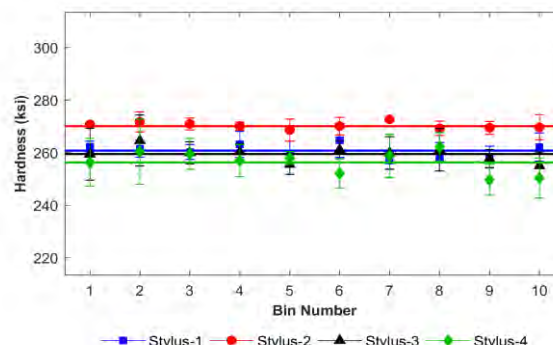
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	8.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	260.7	270.1	259.5	256.2
2	260.7	270.1	259.5	256.2
3	260.7	270.1	259.5	256.2
4	260.7	270.1	259.5	256.2
5	260.7	270.1	259.5	256.2
6	260.7	270.1	259.5	256.2
7	260.7	270.1	259.5	256.2
8	260.7	270.1	259.5	256.2
9	260.7	270.1	259.5	256.2
10	260.7	270.1	259.5	256.2

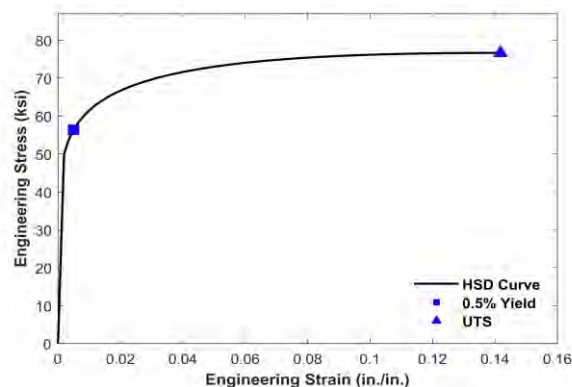


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.16 in./in. The HSD Curve is a solid black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.005, 56). The UTS point is marked with a blue triangle at approximately (0.14, 76).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~56
UTS	~0.14	~76



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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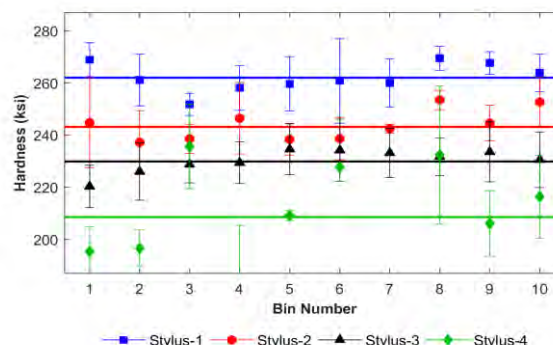
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523165856	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

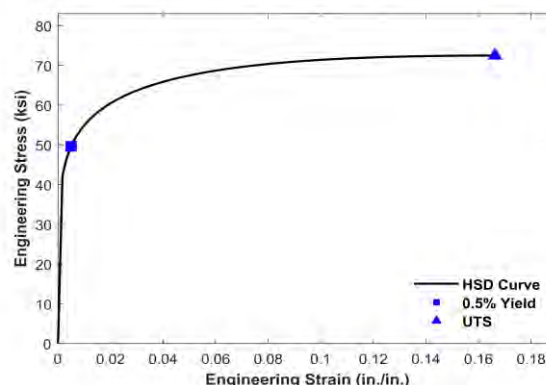
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	262.0	9.46
Stylus-2	243.2	10.21
Stylus-3	229.8	9.62
Stylus-4	208.6	18.55
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.24	0.80	0.010
S	Cr	Nb
0.024	0.02	< 0.01
Cu	Al	Mo
0.05	< 0.01	< 0.01
Ni	Si	Ti
0.01	0.03	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	49.6	48.2
UTS (ksi)	72.4	72.3
	Subset-2	Subset-3
	50.6	50.9
	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

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.	190523191202	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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

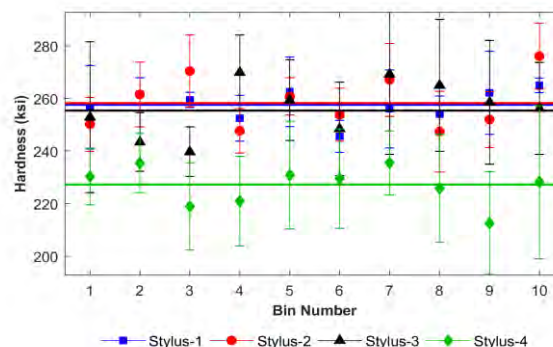
Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	255	252	252	232
2	258	262	245	235
3	260	272	240	220
4	255	248	272	222
5	262	252	262	232
6	252	255	255	232
7	258	270	272	235
8	255	248	265	228
9	262	252	252	212
10	265	278	258	230

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	10.4

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



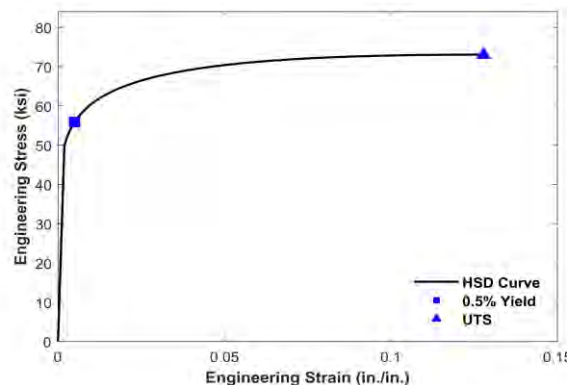
Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend: HSD Curve, 0.5% Yield, UTS



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.	190523194040	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

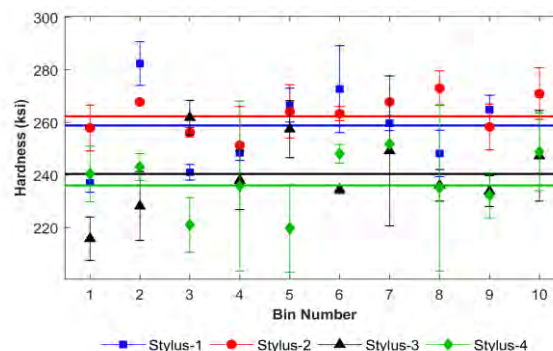
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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. %)

Grain Size

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

mli (μm)
10.4

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

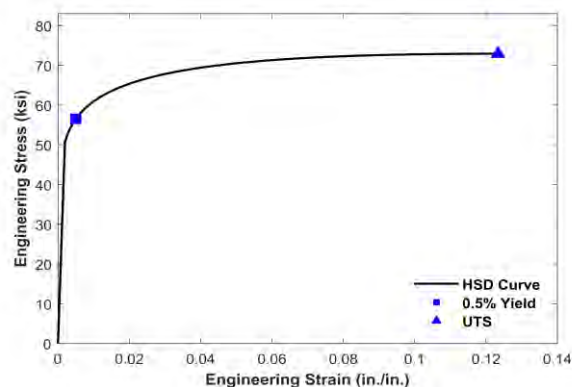
Results

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

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.	190523131921	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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

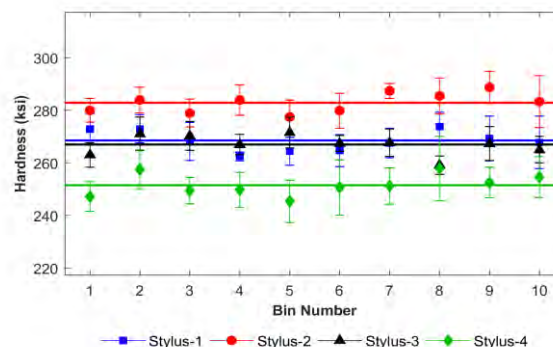
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	16.3

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	269.0	280.0	263.0	247.0
2	270.0	283.0	273.0	258.0
3	268.0	279.0	271.0	250.0
4	265.0	283.0	265.0	250.0
5	265.0	278.0	265.0	245.0
6	266.0	280.0	266.0	251.0
7	270.0	287.0	269.0	251.0
8	274.0	285.0	268.0	259.0
9	270.0	288.0	268.0	253.0
10	268.0	283.0	266.0	255.0

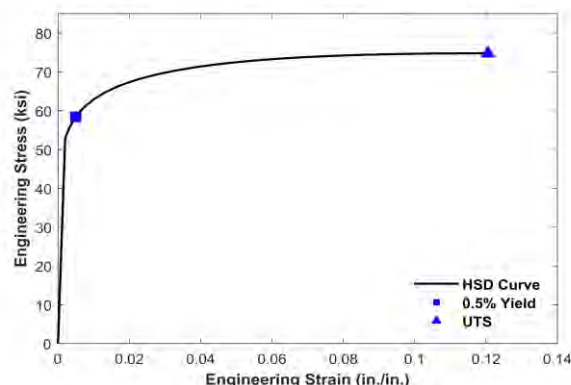


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.14 in./in. The HSD Curve is a black line showing the material's response. The 0.5% Yield point is marked with a blue square at approximately 0.005 strain and 58.4 ksi. The UTS (Ultimate Tensile Strength) point is marked with a blue triangle at approximately 0.12 strain and 74.8 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	58.4
UTS	~0.12	74.8



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

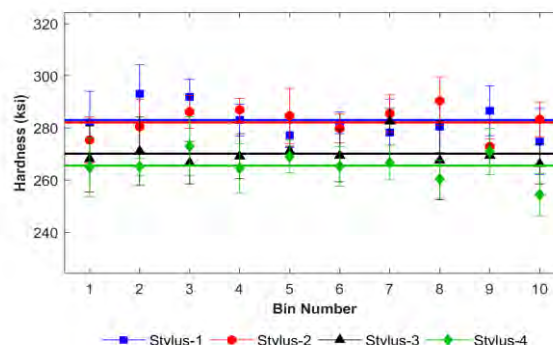
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523124441	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	12:44	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7003-EB7003	
Sample ID	33-Q1	Pipe Size	16 OD x 0.40 WT (in)	Operator Initials		
Test Name	33-Q1_BM-02_7003-EB7003_190523124441			Sample Type	Cutout	
Sample Description						
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	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. %)

Grain Size

mli (μm)

16.3

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

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

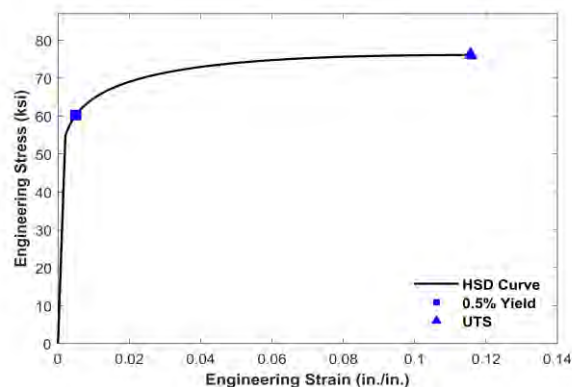
Results

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

Prepared:

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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.	190523162340	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

Measurements

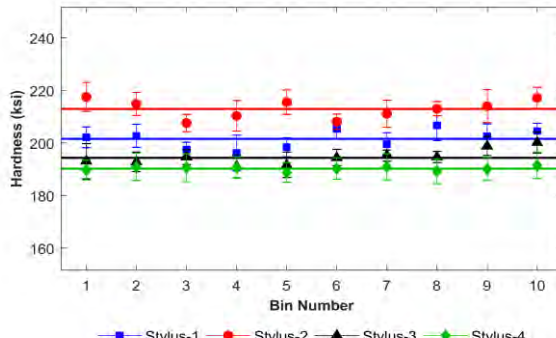
Post-Processing Ver.

2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

Hardness = (Stylus force)/(Contact area)



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.08	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, which plots Engineering Stress (ksi) against Engineering Strain (in./in.). The curve starts at the origin, rises steeply to the 0.5% Yield point (marked with a blue square at approximately 0.01 strain and 52.5 ksi), and then continues to rise more gradually, reaching the Ultimate Tensile Strength (UTS) point (marked with a blue triangle at approximately 0.085 strain and 61.5 ksi). The curve then levels off, indicating a plateau in stress. The legend identifies the HSD Curve, the 0.5% Yield point, and the UTS point.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	52.5
UTS	0.085	61.5

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.	190523142513	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.08	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, which plots Engineering Stress (ksi) against Engineering Strain (in./in.). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately (0.01, 51), and then continues to rise more gradually, reaching a peak at the Ultimate Tensile Strength (UTS) marked by a blue triangle at approximately (0.09, 61). The x-axis ranges from 0 to 0.1 in./in. with major ticks every 0.01. The y-axis ranges from 0 to 70 ksi with major ticks every 10. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	51.0
UTS	0.09	61.4

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.	190509124425	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

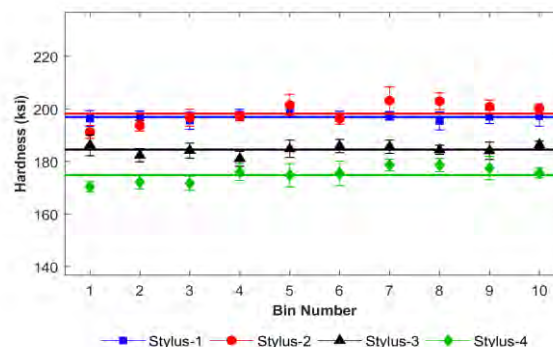
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.07	0.40	0.007	0.016	0.03	< 0.01	0.05	< 0.01	< 0.01	0.05	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size mli (μm)

14.5

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	197.0	198.3	184.5	174.9
2	197.0	198.3	184.5	174.9
3	197.0	198.3	184.5	174.9
4	197.0	198.3	184.5	174.9
5	197.0	198.3	184.5	174.9
6	197.0	198.3	184.5	174.9
7	197.0	198.3	184.5	174.9
8	197.0	198.3	184.5	174.9
9	197.0	198.3	184.5	174.9
10	197.0	198.3	184.5	174.9

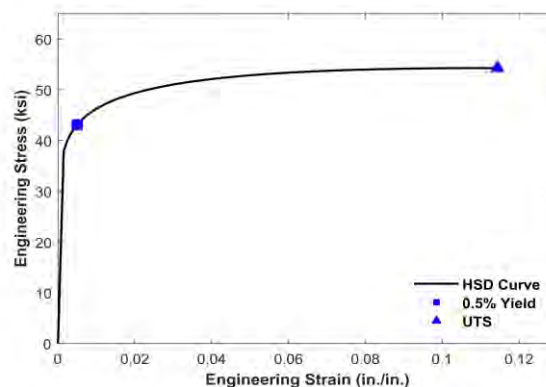


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 60 ksi, and the x-axis ranges from 0 to 0.12 in./in. The HSD Curve is a black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually increases to the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.005, 43.1). The UTS point is marked with a blue triangle at approximately (0.11, 54.3).

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	43.1	0.005
UTS	54.3	0.11



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Massachusetts Materials Technologies LLC

167 Prospect Street, Unit 4

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617-502-5636

HSD@byMMT.com

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 Plaines, 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						
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	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

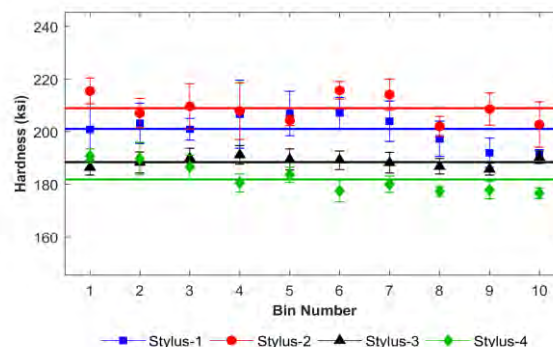
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	14.5

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	201.0	215.0	185.0	190.0
2	202.0	208.0	190.0	188.0
3	201.0	210.0	188.0	185.0
4	203.0	208.0	192.0	180.0
5	204.0	205.0	190.0	182.0
6	208.0	215.0	190.0	178.0
7	204.0	212.0	188.0	180.0
8	202.0	202.0	188.0	178.0
9	192.0	208.0	188.0	178.0
10	202.0	202.0	190.0	178.0

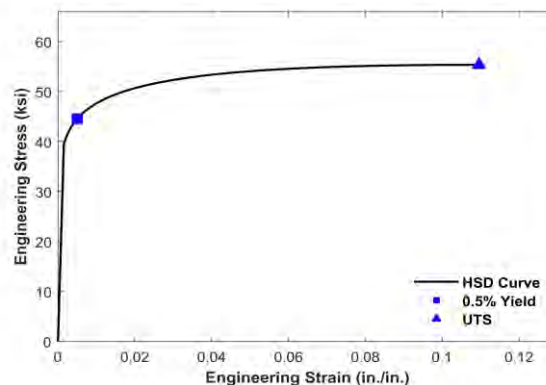


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 60 in increments of 10. The x-axis ranges from 0 to 0.12 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off. A blue square marker is placed on the curve at approximately (0.005, 44.6), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.11, 55.4), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	44.6
UTS	~0.11	55.4



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.	190523114834	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

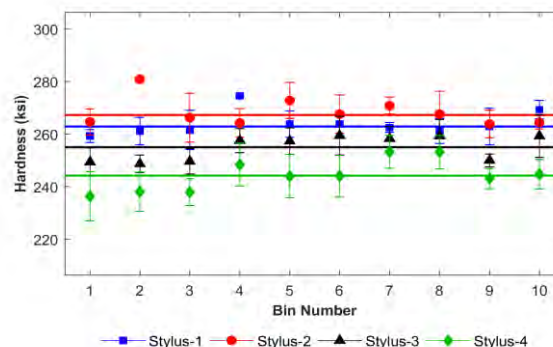
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	13.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	262.8	267.3	255.0	244.1
2	262.8	267.3	255.0	244.1
3	262.8	267.3	255.0	244.1
4	262.8	267.3	255.0	244.1
5	262.8	267.3	255.0	244.1
6	262.8	267.3	255.0	244.1
7	262.8	267.3	255.0	244.1
8	262.8	267.3	255.0	244.1
9	262.8	267.3	255.0	244.1
10	262.8	267.3	255.0	244.1

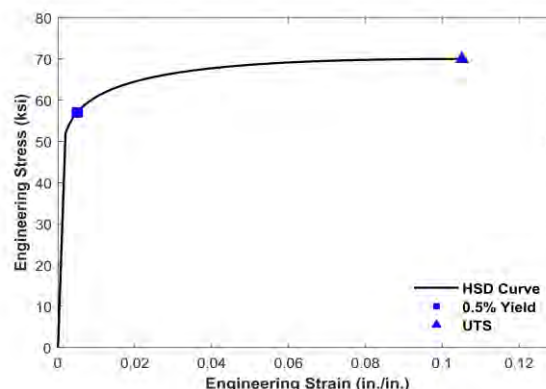


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.12 in./in. in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker indicates the 0.5% Yield point at approximately 57 ksi and 0.005 in./in. strain. A blue triangle marker indicates the Ultimate Tensile Strength (UTS) at approximately 70 ksi and 0.105 in./in. strain.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~57
UTS	~0.105	~70



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.	190522154057	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	270	272	264	236
2	270	271	246	244
3	268	272	254	239
4	271	285	258	238
5	278	272	254	242
6	282	275	254	241
7	263	273	250	241
8	-	266	239	231
9	-	263	239	238
10	-	267	238	238

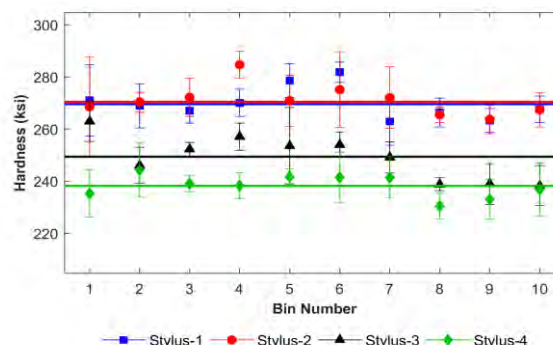
Base Metal Chemical Composition (wt. %)

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.

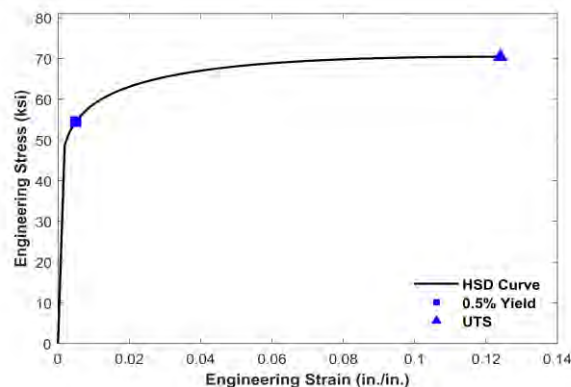


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10, and the x-axis ranges from 0 to 0.14 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 54.5). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.125, 70.4).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~54.5
UTS	~0.125	~70.4



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.	190523120624	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

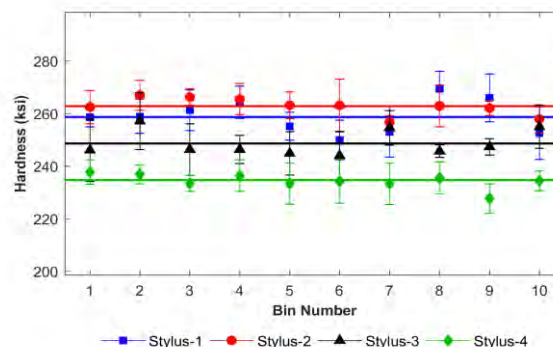
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	13.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	258.7	262.8	248.6	234.7
2	258.7	262.8	248.6	234.7
3	258.7	262.8	248.6	234.7
4	258.7	262.8	248.6	234.7
5	258.7	262.8	248.6	234.7
6	258.7	262.8	248.6	234.7
7	258.7	262.8	248.6	234.7
8	258.7	262.8	248.6	234.7
9	258.7	262.8	248.6	234.7
10	258.7	262.8	248.6	234.7

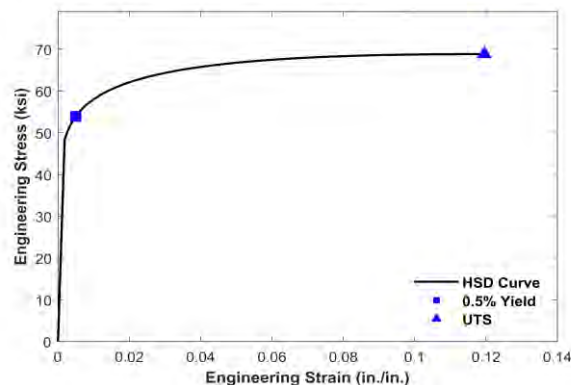


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>53.9</u>	<u>54.3</u>	<u>53.9</u>	<u>53.4</u>
UTS (ksi)	<u>68.8</u>	<u>69.1</u>	<u>68.6</u>	<u>68.9</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10, and the x-axis ranges from 0 to 0.14 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.005, 54), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.12, 69), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~54
UTS	~0.12	~69



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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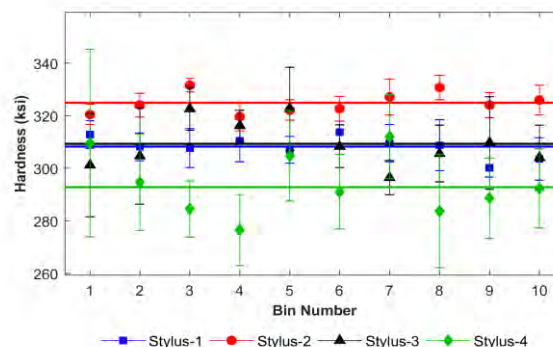
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190523182251	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

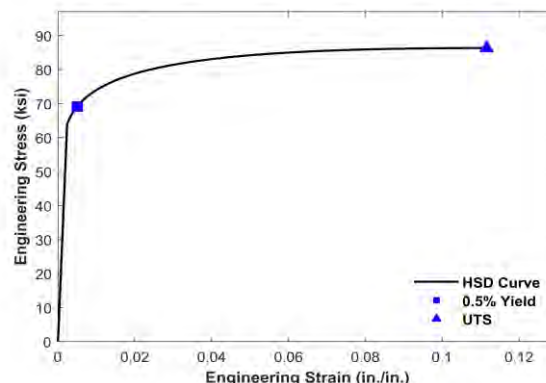
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	308.3	7.13
Stylus-2	325.0	5.79
Stylus-3	309.3	14.83
Stylus-4	292.8	19.83
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.28	0.94	0.019
S	Cr	Nb
0.038	0.04	< 0.01
Cu	Al	Mo
0.15	< 0.01	< 0.01
Ni	Si	Ti
0.08	0.06	< 0.01
V	B	
< 0.01	< 0.0005	
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.		
Grain Size		
mli (μm)		
9.8		



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc	
Tensile Properties	Overall	Subset-1
0.5% EUL Yield (ksi)	69.1	69.4
UTS (ksi)	86.3	86.5
	Subset-2	Subset-3
	69.2	68.7
	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

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.	190523163018	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	305	312	305	292
2	308	315	300	295
3	307	312	305	305
4	306	315	318	282
5	306	312	310	292
6	306	312	292	275
7	305	312	288	278
8	315	310	298	282
9	312	310	305	285
10	310	310	285	280

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the HSD Curve, plotting Engineering Stress (ksi) on the y-axis (0 to 90) against Engineering Strain (in./in.) on the x-axis (0 to 0.12). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately (0.005, 68.6), then continues to rise more gradually, reaching a peak marked by a blue triangle at approximately (0.11, 85.3). The legend identifies the black line as the HSD Curve, the blue square as the 0.5% Yield point, and the blue triangle as the UTS point.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	68.6
UTS	~0.11	85.3

Comments

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

Parth Patel

Approved:

Steven Palkovic, PhD



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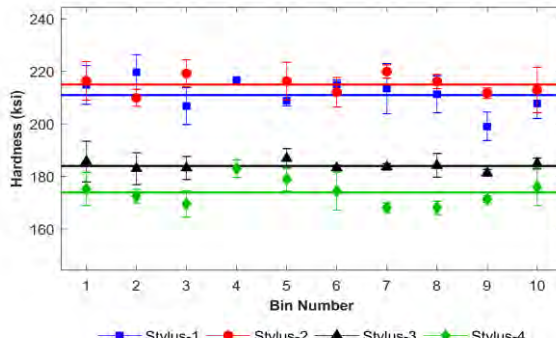
HSD@byMMT.com

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 Plaines, 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						
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	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

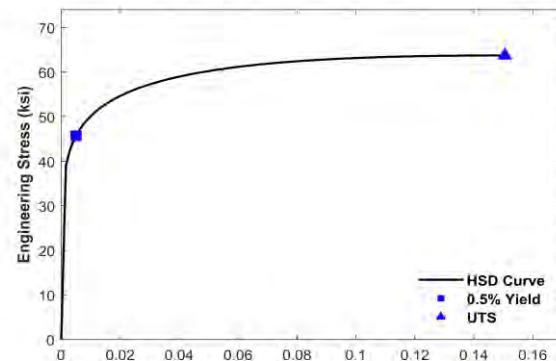
Post-Processing Ver.	2.2													
HSD Stylus Hardness														
	Average (ksi)	Std. Dev. (ksi)	Sample Size											
Stylus-1	210.9	7.84	28											
Stylus-2	214.9	5.67	29											
Stylus-3	184.0	4.17	30											
Stylus-4	173.9	6.24	33											
Hardness = (Stylus force)/(Contact area)														
														
Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
0.16	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	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve, plotting Engineering Stress (ksi) on the y-axis (0 to 70) against Engineering Strain (in./in.) on the x-axis (0 to 0.16). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately (0.005, 45.7), then continues to rise more gradually, reaching a peak marked by a blue triangle at approximately (0.15, 63.7). The legend identifies the HSD Curve as a solid black line, the 0.5% Yield point as a blue square, and the UTS point as a blue triangle.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	45.7
UTS	~0.15	63.7

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.	190523102610	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	228	230	222	210
2	227	238	220	220
3	228	238	218	218
4	227	235	218	210
5	226	245	222	215
6	226	240	220	218
7	227	235	225	215
8	227	235	220	215
9	227	230	220	218
10	227	235	220	218

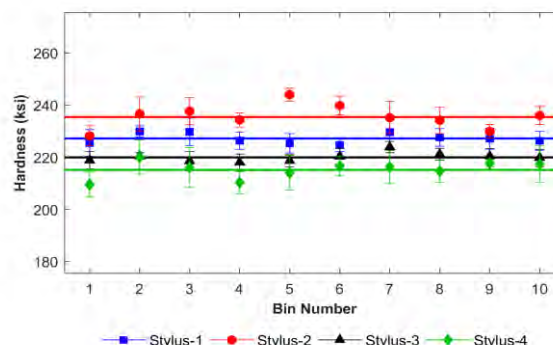
Base Metal Chemical Composition (wt. %)

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

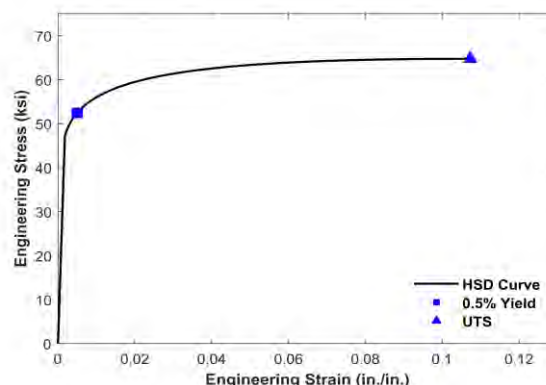
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.005	52.4	0.5% Yield
0.11	64.7	UTS



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.	190522191318	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

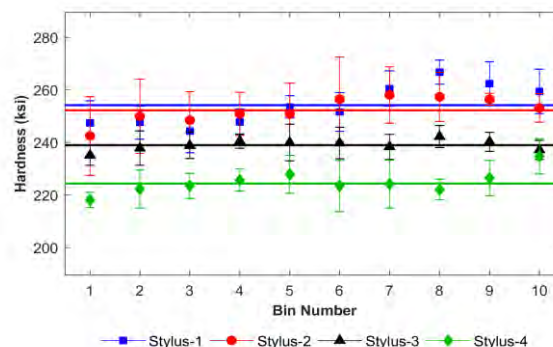
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	12.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245	245	235	218
2	250	250	238	222
3	248	248	240	223
4	250	250	240	225
5	252	252	240	228
6	255	255	240	223
7	258	258	238	225
8	260	258	242	222
9	258	258	240	228
10	255	255	235	235

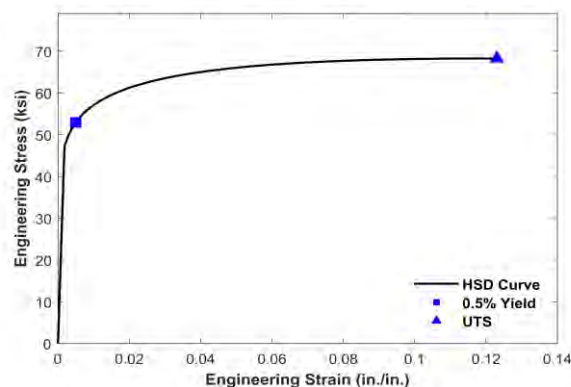


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>53.0</u>	<u>53.1</u>	<u>53.5</u>	<u>52.4</u>
UTS (ksi)	<u>68.3</u>	<u>67.3</u>	<u>68.4</u>	<u>69.2</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 with increments of 10. The x-axis ranges from 0 to 0.14 with increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.005, 53), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.12, 69), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~53
UTS	~0.12	~69



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

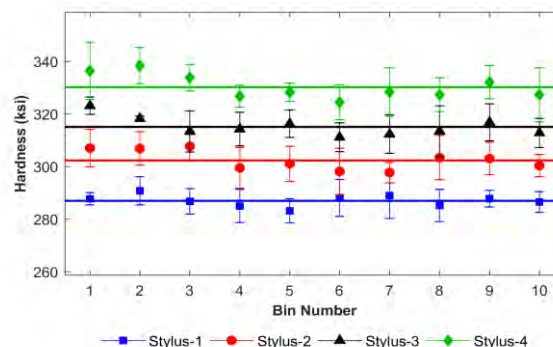
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531100354	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	10:03	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	44-Q1	Pipe 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						
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	1.33	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 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

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
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

mli (μm)
10.7

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

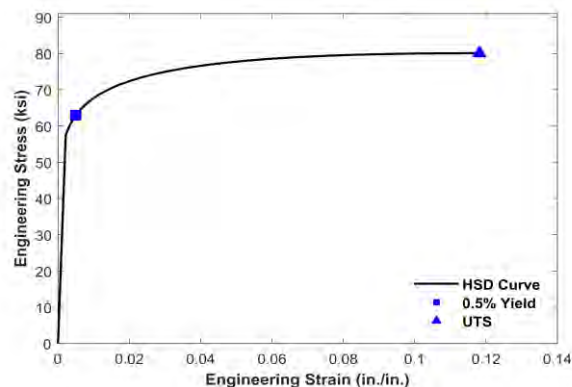
Results

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

Prepared:

Parth Patel

Approved:

Steven Palkovic, PhD



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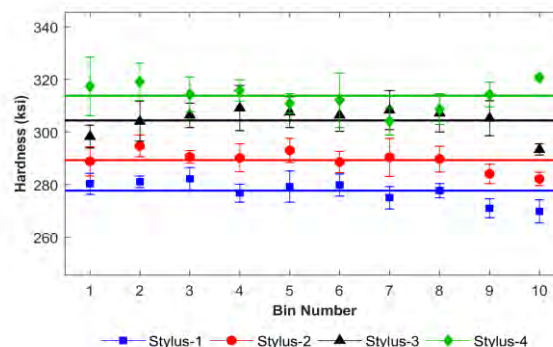
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531102016	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	277.7	5.26
Stylus-2	289.4	5.49
Stylus-3	304.5	7.54
Stylus-4	313.8	7.67
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.10	1.48	0.012
S	Cr	Nb
< 0.005	< 0.01	< 0.01
Cu	Al	Mo
< 0.01	0.03	< 0.01
Ni	Si	Ti
0.01	0.28	< 0.01
V	B	
0.04	< 0.0005	
Grain Size		mli (μm)
		10.7

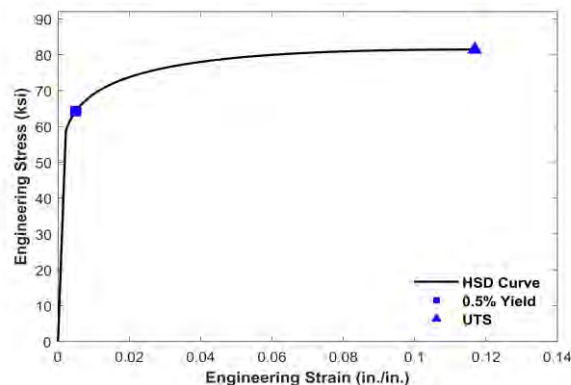


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10. The x-axis ranges from 0 to 0.14 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 64.3). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) point at approximately (0.115, 81.4).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	64.3
UTS	~0.115	81.4



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

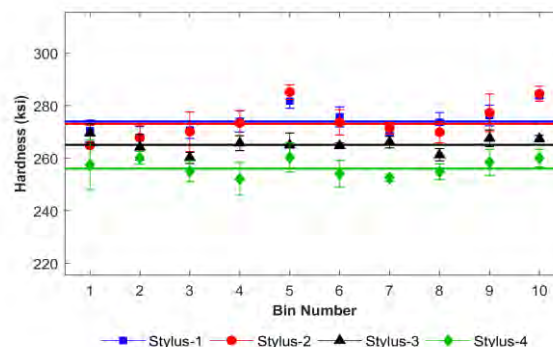
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Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	8:39	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	50-Q1	Pipe Size	24 OD x 0.37 WT (in)	Operator Initials	JJ	
Test Name	50-Q1_BM-01_5002-EB5002_190531083958			Sample Type	Cutout	
Sample Description						
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	1.33	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 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. %)

Grain Size

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

mli (μm)
5.7

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

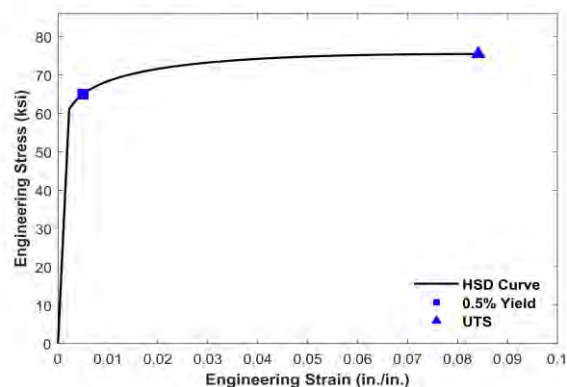
Results

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

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.	190531090012	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

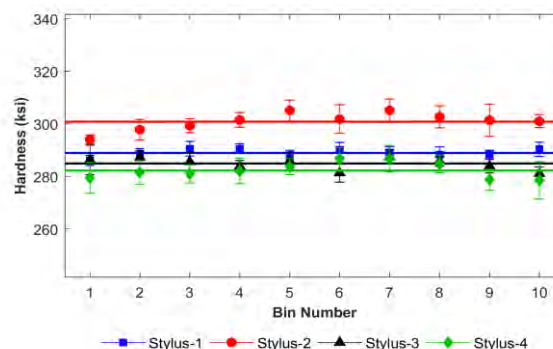
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	289.0	300.8	285.0	282.3
2	289.0	300.8	285.0	282.3
3	289.0	300.8	285.0	282.3
4	289.0	300.8	285.0	282.3
5	289.0	300.8	285.0	282.3
6	289.0	300.8	285.0	282.3
7	289.0	300.8	285.0	282.3
8	289.0	300.8	285.0	282.3
9	289.0	300.8	285.0	282.3
10	289.0	300.8	285.0	282.3

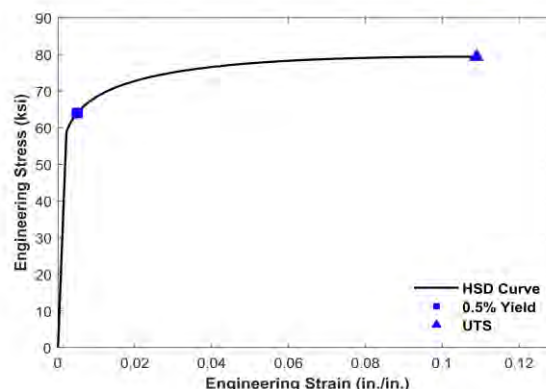


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 ksi in increments of 10, and the x-axis ranges from 0 to 0.12 in./in. in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 64). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.11, 79.3).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~64
UTS	~0.11	~79.3



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.	190531104359	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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	Grain Size mli (μm)
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	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the HSD Curve, which plots Engineering Stress (ksi) against Engineering Strain (in./in.). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately 0.01 strain and 67 ksi, then continues to rise more gradually, reaching a peak marked by a blue triangle at approximately 0.08 strain and 76.6 ksi. The legend identifies the solid black line as the HSD Curve, the blue square as the 0.5% Yield point, and the blue triangle as the UTS point.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	67.2	0.5% Yield
0.08	76.6	UTS

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.	190523174239	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	187.5	181.8	155.0	139.0
2	187.5	181.8	155.0	139.0
3	187.5	181.8	155.0	139.0
4	187.5	181.8	155.0	139.0
5	187.5	181.8	155.0	139.0
6	187.5	181.8	155.0	139.0
7	187.5	181.8	155.0	139.0
8	187.5	181.8	155.0	139.0
9	187.5	181.8	155.0	139.0
10	187.5	181.8	155.0	139.0

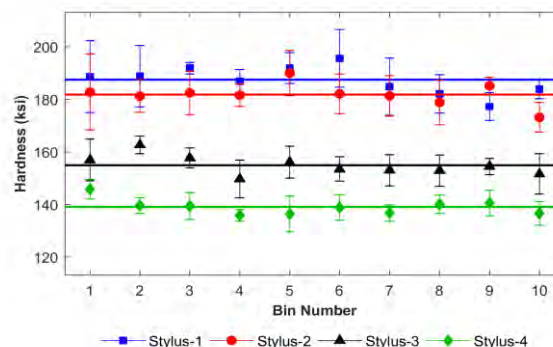
Base Metal Chemical Composition (wt. %)

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.

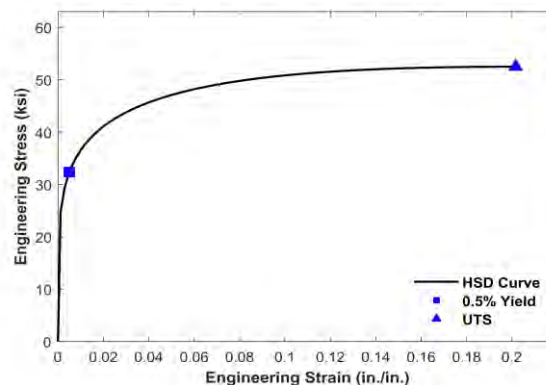


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>32.4</u>	<u>32.9</u>	<u>31.6</u>	<u>32.8</u>
UTS (ksi)	<u>52.5</u>	<u>52.6</u>	<u>53.6</u>	<u>51.1</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 60 in increments of 10, and the x-axis ranges from 0 to 0.2 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin and rises steeply before leveling off. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 32.4). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.2, 52.5).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~32.4
UTS	~0.2	~52.5



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.	190523150452	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

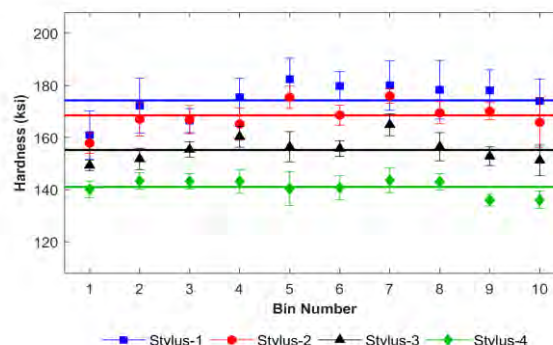
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	31.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	161	158	148	140
2	172	167	152	143
3	168	167	155	143
4	175	165	160	143
5	182	175	155	140
6	178	170	155	141
7	178	172	165	143
8	178	170	155	142
9	178	170	152	137
10	174	167	150	137

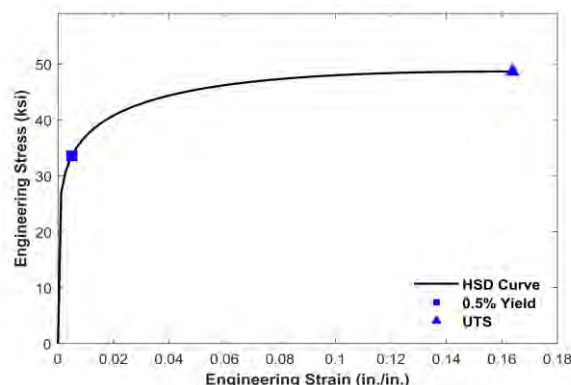


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 50 ksi, and the x-axis ranges from 0 to 0.18 in./in. The HSD Curve is a black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.01, 33.6). The UTS point is marked with a blue triangle at approximately (0.16, 48.6).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	33.6
UTS	0.16	48.6



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.	190521110448	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	188	178	152	141
2	188	176	156	136
3	178	176	155	138
4	188	186	157	137
5	186	185	163	138
6	186	186	163	147
7	196	187	157	147
8	199	178	155	144
9	191	181	152	137
10	198	179	158	143

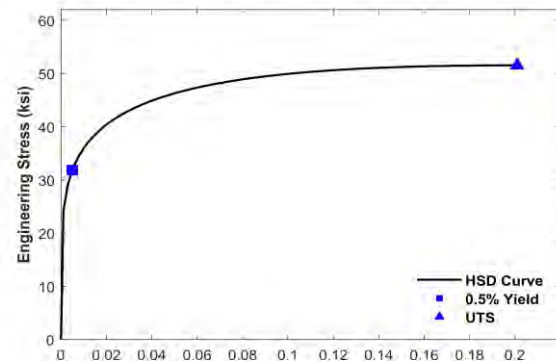
Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				



The graph displays the HSD Curve (solid black line) and the 0.5% Yield point (blue square) and UTS point (blue triangle). The Y-axis represents Engineering Stress (ksi) from 0 to 60, and the X-axis represents Engineering Strain (in./in.) from 0 to 0.2. The 0.5% Yield point is at approximately 31.8 ksi and 0.005 in./in. The UTS point is at approximately 51.5 ksi and 0.18 in./in.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.005	31.8	0.5% Yield
0.18	51.5	UTS

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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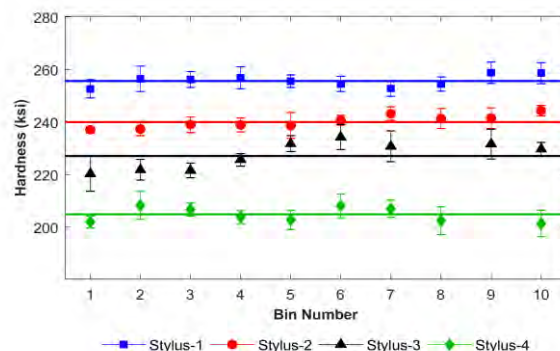
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425185942	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	255.6	3.77
Stylus-2	240.0	3.53
Stylus-3	227.1	6.33
Stylus-4	204.9	4.42
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.21	0.79	0.007
S	Cr	Nb
0.028	0.02	< 0.01
Cu	Al	Mo
0.06	< 0.01	< 0.01
Ni	Si	Ti
0.02	0.06	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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.

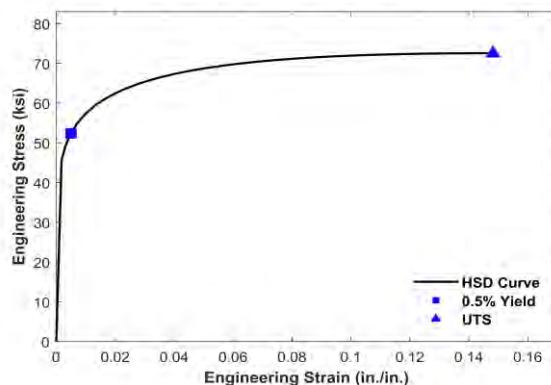
Each subset is calculated using one-third of the measurements to assess variations along the test length (start, middle and end).

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend: HSD Curve, 0.5% Yield, UTS

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	52.4
UTS	0.145	73.2



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.	190507155933	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

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	0.79	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.

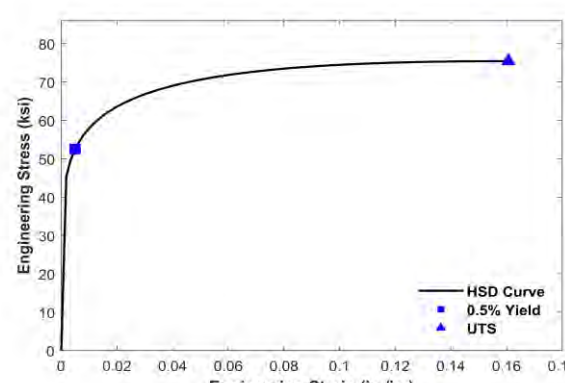
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.18). The curve starts at the origin, rises steeply to a yield point of approximately 52 ksi at 0.01 strain, then continues to a peak of approximately 75 ksi at 0.16 strain. The 0.5% Yield point is marked with a blue square and the UTS point with a blue triangle.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	52.5
UTS	0.16	75.4

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.	190530142125	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	228	228	185	148
2	222	230	198	155
3	235	235	202	158
4	238	232	192	162
5	235	230	192	155
6	238	235	188	148
7	238	228	185	160
8	238	225	190	152
9	238	225	190	150
10	225	220	185	158

Base Metal Chemical Composition (wt. %)

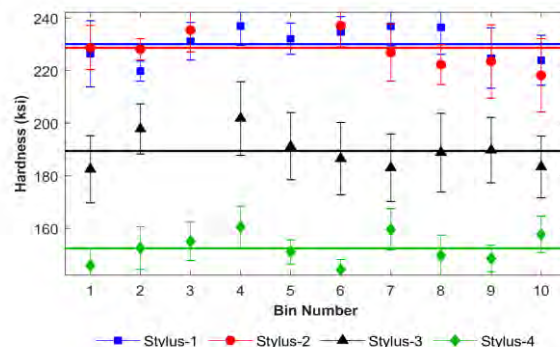
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	0.52	0.005	0.030	0.02	< 0.01	< 0.01	0.02	0.02	0.02	0.02	< 0.01	< 0.01	< 0.0005

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

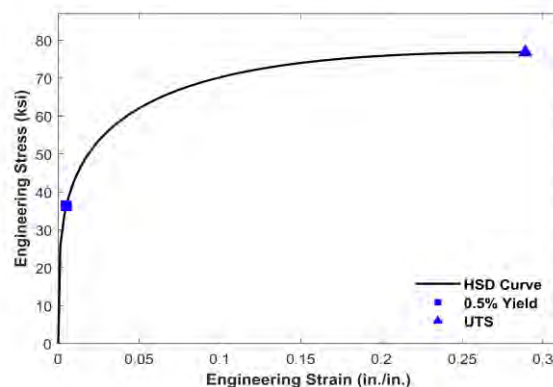
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	36.3	36.6	36.2	36.4
UTS (ksi)	76.8	75.2	80.1	75.6

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).

The graph displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.3 in increments of 0.05. A solid black line represents the HSD Curve, which starts at the origin and rises steeply before leveling off. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 36.4). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) point at approximately (0.28, 75.6).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~36.4
UTS	~0.28	~75.6



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.	190530113404	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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

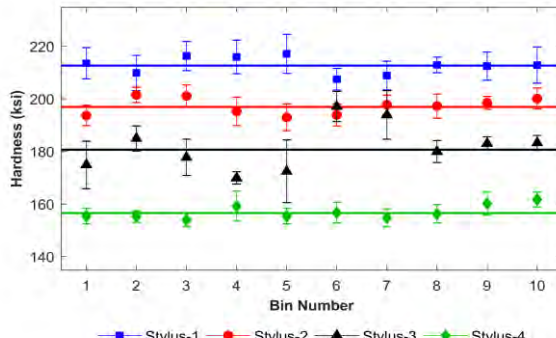
Post-Processing Ver.

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

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	0.52	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 70) and Engineering Strain (in./in.) on the x-axis (0 to 0.2). The curve starts at the origin and rises steeply, then levels off. Key points are marked: 0.5% Yield (blue square) at approximately (0.01, 40) and UTS (blue triangle) at approximately (0.18, 65).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	40
UTS	0.18	65

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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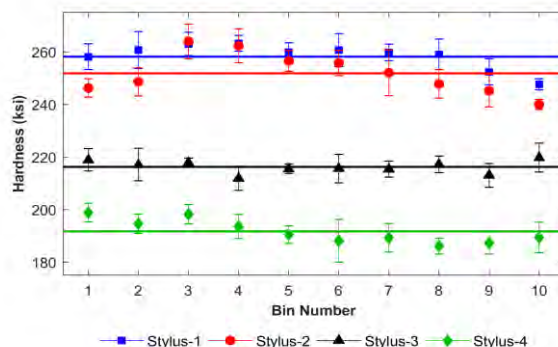
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521102244	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	258.2	6.41
Stylus-2	251.8	9.08
Stylus-3	216.2	4.55
Stylus-4	191.7	6.09
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.19	0.81	0.011
S	Cr	Nb
0.030	0.03	< 0.01
Cu	Al	Mo
0.17	< 0.01	0.03
Ni	Si	Ti
0.03	0.07	< 0.01
V	B	
< 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

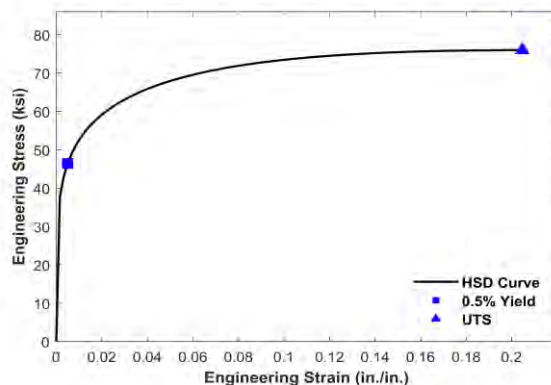
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	46.4	48.0	45.6	46.0
UTS (ksi)	76.0	75.7	77.5	74.7

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).

The graph displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10, and the x-axis ranges from 0 to 0.2 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 46). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.21, 76). A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~46
UTS	~0.21	~76



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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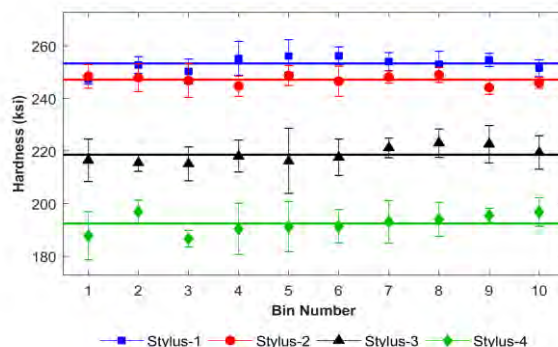
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506123436	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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)
Stylus-1	253.3	4.67
Stylus-2	247.0	4.12
Stylus-3	218.6	6.85
Stylus-4	192.4	7.16
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.19	0.81	0.011
S	Cr	Nb
0.030	0.03	< 0.01
Cu	Al	Mo
0.17	< 0.01	0.03
Ni	Si	Ti
0.03	0.07	< 0.01
V	B	
< 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

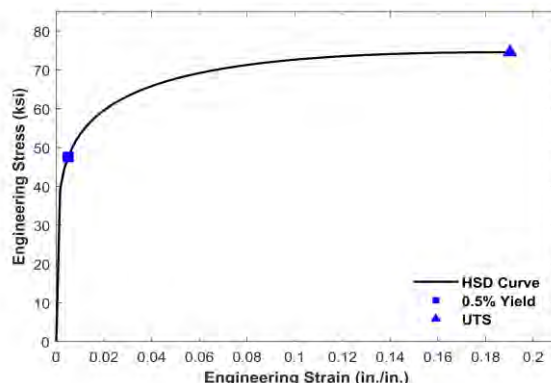
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	47.6	46.8	47.4	48.5
UTS (ksi)	74.5	74.5	74.9	74.3

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).

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.2 in./in. in increments of 0.02. A solid black line represents the HSD Curve. Two specific points are highlighted: the 0.5% Yield point, marked with a blue square at approximately (0.01, 48), and the Ultimate Tensile Strength (UTS) point, marked with a blue triangle at approximately (0.19, 74). The curve starts at the origin, rises steeply to the yield point, then gradually increases to the UTS point before slightly declining.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~48
UTS	~0.19	~74



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.	190507123025	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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

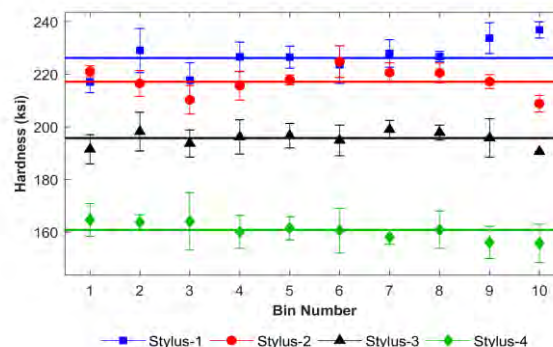
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	226.2	7.85	43
Stylus-2	217.1	6.07	37
Stylus-3	195.6	5.51	45
Stylus-4	160.8	6.64	46

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
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	13.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	218	222	194	164
2	230	217	200	163
3	218	212	195	164
4	227	216	198	161
5	227	218	198	162
6	226	225	196	161
7	228	221	200	158
8	227	221	199	161
9	235	217	197	156
10	237	210	192	156

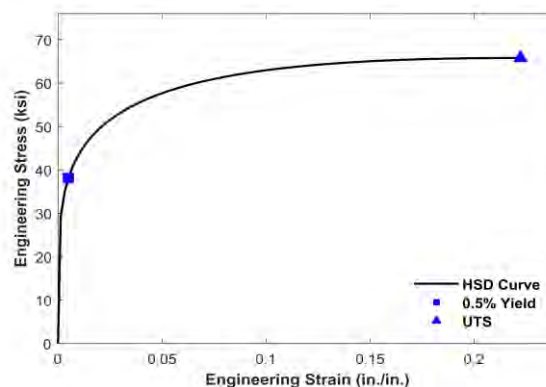


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>38.1</u>	<u>---</u>	<u>38.8</u>	<u>37.4</u>
UTS (ksi)	<u>65.8</u>	<u>---</u>	<u>65.1</u>	<u>66.5</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.05. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.01, 38.1), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.22, 65.8), representing the UTS (Ultimate Tensile Strength) point. The legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	38.1
UTS	~0.22	65.8



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.	190507125659	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

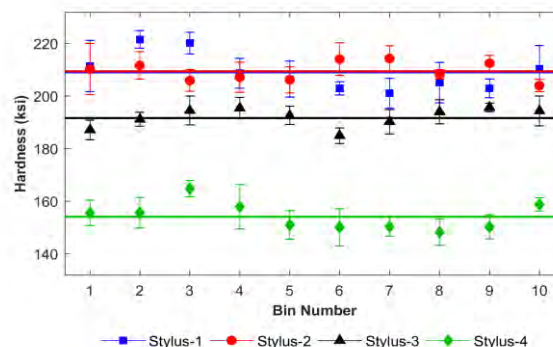
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	13.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	210	210	188	155
2	220	210	192	155
3	220	205	195	165
4	210	205	195	158
5	205	205	195	150
6	205	215	185	150
7	200	215	192	150
8	205	205	195	148
9	205	210	195	150
10	210	205	195	160

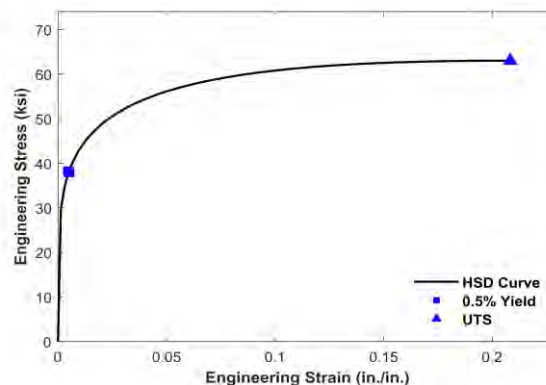


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.05. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 38). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.21, 63).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~38
UTS	~0.21	~63



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.	190530134549	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

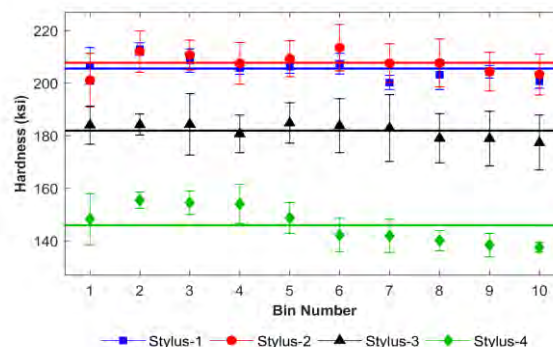
Grain Size

mli (μm)

13.2

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	205	200	185	148
2	208	215	185	155
3	208	212	185	155
4	208	205	180	155
5	208	210	185	150
6	205	215	185	142
7	202	208	185	140
8	205	208	180	140
9	205	205	180	138
10	202	205	178	138

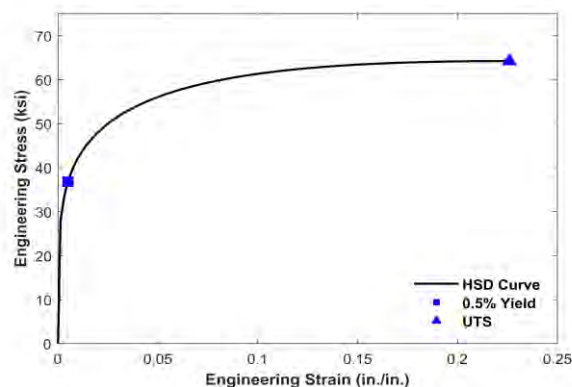


Results

Prediction Ver.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>36.8</u>	<u>38.0</u>	<u>37.4</u>	<u>35.4</u>
UTS (ksi)	<u>64.2</u>	<u>64.1</u>	<u>64.2</u>	<u>64.4</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.25 in increments of 0.05. A solid black line represents the HSD Curve, which starts at the origin (0,0) and rises steeply, then gradually levels off. A blue square marker is placed on the curve at approximately (0.01, 37), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.22, 64), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~37
UTS	~0.22	~64



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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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.	190530180914	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

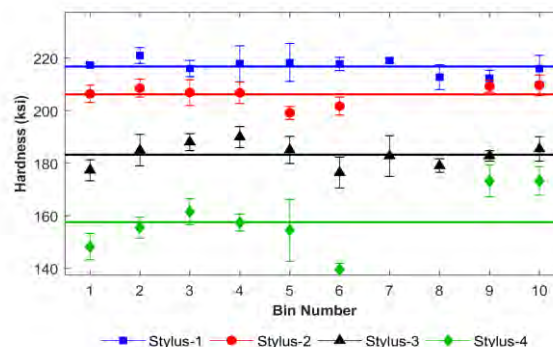
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	13.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	218	206	178	148
2	221	209	185	155
3	216	207	189	162
4	219	208	191	157
5	218	200	185	154
6	218	202	176	140
7	220	207	183	-
8	214	211	179	-
9	211	211	182	174
10	216	210	185	174

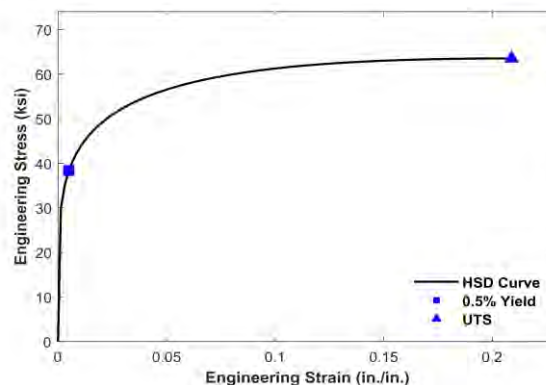


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the stress-strain relationship for the material. The x-axis represents Engineering Strain in in./in., ranging from 0 to 0.2. The y-axis represents Engineering Stress in ksi, ranging from 0 to 70. A solid black line represents the HSD Curve. A blue square marks the 0.5% Yield point at approximately 0.01 strain and 38.3 ksi. A blue triangle marks the UTS (Ultimate Tensile Strength) at approximately 0.21 strain and 63.5 ksi, which is highlighted with a yellow circle.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	38.3
UTS	~0.21	63.5



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.	190506165415	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

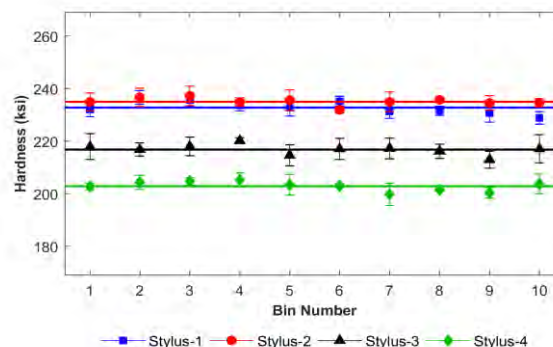
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

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
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

mli (μm)
10.2

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

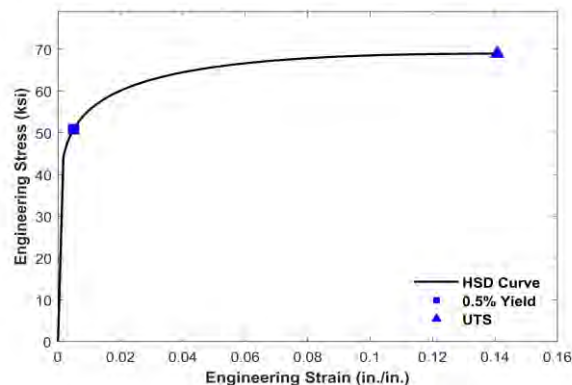
Results

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

Prepared:

Parth Patel

Approved:

Steven Palkovic, PhD



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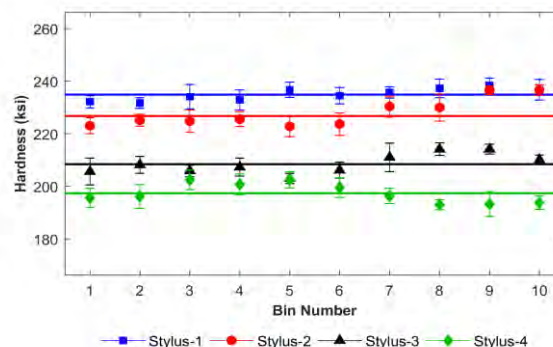
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520173954	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

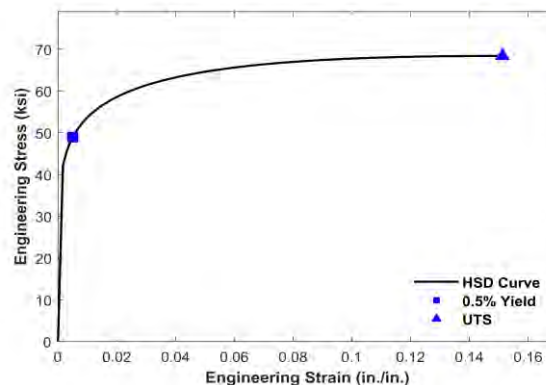
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	234.8	3.67
Stylus-2	226.8	5.52
Stylus-3	208.4	4.62
Stylus-4	197.4	4.80
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.89	0.007
S	Cr	Nb
0.022	0.02	< 0.01
Cu	Al	Mo
0.03	0.02	< 0.01
Ni	Si	Ti
0.02	0.04	< 0.01
V	B	
< 0.01	< 0.0005	
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.		
Grain Size		
mli (μm)		
10.2		



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc	
Tensile Properties	Overall	Subset-1
0.5% EUL Yield (ksi)	48.9	49.1
UTS (ksi)	68.4	68.0
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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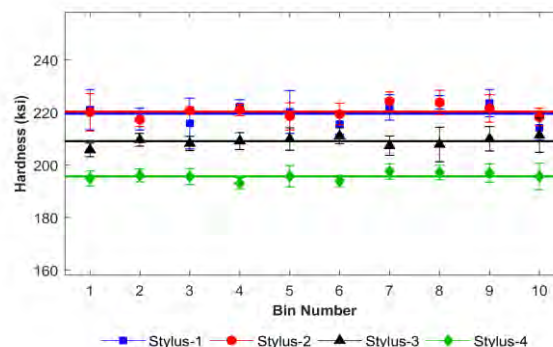
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521152136	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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)
Stylus-1	219.5	6.19
Stylus-2	220.3	4.35
Stylus-3	209.0	3.93
Stylus-4	195.7	3.13
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.18	0.71	0.006
S	Cr	Nb
0.014	0.02	< 0.01
Cu	Al	Mo
0.04	< 0.01	< 0.01
Ni	Si	Ti
0.02	< 0.01	< 0.01
V	B	
< 0.01	< 0.0005	
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.		
Grain Size		
mli (μm)		
21.0		

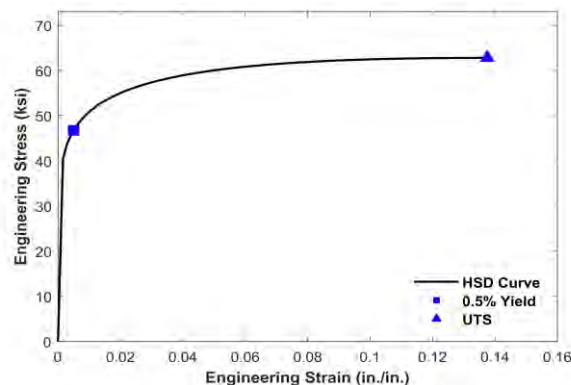


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 46.7). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.135, 63.0).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	46.7
UTS	~0.135	63.0



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.	190507141927	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

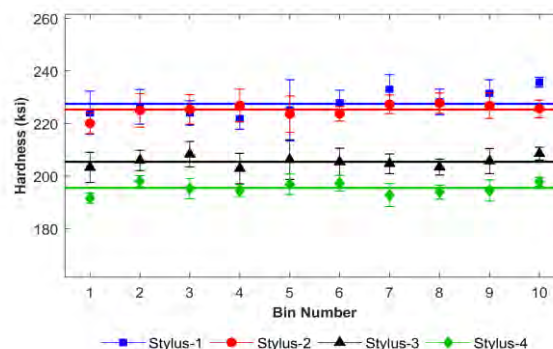
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	21.0

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	225	220	205	192
2	228	225	208	198
3	225	225	210	195
4	222	225	205	195
5	228	225	208	198
6	228	225	208	198
7	232	228	205	192
8	228	228	205	195
9	230	228	208	195
10	235	228	210	198

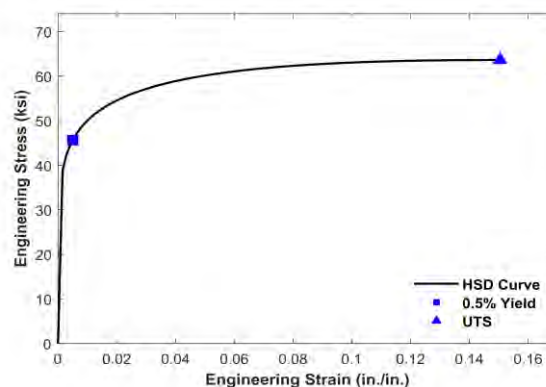


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.01, 45.6), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.15, 63.6), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~45.6
UTS	~0.15	~63.6



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.	190509173852	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	222.8	205.0	193.0	182.0
2	222.8	205.0	195.0	176.0
3	222.8	207.0	198.0	178.0
4	215.0	203.0	192.0	176.0
5	213.0	200.0	193.0	174.0
6	222.8	212.0	197.0	182.0
7	-	228.0	208.0	190.0
8	-	225.0	208.0	197.0
9	-	227.0	212.0	200.0
10	-	231.0	213.0	198.0

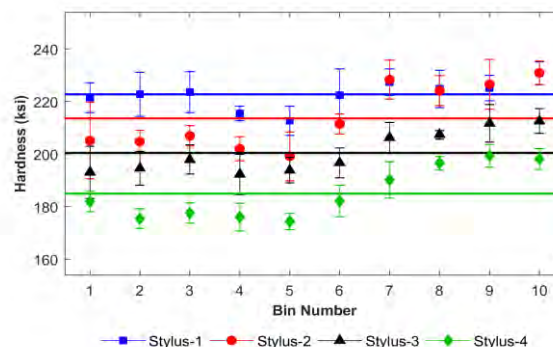
Base Metal Chemical Composition (wt. %)

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.

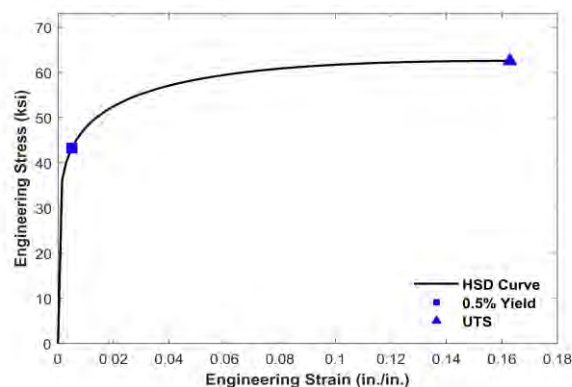


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.18 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 43.3). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.16, 62.5).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	43.3
UTS	0.16	62.5



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.	190529124859	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

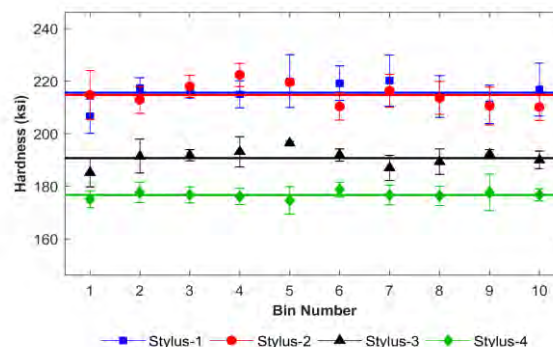
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.85	0.007	0.023	0.02	< 0.01	0.09	< 0.01	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.0005

Grain Size mli (μm)

19.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	208	215	185	175
2	218	212	192	178
3	218	218	193	177
4	218	222	194	176
5	218	220	198	175
6	220	210	193	178
7	218	218	188	177
8	215	215	191	177
9	212	211	193	178
10	218	210	191	177

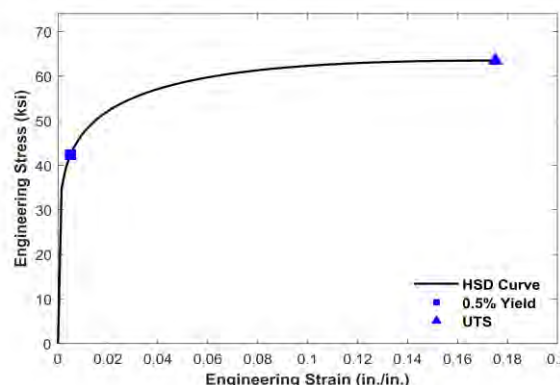


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the HSD Curve, which plots Engineering Stress (ksi) on the y-axis against Engineering Strain (in./in.) on the x-axis. The curve shows a rapid increase in stress with strain, followed by a plateau. The 0.5% Yield point is marked with a blue square at approximately (0.01, 42.4) ksi. The Ultimate Tensile Strength (UTS) is marked with a blue triangle at approximately (0.17, 63.5) ksi.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	42.4	0.5% Yield
0.17	63.5	UTS



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 Plaines, 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						
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	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

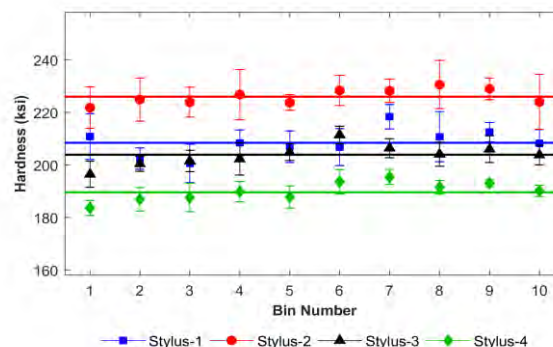
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	19.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	210	222	198	185
2	205	225	202	188
3	208	224	201	187
4	209	227	203	190
5	206	224	204	189
6	208	228	212	194
7	210	229	207	196
8	211	232	205	193
9	209	230	208	195
10	208	225	204	192

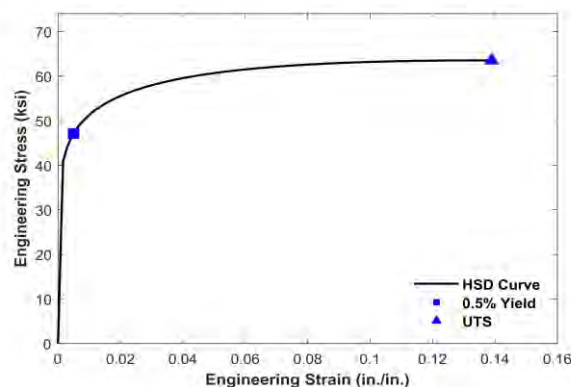


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 47). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.135, 64).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~47
UTS	~0.135	~64



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.	190507141345	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

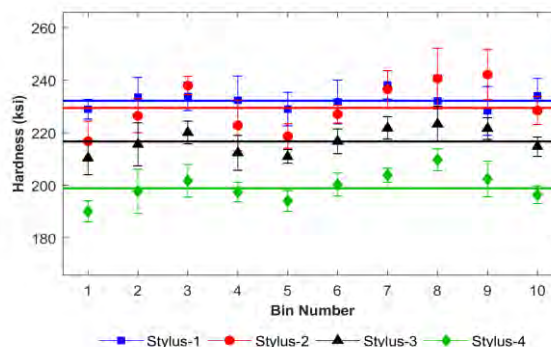
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	19.4

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	230	218	212	190
2	233	227	217	198
3	237	238	221	202
4	233	223	213	197
5	231	219	212	194
6	232	228	216	200
7	237	237	223	203
8	232	240	225	202
9	233	242	224	202
10	234	230	216	197

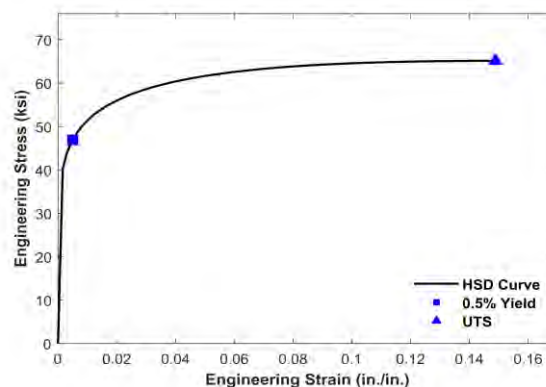


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.16 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 46.9). The UTS point is marked with a blue triangle at approximately (0.145, 65.1).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	46.9
UTS	0.145	65.1



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.	190507152744	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	228	225	212	202
2	230	230	214	200
3	231	231	211	191
4	231	224	215	193
5	238	227	218	191
6	230	235	217	200
7	241	231	217	199
8	244	227	206	198
9	231	230	207	193
10	229	227	207	195

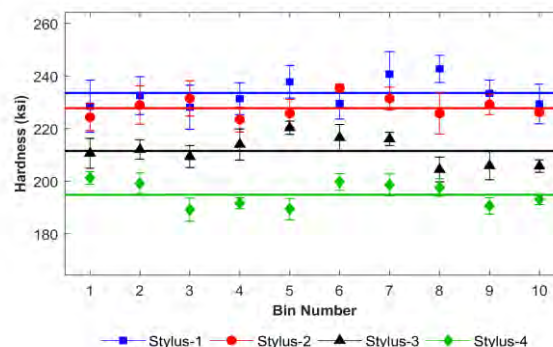
Base Metal Chemical Composition (wt. %)

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.

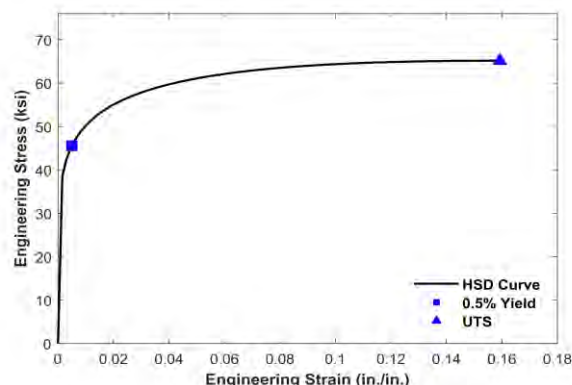


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 in increments of 10. The x-axis ranges from 0 to 0.18 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marks the 0.5% Yield point at approximately (0.01, 45). A blue triangle marks the UTS point at approximately (0.155, 65). The curve starts at the origin, rises steeply to the yield point, then curves more gradually to the UTS point, where it begins to level off.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~45
UTS	~0.155	~65



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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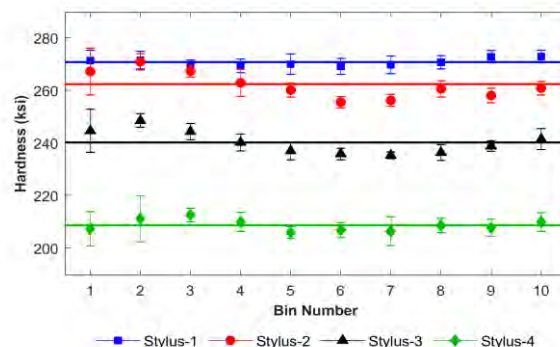
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190425134314	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

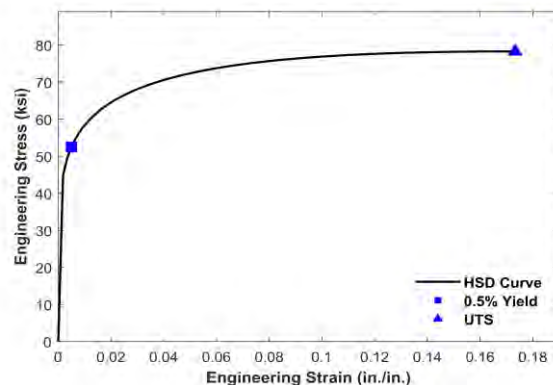
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	270.7	3.02
Stylus-2	262.3	6.24
Stylus-3	240.1	5.25
Stylus-4	208.6	4.54
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.25	1.07	0.009
S	Cr	Nb
0.025	0.08	< 0.01
Cu	Al	Mo
0.04	0.01	0.02
Ni	Si	Ti
0.02	0.05	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	52.5	53.9
UTS (ksi)	78.3	78.9
	Subset-2	Subset-3
	52.2	51.8
	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).		
HSD Curve		
0.5% Yield		
UTS		



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.	190425172128	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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

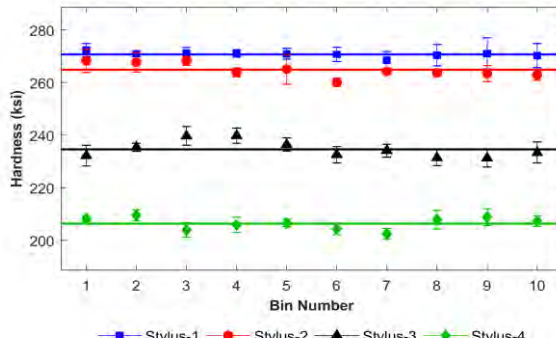
Post-Processing Ver.

2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

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.

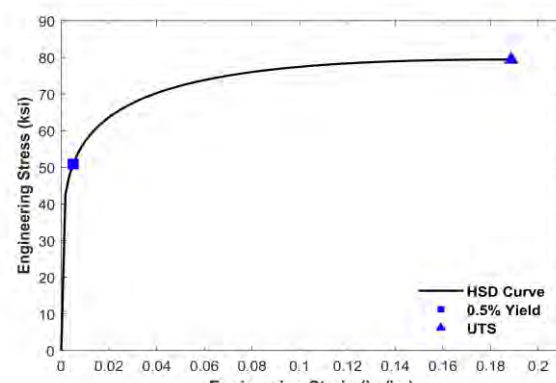
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve, which plots Engineering Stress (ksi) on the y-axis (0 to 90) against Engineering Strain (in./in.) on the x-axis (0 to 0.2). The curve starts at the origin, rises steeply to a yield point marked by a blue square at approximately (0.01, 50.9), and then continues to rise more gradually, reaching a peak marked by a red triangle at approximately (0.19, 79.4). The legend identifies the black line as the HSD Curve, the blue square as the 0.5% Yield point, and the red triangle as the UTS (Ultimate Tensile Strength) point.

Point Type	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	50.9
UTS	0.19	79.4

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.	190506125223	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	250.1	231.8	216.6	189.2
2	250.1	231.8	216.6	189.2
3	250.1	231.8	216.6	189.2
4	250.1	231.8	216.6	189.2
5	250.1	231.8	216.6	189.2
6	250.1	231.8	216.6	189.2
7	250.1	231.8	216.6	189.2
8	250.1	231.8	216.6	189.2
9	250.1	231.8	216.6	189.2
10	250.1	231.8	216.6	189.2

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

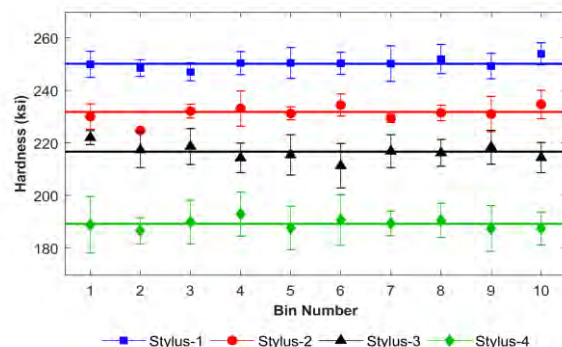
Grain Size

mli (μm)

10.1

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

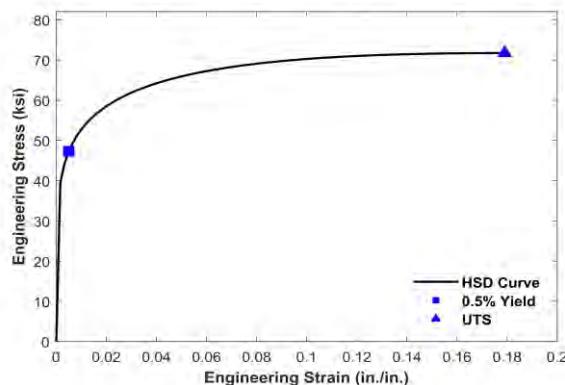
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.



Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	47.3	0.5% Yield
0.18	71.7	UTS



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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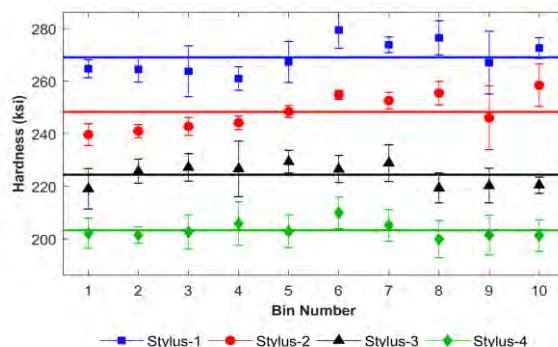
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190506145853	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

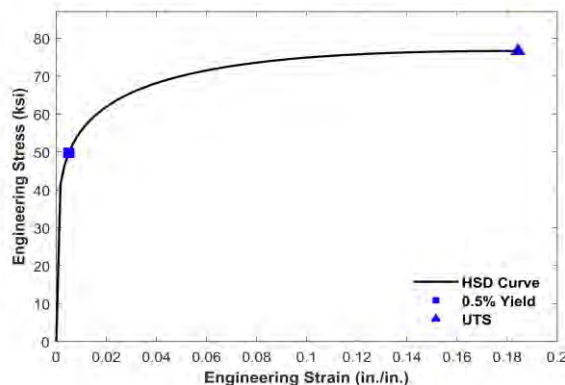
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	269.1	8.63
Stylus-2	248.3	7.79
Stylus-3	224.5	7.07
Stylus-4	203.2	6.49
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.22	0.90	< 0.005
S	Cr	Nb
0.020	0.04	< 0.01
Cu	Al	Mo
0.04	0.02	0.02
Ni	Si	Ti
0.02	0.06	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	49.8	49.6
UTS (ksi)	76.6	75.0
	Subset-2	Subset-3
	50.9	48.9
	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 Plaines, 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						
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	1.33	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 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

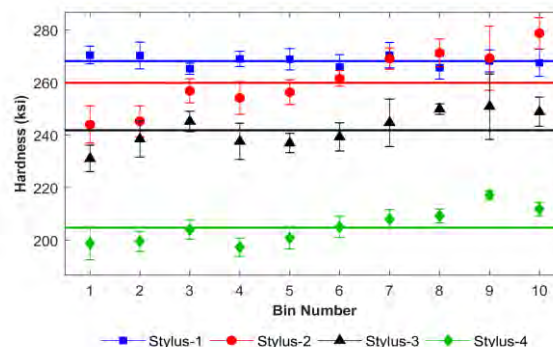
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	9.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	271	245	232	198
2	271	246	238	200
3	265	257	246	204
4	270	255	238	197
5	270	256	238	201
6	266	261	240	205
7	267	270	245	208
8	265	272	251	209
9	269	269	253	217
10	267	278	249	212

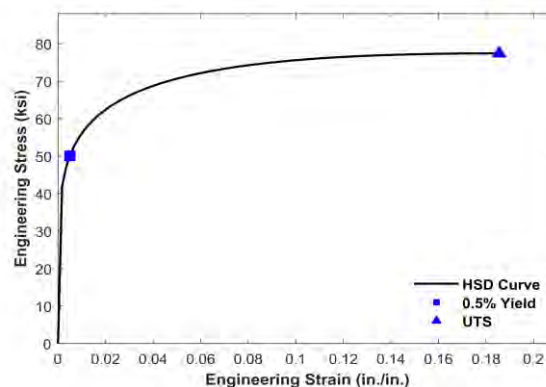


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.2 in./in. The HSD Curve is a black line showing a rapid initial increase in stress followed by a plateau. The 0.5% Yield point is marked with a blue square at approximately 0.01 in./in. strain and 50 ksi stress. The UTS (Ultimate Tensile Strength) point is marked with a blue triangle at approximately 0.18 in./in. strain and 78 ksi stress.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	50
UTS	~0.18	78



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.	190506172406	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

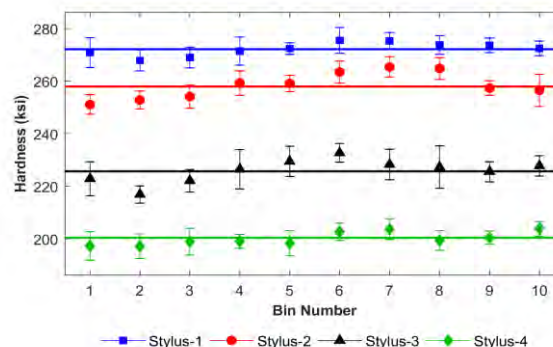
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	1.03	0.008	0.021	0.04	< 0.01	0.04	< 0.01	0.02	0.02	0.05	< 0.01	< 0.01	< 0.0005

Grain Size mli (μm)

9.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	272.2	252.0	223.0	198.0
2	269.0	253.0	218.0	197.0
3	269.0	254.0	223.0	200.0
4	272.0	259.0	228.0	199.0
5	273.0	259.0	231.0	198.0
6	276.0	264.0	234.0	203.0
7	275.0	265.0	229.0	204.0
8	274.0	265.0	227.0	200.0
9	274.0	258.0	226.0	201.0
10	273.0	257.0	229.0	204.0

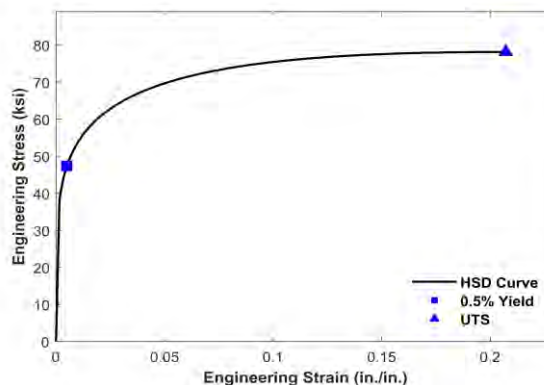


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.2). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.01, 47.4). The UTS point is marked with a blue triangle at approximately (0.21, 78.1).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	47.4
UTS	0.21	78.1



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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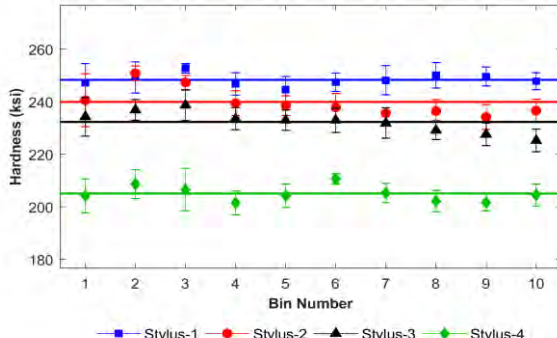
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

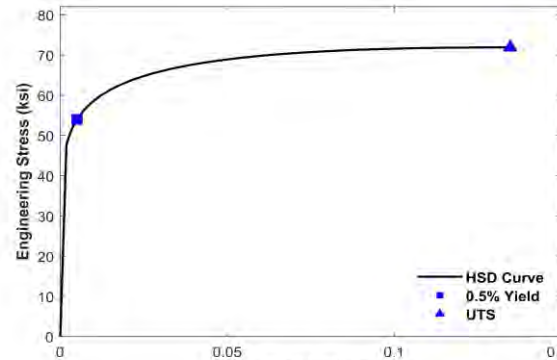
Testing Information

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 Plaines, 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						
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)
Stylus-1	248.3	4.73
Stylus-2	240.0	6.96
Stylus-3	232.3	5.85
Stylus-4	205.1	5.38
Hardness = (Stylus force)/(Contact area)		
		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.22	0.70	0.007
S	Cr	Nb
0.024	0.05	< 0.01
Cu	Al	Mo
< 0.01	< 0.01	0.02
Ni	Si	Ti
0.01	0.04	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	53.9	54.6
UTS (ksi)	71.9	72.9
	Subset-2	Subset-3
	54.8	52.7
	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

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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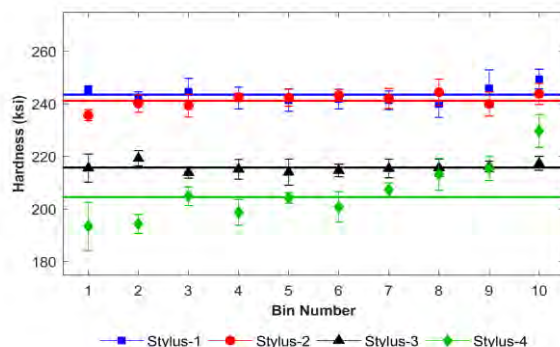
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522141919	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

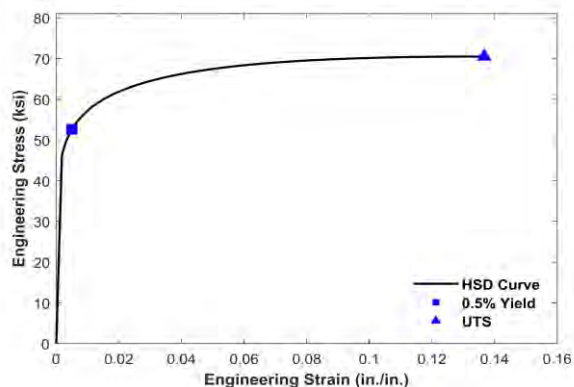
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	243.4	4.68
Stylus-2	241.1	4.07
Stylus-3	215.6	3.58
Stylus-4	204.5	10.35
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.22	0.70	0.007
S	Cr	Nb
0.024	0.05	< 0.01
Cu	Al	Mo
< 0.01	< 0.01	0.02
Ni	Si	Ti
0.01	0.04	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	52.6	50.3
UTS (ksi)	70.5	70.9
	Subset-2	Subset-3
	53.4	58.1
	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

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.	190506133345	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

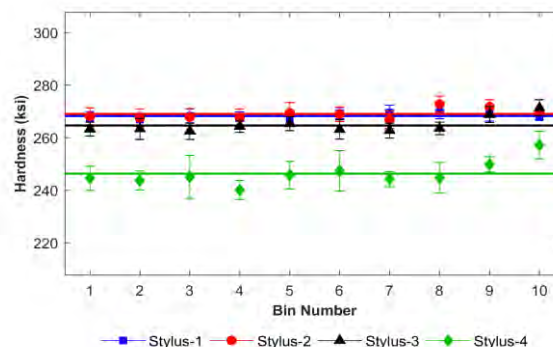
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	6.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	268.2	269.0	264.6	246.3
2	268.5	268.8	264.8	246.5
3	269.0	269.2	265.0	246.8
4	269.5	269.5	265.2	247.0
5	270.0	270.0	265.5	247.2
6	270.5	270.5	265.8	247.5
7	271.0	271.0	266.0	247.8
8	271.5	271.5	266.2	248.0
9	272.0	272.0	266.5	248.2
10	272.5	272.5	266.8	248.5



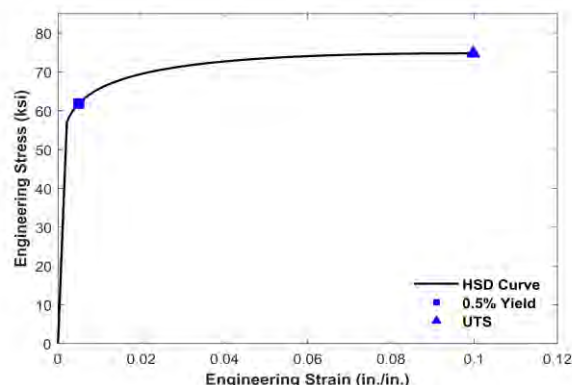
Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>61.8</u>	<u>61.2</u>	<u>61.6</u>	<u>63.1</u>
UTS (ksi)	<u>74.8</u>	<u>74.5</u>	<u>74.7</u>	<u>75.1</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend: HSD Curve, 0.5% Yield, UTS



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.	190425162217	REV --
Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

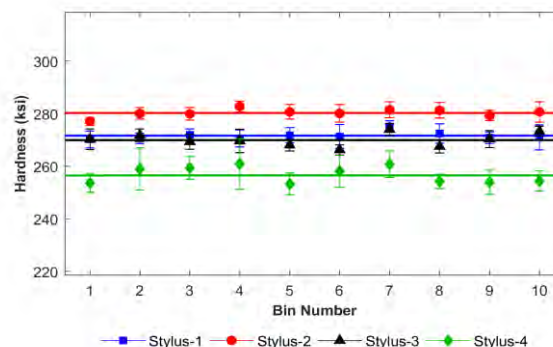
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	6.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	270	278	270	255
2	271	280	271	260
3	271	280	270	260
4	271	282	270	261
5	271	280	269	254
6	271	280	268	258
7	271	281	275	261
8	271	281	269	255
9	271	280	270	255
10	271	281	274	256

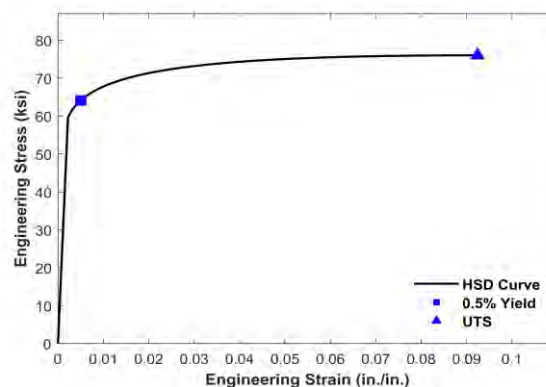


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.1 in increments of 0.01. A solid black line represents the HSD Curve, which rises steeply from the origin and then levels off. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 64.1). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) point at approximately (0.09, 76.0).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	64.1
UTS	0.09	76.0



Comments

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



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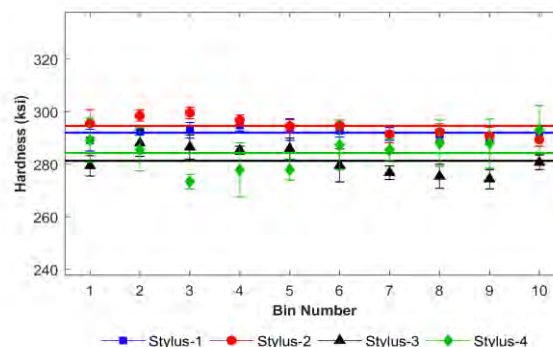
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529163957	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

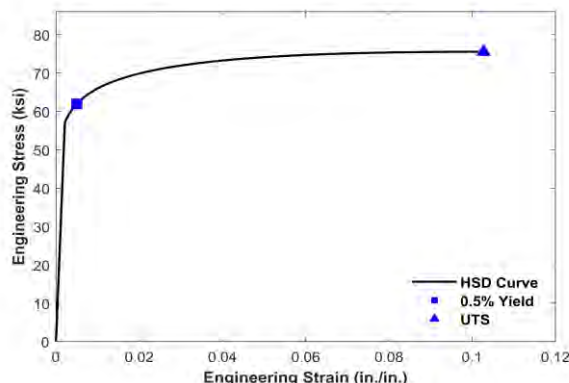
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	292.0	2.92
Stylus-2	294.6	4.18
Stylus-3	281.3	5.98
Stylus-4	284.3	9.40
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.10	0.73	0.005
S	Cr	Nb
0.018	0.01	0.03
Cu	Al	Mo
0.03	0.05	< 0.01
Ni	Si	Ti
0.01	0.02	< 0.01
V	B	
< 0.01	< 0.0005	
Grain Size		
mli (μm)		
7.4		



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc	
Tensile Properties	Overall	Subset-1
0.5% EUL Yield (ksi)	62.0	68.4
UTS (ksi)	75.5	75.7
The overall results are calculated using the entire sample size.		
Each subset is calculated using one-third of the measurements		
Engineering Stress (ksi) vs Engineering Strain (in./in.)		
HSD Curve, 0.5% Yield, UTS		



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

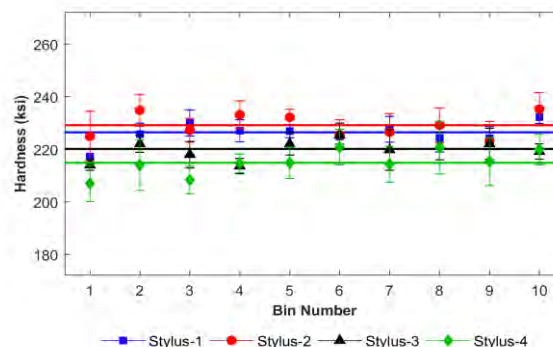
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521092648	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	9:26	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	124-Q2	Pipe 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						
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	1.33	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 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

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)
0.18	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	12.7

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

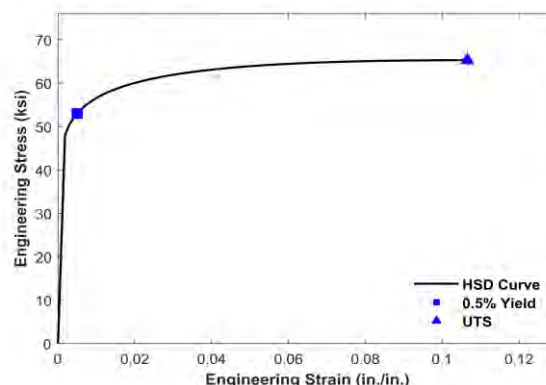
Results

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

Prepared:

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Approved:

Steven Palkovic, PhD



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

Testing Information

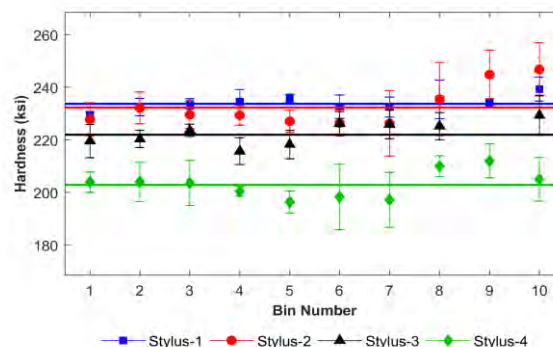
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190520125642	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	12:56	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	124-Q2	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						
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	1.33	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 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

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
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

mli (μm)
12.7

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

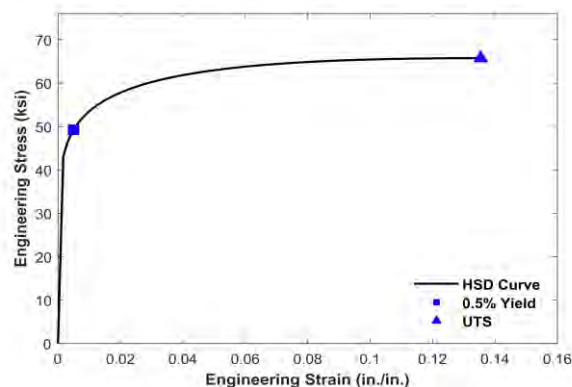
Results

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

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.	190529181230	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

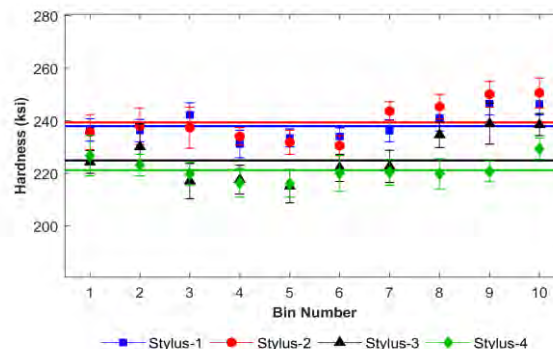
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	12.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	235	238	225	222
2	238	240	230	225
3	242	238	218	218
4	235	235	220	215
5	232	232	215	212
6	232	230	222	220
7	238	245	222	220
8	235	245	235	220
9	248	250	240	220
10	248	252	238	230



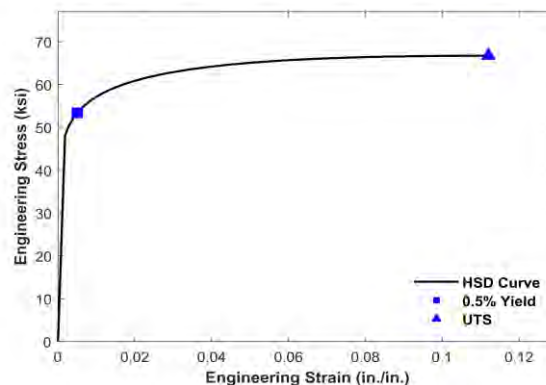
Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend: HSD Curve, 0.5% Yield, UTS



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.	190508163256	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

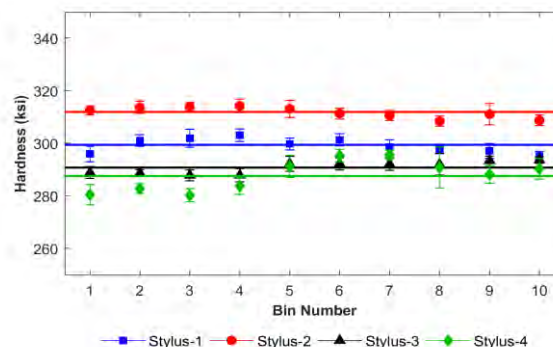
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	298	313	290	282
2	301	315	291	283
3	302	314	289	282
4	303	315	290	284
5	300	314	291	290
6	301	312	290	293
7	299	311	291	291
8	298	310	291	288
9	297	312	292	290
10	296	310	291	290

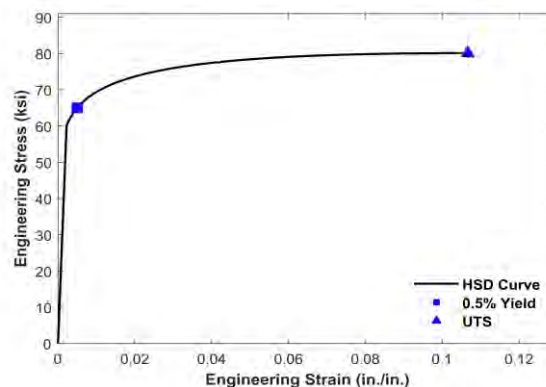


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10, and the x-axis ranges from 0 to 0.12 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 65). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.105, 80). The curve rises steeply from the origin, passes through the yield point, and then gradually levels off towards the UTS point.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	65.0
UTS	~0.105	80.1



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.	190529150105	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

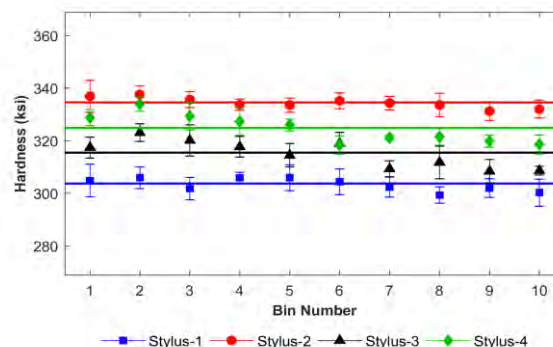
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	304.0	336.0	318.0	330.0
2	305.0	337.0	324.0	334.0
3	303.0	335.0	321.0	331.0
4	306.0	334.0	319.0	328.0
5	305.0	334.0	316.0	327.0
6	304.0	335.0	314.0	321.0
7	303.0	334.0	311.0	321.0
8	300.0	334.0	312.0	321.0
9	302.0	332.0	311.0	321.0
10	300.0	332.0	309.0	319.0

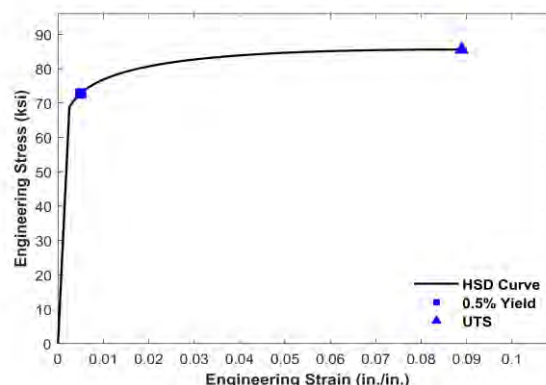


Results

Prediction Ver.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>72.8</u>	<u>73.9</u>	<u>72.4</u>	<u>71.6</u>
UTS (ksi)	<u>85.5</u>	<u>86.8</u>	<u>85.2</u>	<u>84.4</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The graph displays the stress-strain relationship for the material. The x-axis represents Engineering Strain in in./in., ranging from 0 to 0.1. The y-axis represents Engineering Stress in ksi, ranging from 0 to 90. The HSD Curve is a solid black line that rises steeply from the origin, reaching a yield point marked by a blue square at approximately 0.005 strain and 72.8 ksi. The curve then continues to rise, reaching a peak marked by a blue triangle at approximately 0.088 strain and 85.5 ksi, before slightly declining.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	72.8
UTS	~0.088	85.5



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.	190531114611	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

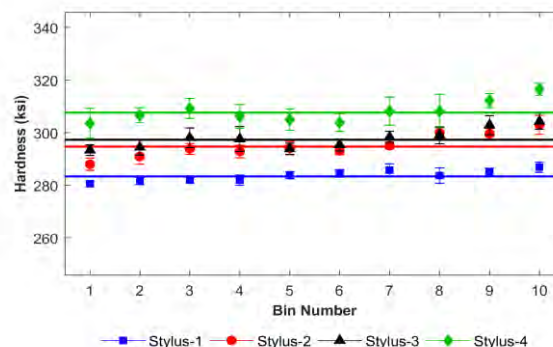
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	5.8

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	281.0	287.0	293.0	304.0
2	281.0	290.0	297.0	307.0
3	281.0	294.0	300.0	310.0
4	281.0	292.0	296.0	307.0
5	283.0	294.0	296.0	306.0
6	284.0	295.0	297.0	305.0
7	286.0	296.0	299.0	309.0
8	284.0	299.0	300.0	310.0
9	285.0	301.0	302.0	313.0
10	287.0	303.0	304.0	317.0

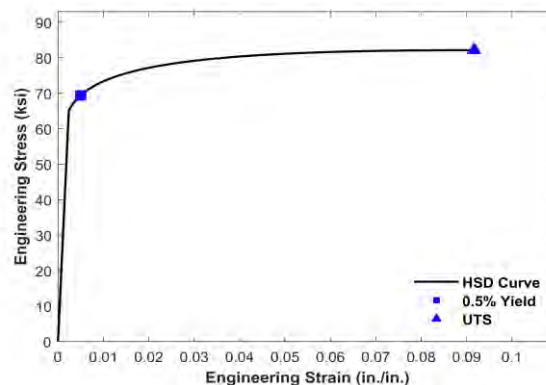


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 90 in increments of 10, and the x-axis ranges from 0 to 0.1 in increments of 0.01. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 70). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.09, 82). The curve rises steeply from the origin, passes through the yield point, and then gradually levels off towards the UTS point.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~70
UTS	~0.09	~82



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.	190506171006	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

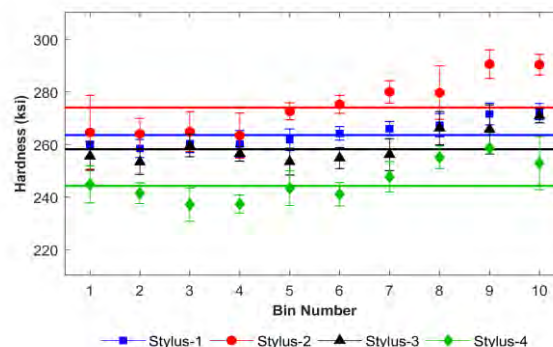
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	10.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	260	265	258	245
2	261	264	259	242
3	262	265	260	238
4	261	264	258	238
5	263	273	257	243
6	264	276	256	241
7	265	280	257	248
8	266	280	267	255
9	267	292	270	259
10	267	292	272	253

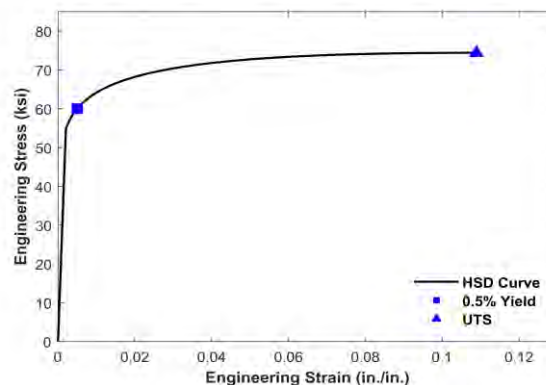


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>60.0</u>	<u>59.7</u>	<u>59.1</u>	<u>61.9</u>
UTS (ksi)	<u>74.4</u>	<u>73.6</u>	<u>74.0</u>	<u>75.8</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.12 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point at approximately (0.005, 60), and then gradually levels off, reaching a peak at approximately (0.11, 74.4). A blue square marker is placed on the curve at the 0.5% yield point (0.005, 60). A blue triangle marker is placed at the end of the curve, representing the Ultimate Tensile Strength (UTS) at approximately (0.11, 74.4).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	60.0
UTS	0.11	74.4



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.	190506180031	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

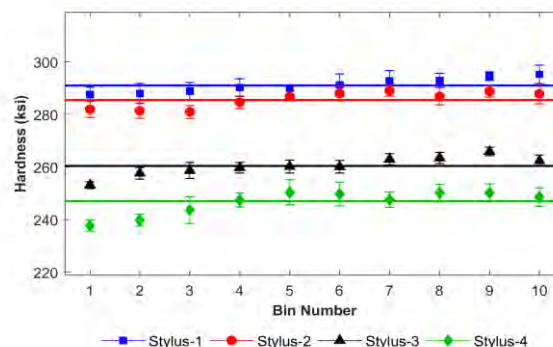
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	10.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	291.0	285.4	260.3	247.0
2	291.0	285.4	260.3	247.0
3	291.0	285.4	260.3	247.0
4	291.0	285.4	260.3	247.0
5	291.0	285.4	260.3	247.0
6	291.0	285.4	260.3	247.0
7	291.0	285.4	260.3	247.0
8	291.0	285.4	260.3	247.0
9	291.0	285.4	260.3	247.0
10	291.0	285.4	260.3	247.0

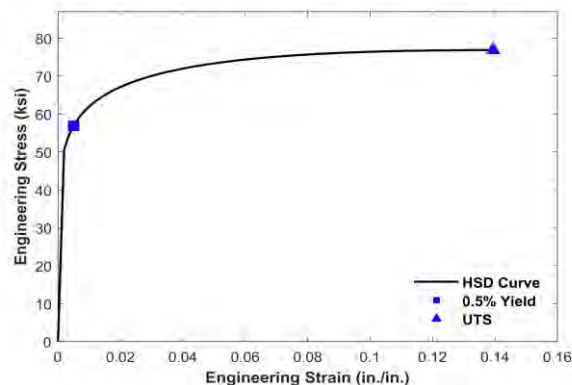


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the HSD Curve, plotting Engineering Stress (ksi) on the y-axis (0 to 80) against Engineering Strain (in./in.) on the x-axis (0 to 0.16). The curve starts at the origin, rises steeply to a yield point marked with a blue square at approximately (0.005, 56.9), then continues to rise more gradually, reaching a peak marked with a blue triangle at approximately (0.14, 76.9). The legend identifies the solid line as the HSD Curve, the blue square as the 0.5% Yield point, and the blue triangle as the UTS point.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	56.9
UTS	0.14	76.9



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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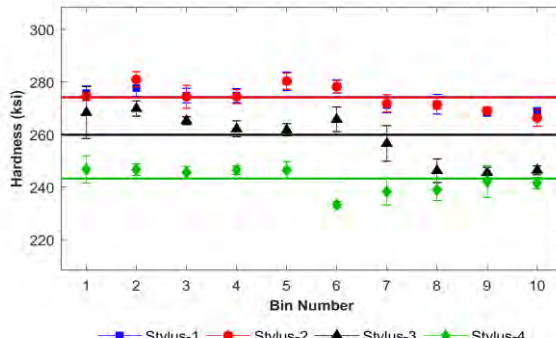
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

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 Plaines, 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						
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	1.33	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

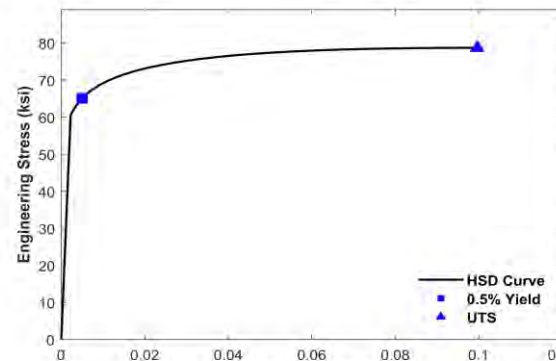
Post-Processing Ver.	2.2													
HSD Stylus Hardness														
	Average (ksi)	Std. Dev. (ksi)	Sample Size											
Stylus-1	274.2	4.58	51											
Stylus-2	274.2	5.14	51											
Stylus-3	259.9	9.46	46											
Stylus-4	243.2	5.19	46											
Hardness = (Stylus force)/(Contact area)														
														
Base Metal Chemical Composition (wt. %)														
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve (black line) and the 0.5% Yield point (blue square) and UTS (blue triangle). The Y-axis represents Engineering Stress (ksi) from 0 to 80, and the X-axis represents Engineering Strain (in./in.) from 0 to 0.12. The curve shows a rapid increase in stress up to the yield point, followed by a gradual increase to the UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	65.1
UTS	~0.10	78.7

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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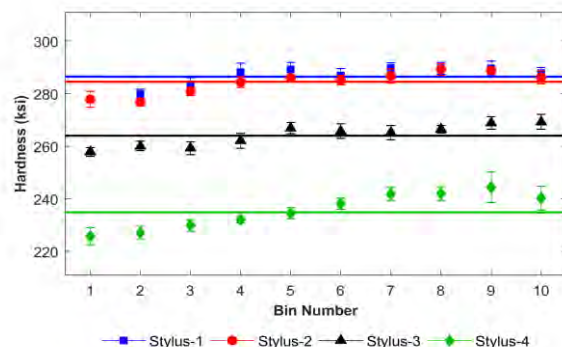
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530202522	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	286.5	4.49
Stylus-2	284.5	4.24
Stylus-3	264.0	4.50
Stylus-4	234.9	6.85
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.07	0.95	0.008
S	Cr	Nb
0.013	0.01	0.05
Cu	Al	Mo
0.02	0.03	< 0.01
Ni	Si	Ti
0.01	0.02	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).

The graph displays the Engineering Stress (ksi) on the y-axis (0 to 90) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 61.1). The UTS point is marked with a blue triangle at approximately (0.135, 82.1).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	61.1
UTS	0.135	82.1

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

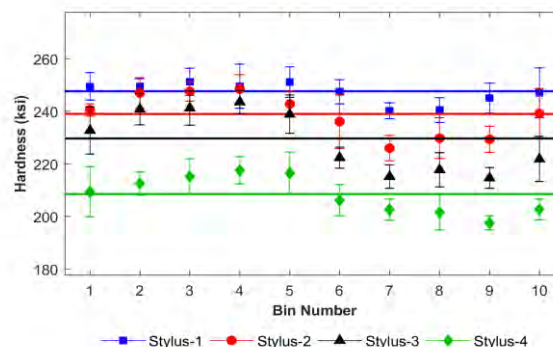
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190531110826	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	11:08	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	130-Q1	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						
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	1.33	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 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. %)

Grain Size

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

mli (μm)
14.9

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

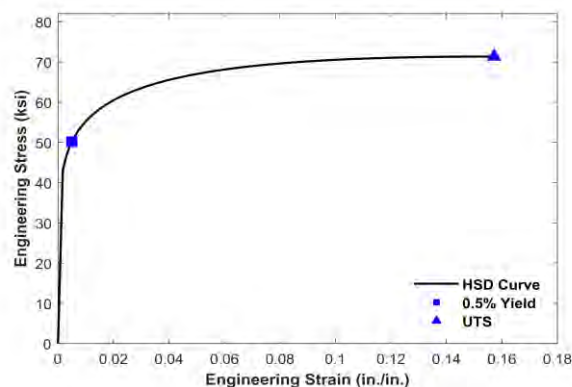
Results

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

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.	190531112344	REV --
Test Location	Gas Technology Institute			Test Date	5/31/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

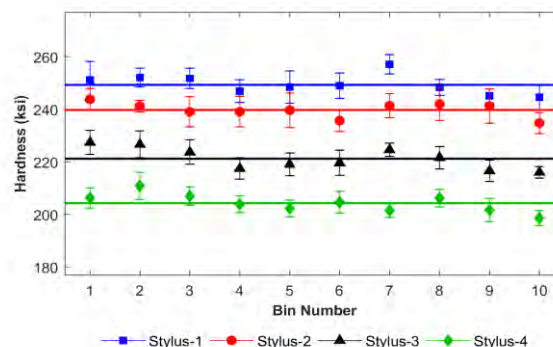
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	14.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	250	242	228	206
2	252	242	228	210
3	251	240	224	207
4	247	240	218	204
5	248	240	220	203
6	249	236	220	204
7	258	242	225	202
8	248	242	222	206
9	244	242	218	202
10	245	235	217	199

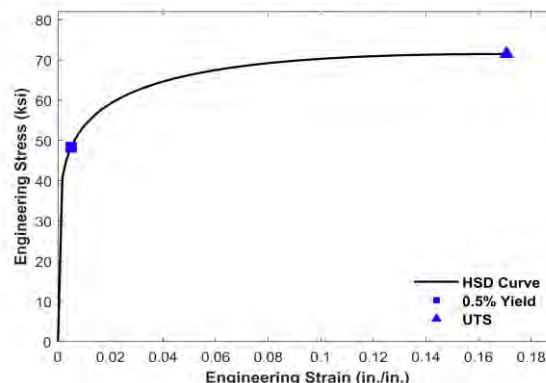


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.18 in./in. in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.005, 48.3). The UTS point is marked with a blue triangle at approximately (0.165, 71.5). A legend in the bottom right corner identifies the HSD Curve, 0.5% Yield, and UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	48.3
UTS	~0.165	71.5



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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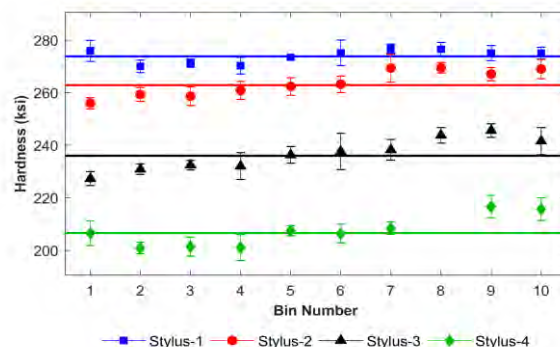
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509163316	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	273.7	3.61
Stylus-2	262.9	5.54
Stylus-3	236.0	6.68
Stylus-4	206.5	6.33
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.26	0.82	0.011
S	Cr	Nb
0.034	0.02	< 0.01
Cu	Al	Mo
0.02	0.01	< 0.01
Ni	Si	Ti
0.01	0.05	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays a stress-strain curve for a material. The y-axis represents Engineering Stress in ksi, ranging from 0 to 90. The x-axis represents Engineering Strain in in./in., ranging from 0 to 0.2. A solid black line represents the HSD Curve. A blue square marks the 0.5% Yield point at approximately 50 ksi stress and 0.01 in./in. strain. A blue triangle marks the UTS (Ultimate Tensile Strength) point at approximately 80 ksi stress and 0.19 in./in. strain.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~50
UTS	~0.19	~80

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.	190520121540	REV --
Test Location	Gas Technology Institute			Test Date	5/20/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	256.0	265.0	228.0	204.0
2	262.0	268.0	230.0	208.0
3	262.0	267.0	225.0	209.0
4	261.0	265.0	230.0	207.0
5	262.0	268.0	232.0	208.0
6	258.0	265.0	228.0	210.0
7	253.0	265.0	228.0	206.0
8	256.0	269.0	232.0	211.0
9	252.0	266.0	229.0	209.0
10	252.0	271.0	232.0	211.0

Base Metal Chemical Composition (wt. %)

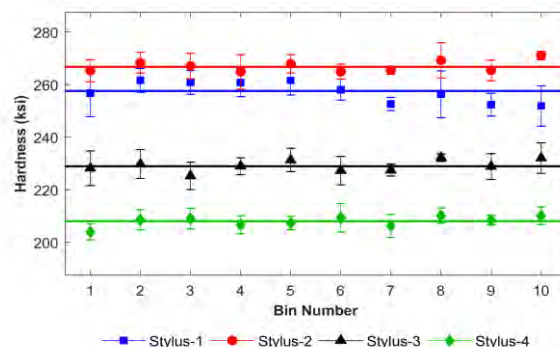
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.26	0.82	0.011	0.034	0.02	< 0.01	0.02	0.01	< 0.01	0.01	0.05	< 0.01	< 0.01	< 0.0005

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

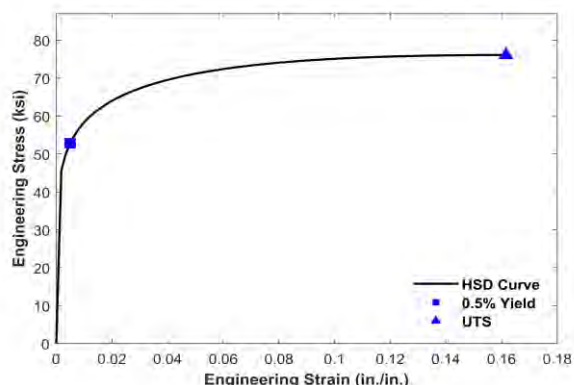
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	52.8	52.3	52.3	53.9
UTS (ksi)	76.1	76.7	76.4	75.3

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).

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.18 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately 0.01 in./in. strain and 53 ksi stress. The UTS point is marked with a blue triangle at approximately 0.16 in./in. strain and 76 ksi stress.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	53	0.5% Yield
0.16	76	UTS



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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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.	190506180859	REV --
Test Location	Gas Technology Institute			Test Date	5/6/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

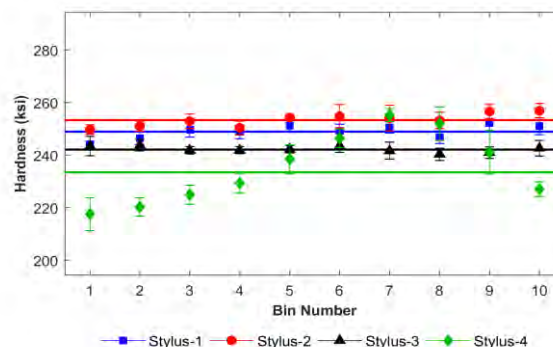
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.4

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	248.0	250.0	245.0	218.0
2	249.0	251.0	246.0	221.0
3	248.0	252.0	244.0	226.0
4	249.0	251.0	243.0	230.0
5	249.0	253.0	244.0	240.0
6	249.0	254.0	246.0	246.0
7	249.0	253.0	243.0	255.0
8	249.0	254.0	242.0	253.0
9	249.0	256.0	241.0	241.0
10	249.0	257.0	244.0	228.0

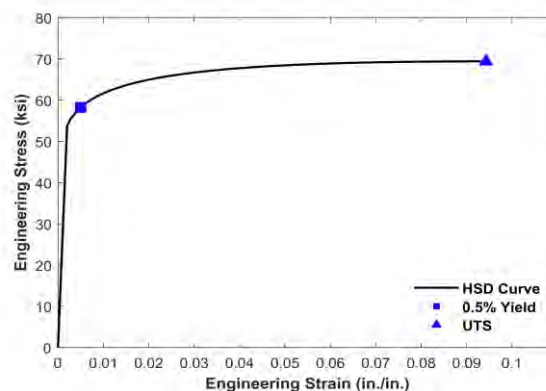


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.1 in./in. in increments of 0.01. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.005 strain and 58.2 ksi. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.095 strain and 70 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	58.2
UTS	~0.095	70



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.	190530200643	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

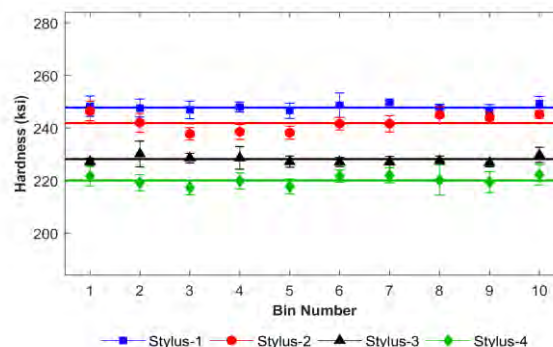
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	248.0	242.0	228.0	220.0
2	247.5	241.5	227.5	219.5
3	247.0	241.0	227.0	219.0
4	247.5	241.5	227.5	219.5
5	247.0	241.0	227.0	219.0
6	247.5	241.5	227.5	219.5
7	247.0	241.0	227.0	219.0
8	247.5	241.5	227.5	219.5
9	247.0	241.0	227.0	219.0
10	247.5	241.5	227.5	219.5

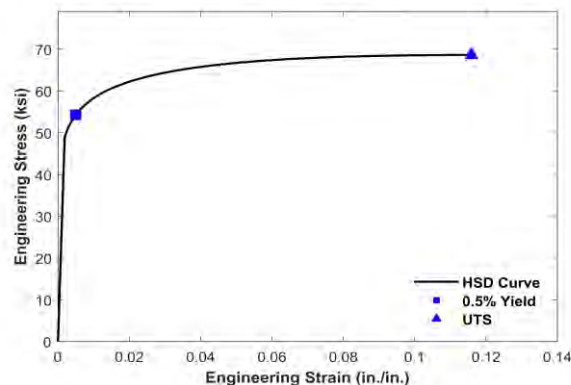


Results

Prediction Ver.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>54.3</u>	<u>54.3</u>	<u>54.4</u>	<u>54.3</u>
UTS (ksi)	<u>68.6</u>	<u>68.7</u>	<u>68.4</u>	<u>68.7</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 70) versus Engineering Strain (in./in.) on the x-axis (0 to 0.14). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 54.3). The UTS point is marked with a blue triangle at approximately (0.115, 68.7).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	54.3
UTS	0.115	68.7



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.	190507143347	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

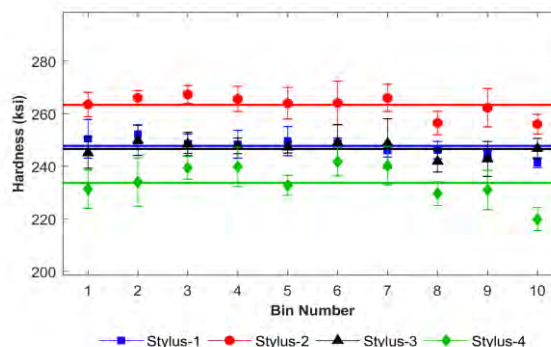
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	248	265	247	233
2	248	266	247	234
3	248	268	248	234
4	248	266	248	240
5	248	265	248	233
6	248	265	248	241
7	248	267	248	240
8	247	257	245	230
9	246	263	246	231
10	243	256	248	220

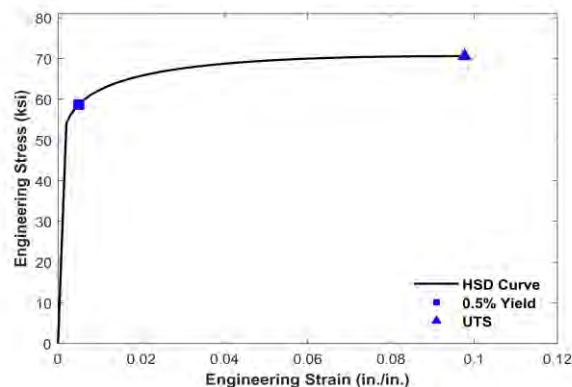


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.12 in./in. The HSD Curve (black line) shows a rapid increase in stress up to the 0.5% Yield point, followed by a gradual increase to the UTS point. The 0.5% Yield point is marked with a blue square at approximately 0.005 in./in. strain and 58.7 ksi. The UTS point is marked with a blue triangle at approximately 0.095 in./in. strain and 71.0 ksi.

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	58.7	0.005
UTS	71.0	0.095



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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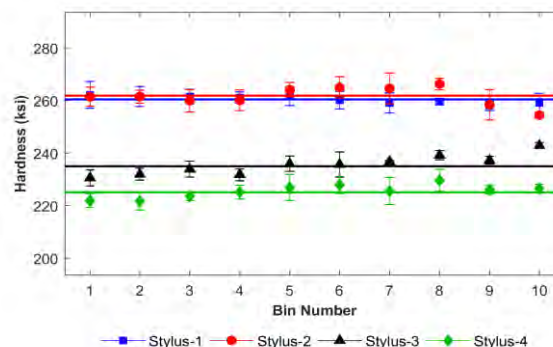
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190507122145	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	260.4	3.28
Stylus-2	261.8	4.72
Stylus-3	235.0	4.08
Stylus-4	225.1	3.83
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.54	0.011
S	Cr	Nb
0.020	0.01	< 0.01
Cu	Al	Mo
0.05	0.02	< 0.01
Ni	Si	Ti
0.02	0.01	< 0.01
V	B	
< 0.01	< 0.0005	
Base metal chemical composition is measured through laboratory testing of burrs removed from the pipe surface.		
Grain Size		
mli (μm)		
7.9		

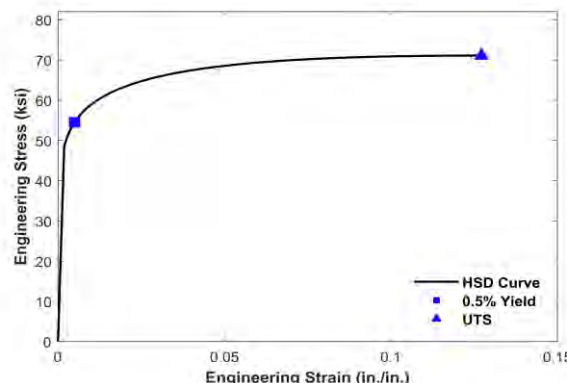


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.15 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 54.5). The UTS point is marked with a blue triangle at approximately (0.12, 71.1).

Property	Value (ksi)	Strain (in./in.)
0.5% Yield	54.5	0.005
UTS	71.1	0.12



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.	190509162929	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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. %)

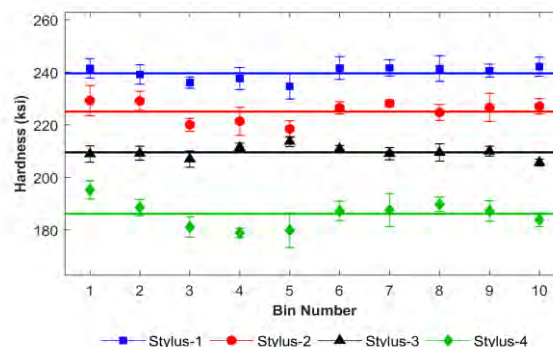
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.54	0.011	0.020	0.01	< 0.01	0.05	0.02	< 0.01	0.02	0.01	< 0.01	< 0.01	< 0.0005

Grain Size mli (μm)

7.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	242	230	210	195
2	240	230	210	190
3	238	220	208	182
4	238	222	212	180
5	235	218	215	180
6	242	228	212	188
7	242	230	210	188
8	242	225	210	190
9	240	228	210	188
10	242	228	208	185

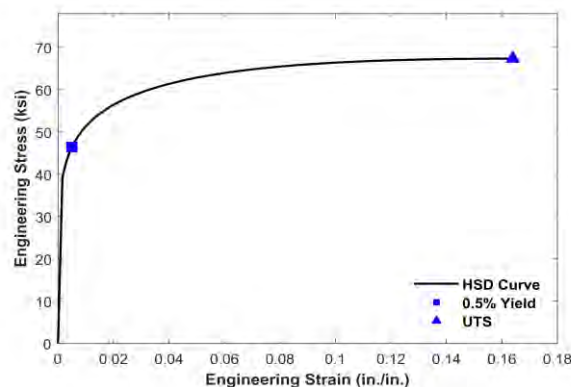


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>46.5</u>	<u>47.3</u>	<u>45.9</u>	<u>46.3</u>
UTS (ksi)	<u>67.4</u>	<u>67.1</u>	<u>67.3</u>	<u>67.7</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.18 in./in. The HSD Curve is a solid black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.01, 46). The UTS point is marked with a blue triangle at approximately (0.16, 67).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~46
UTS	~0.16	~67



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.	190507132335	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				

The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 90) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The curve starts at the origin, rises steeply to a yield point of approximately 59 ksi at 0.01 strain, then continues to a UTS of approximately 80 ksi at 0.14 strain. Markers indicate the 0.5% Yield point and the UTS.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	59.0	0.5% Yield
0.14	80.5	UTS

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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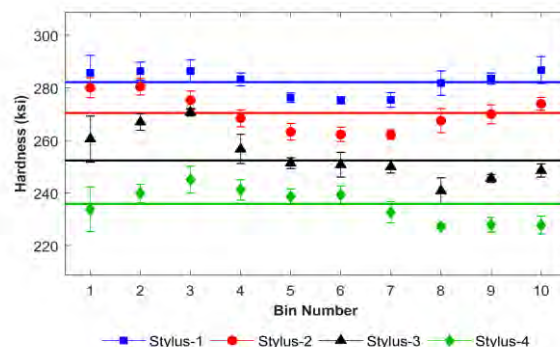
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530194751	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

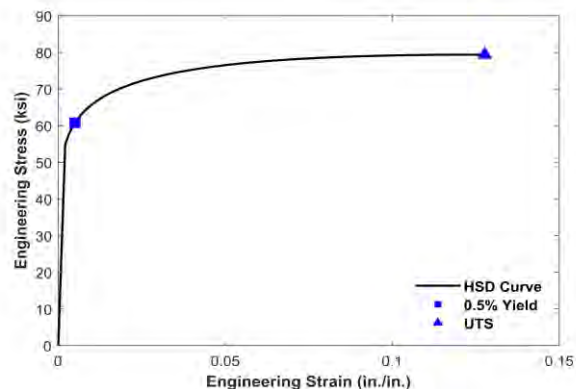
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	282.2	5.73
Stylus-2	270.4	7.34
Stylus-3	252.4	8.75
Stylus-4	235.8	7.25
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.24	1.06	0.016
S	Cr	Nb
0.022	0.03	< 0.01
Cu	Al	Mo
< 0.01	0.01	< 0.01
Ni	Si	Ti
0.04	0.04	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	60.8	62.6
UTS (ksi)	79.4	81.1
	Subset-2	Subset-3
	62.6	57.8
	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

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.	190529184330	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

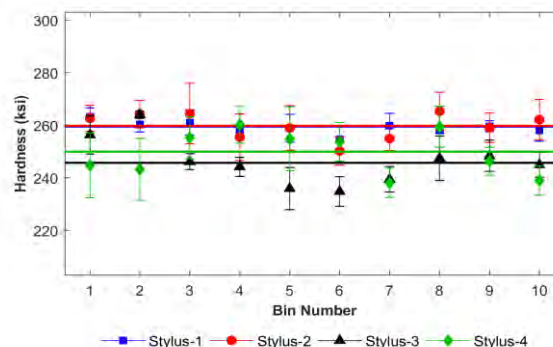
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	260.0	265.0	245.0	245.0
2	260.0	265.0	245.0	245.0
3	260.0	265.0	245.0	245.0
4	260.0	265.0	245.0	245.0
5	260.0	265.0	245.0	245.0
6	260.0	265.0	245.0	245.0
7	260.0	265.0	245.0	245.0
8	260.0	265.0	245.0	245.0
9	260.0	265.0	245.0	245.0
10	260.0	265.0	245.0	245.0

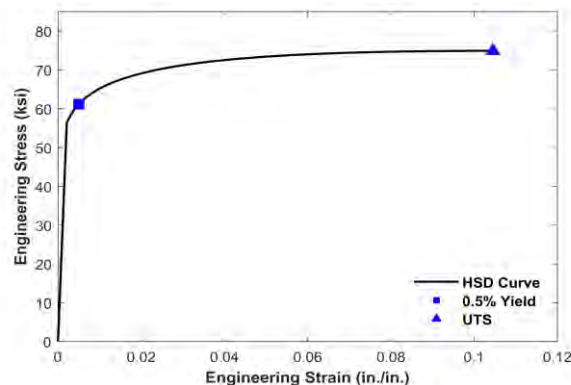


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.12 in./in. The HSD Curve is a black line showing the material's response. The 0.5% Yield point is marked with a blue square at approximately 0.005 strain and 61.1 ksi. The UTS point is marked with a blue triangle at approximately 0.105 strain and 74.9 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	61.1
UTS	~0.105	74.9



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Massachusetts Materials Technologies LLC

167 Prospect Street, Unit 4

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617-502-5636

HSD@byMMT.com

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 Plaines, 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						
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	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

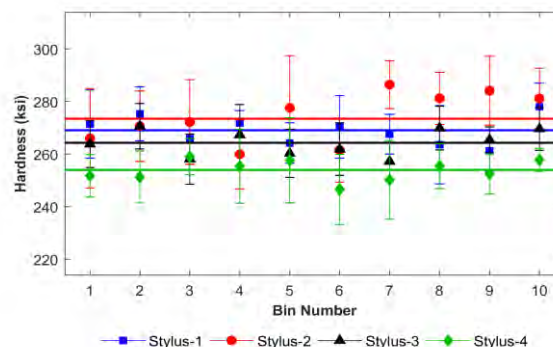
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.7

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	270	265	265	255
2	275	270	265	255
3	270	270	260	258
4	270	260	268	255
5	270	278	265	258
6	272	262	260	248
7	270	285	258	252
8	265	282	270	255
9	262	285	265	252
10	278	280	270	258

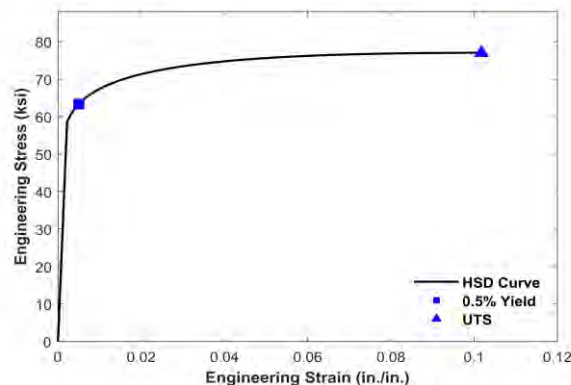


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10, and the x-axis ranges from 0 to 0.12 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually increases to a peak before slightly declining. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 63.3). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) point at approximately (0.1, 77.1).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	63.3
UTS	0.1	77.1



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.	190522102959	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	2.80002	in/min		Stylus-2 Serial No.	105-190412	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

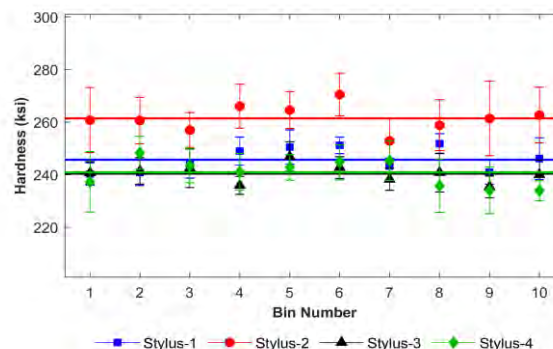
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

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



Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.20	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.

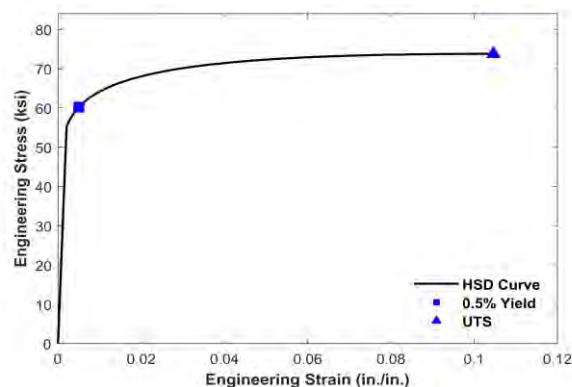
Results

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

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.	190529171522	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver. 2.2

HSD Stylus Hardness

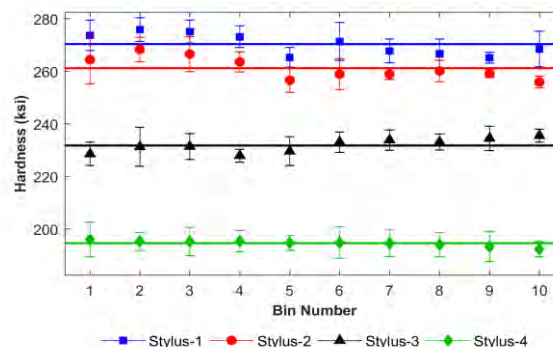
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	270.3	6.13	67
Stylus-2	261.2	6.03	65
Stylus-3	231.8	4.84	62
Stylus-4	194.6	4.48	61

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
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	9.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	275	265	228	195
2	278	268	232	195
3	275	266	231	195
4	275	264	228	195
5	265	256	230	195
6	272	259	233	195
7	267	259	233	194
8	266	260	234	194
9	265	259	235	194
10	268	256	236	193

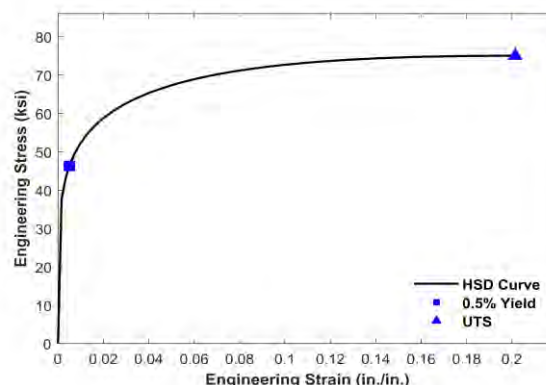


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi with increments of 10. The x-axis ranges from 0 to 0.2 in./in. with increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.01 in./in. strain and 46 ksi stress. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.2 in./in. strain and 75 ksi stress.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~46
UTS	~0.20	~75



Comments

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

Parth Patel

Approved:

Steven Palkovic, PhD



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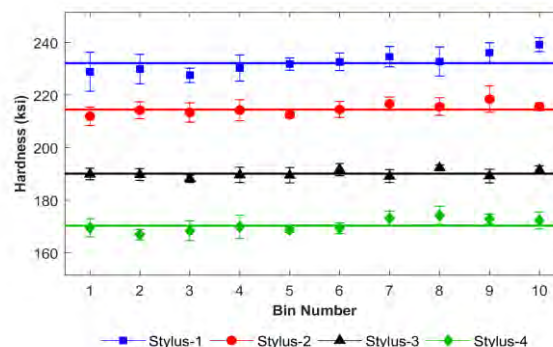
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522113910	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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)
Stylus-1	232.2	5.29
Stylus-2	214.5	3.47
Stylus-3	190.0	2.38
Stylus-4	170.3	3.54
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.24	0.52	0.009
S	Cr	Nb
0.021	0.01	< 0.01
Cu	Al	Mo
< 0.01	0.02	< 0.01
Ni	Si	Ti
0.02	0.10	< 0.01
V	B	
< 0.01	< 0.0005	
Grain Size		mli (μm)
		9.9

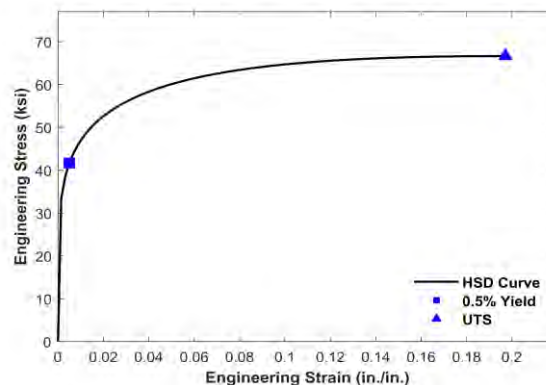


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 70 ksi, and the x-axis ranges from 0 to 0.2 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately 0.01 in./in. strain and 41.6 ksi. The UTS point is marked with a blue triangle at approximately 0.19 in./in. strain and 66.6 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	41.6
UTS	0.19	66.6



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.	190521095816	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

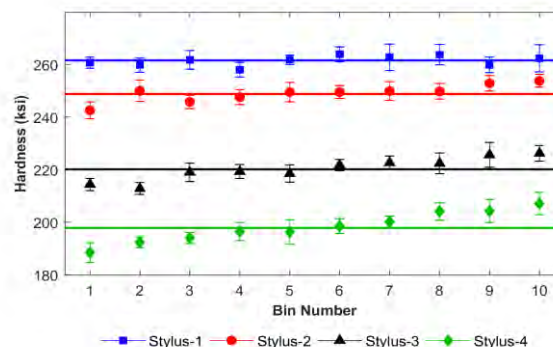
Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	261.5	248.8	215	190
2	261.5	248.8	213	192
3	261.5	248.8	220	195
4	261.5	248.8	220	197
5	261.5	248.8	219	196
6	261.5	248.8	222	199
7	261.5	248.8	223	200
8	261.5	248.8	223	203
9	261.5	248.8	226	204
10	261.5	248.8	226	205

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	10.5

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

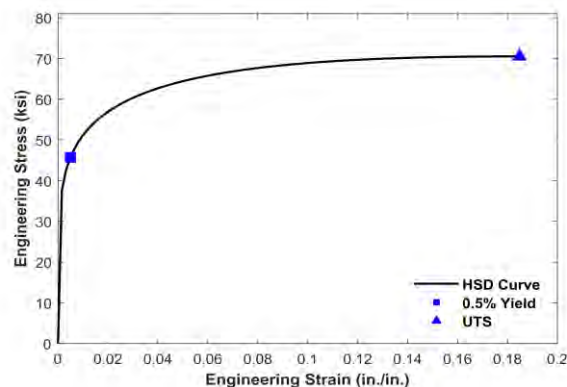


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 45.7). A blue triangle marker indicates the UTS point at approximately (0.18, 70.5).

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~45.7
UTS	~0.18	~70.5



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.	190507152045	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

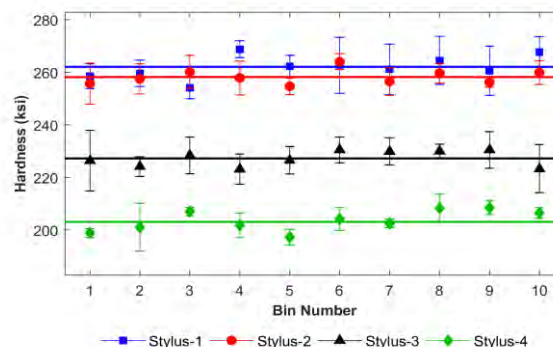
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	10.5

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	260	255	227	200
2	260	258	225	201
3	255	260	229	207
4	270	258	223	202
5	263	255	227	198
6	265	264	232	204
7	261	257	231	202
8	265	260	232	208
9	261	256	232	208
10	268	260	223	206

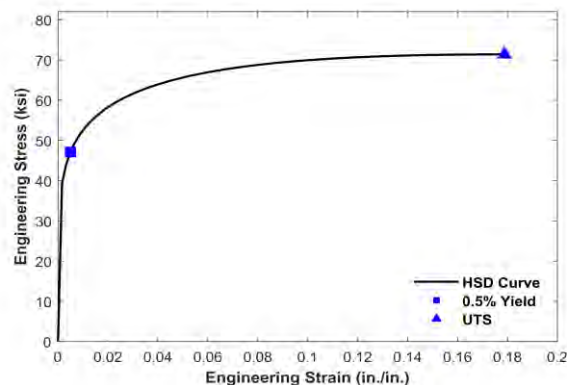


Results

Prediction Ver.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>47.1</u>	<u>46.7</u>	<u>47.0</u>	<u>47.6</u>
UTS (ksi)	<u>71.4</u>	<u>70.8</u>	<u>71.3</u>	<u>71.5</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.02. A black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marks the 0.5% Yield point at approximately (0.005, 47). A blue triangle marks the UTS point at approximately (0.175, 71). The legend in the bottom right corner identifies these elements: HSD Curve, 0.5% Yield, and UTS.

Point Type	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~47
UTS	~0.175	~71



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Massachusetts Materials Technologies LLC

167 Prospect Street, Unit 4

Waltham, MA 02453

617-502-5636

HSD@byMMT.com

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 Plaines, 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						
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	1.33	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 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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	265	270	253	233
2	264	268	252	232
3	263	270	253	233
4	262	271	251	234
5	261	270	250	233
6	260	268	250	232
7	259	270	249	231
8	258	267	250	229
9	257	272	254	231
10	256	268	249	233

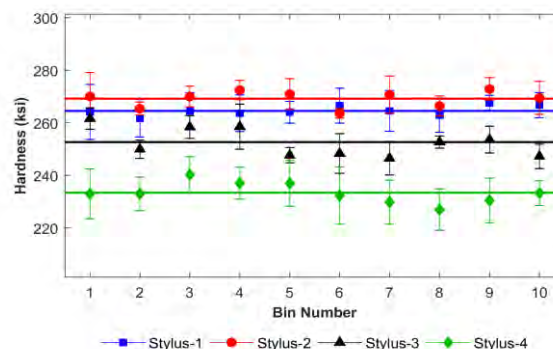
Base Metal Chemical Composition (wt. %)

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.

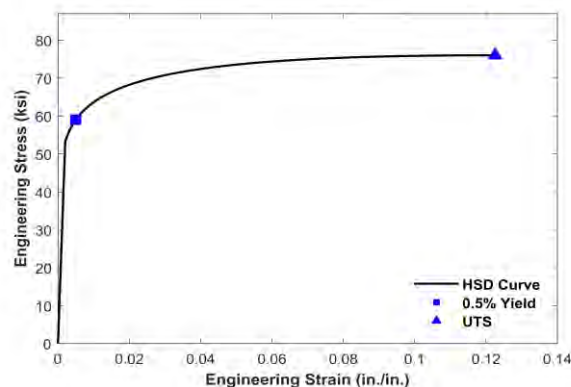


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10, and the x-axis ranges from 0 to 0.14 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off. A blue square marker is placed on the curve at approximately (0.005, 59), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.12, 76), representing the UTS (Ultimate Tensile Strength) point.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~59
UTS	~0.12	~76



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.	190509173130	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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. %)

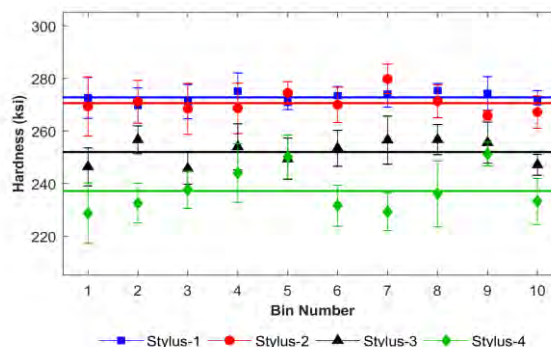
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.23	0.96	0.008	0.025	0.03	< 0.01	0.02	0.01	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.0005

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

Grain Size mli (μm)

6.3

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	272	270	248	228
2	272	271	258	233
3	272	270	245	238
4	275	271	253	243
5	272	274	250	248
6	273	271	253	231
7	273	279	256	228
8	273	273	256	236
9	274	266	252	253
10	272	268	246	233

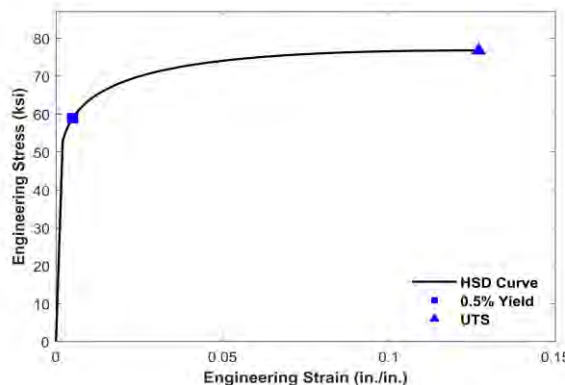


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.15). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.01, 59). The UTS point is marked with a blue triangle at approximately (0.13, 77).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~59
UTS	~0.13	~77



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

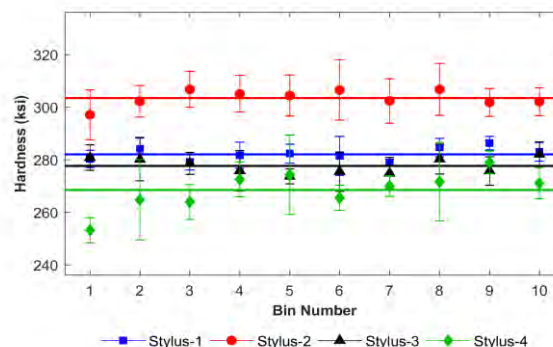
Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190530161145	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	16:11	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	141-Q1	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						
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	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. %)

Grain Size

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

mli (μm)
7.8

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

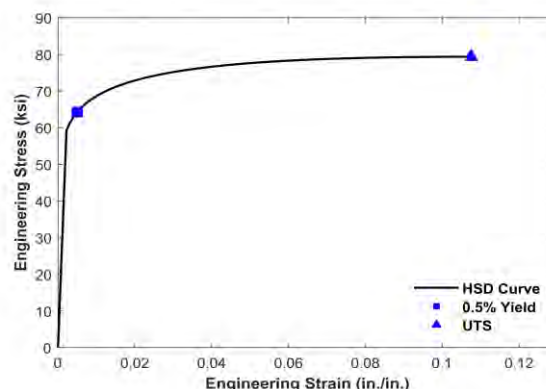
Results

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

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.	190529152443	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

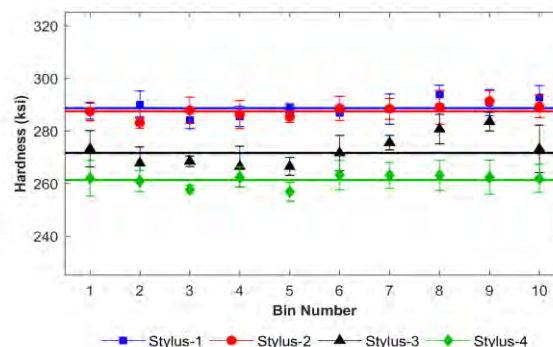
Measurements

Post-Processing 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. %)

Grain Size

mli (μm)

7.8

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

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

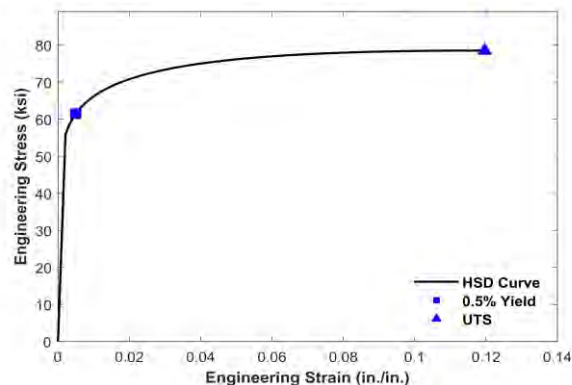
Results

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

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.	190529173923	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

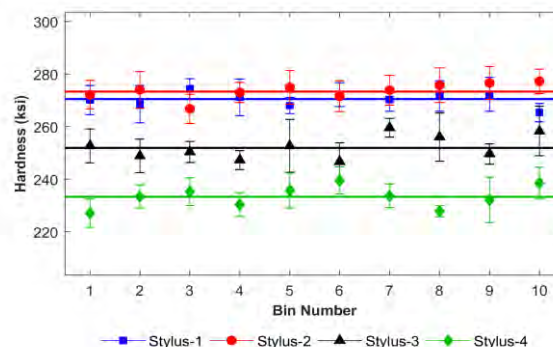
Measurements

Post-Processing 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. %)

Grain Size

mli (μm)

15.9

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

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

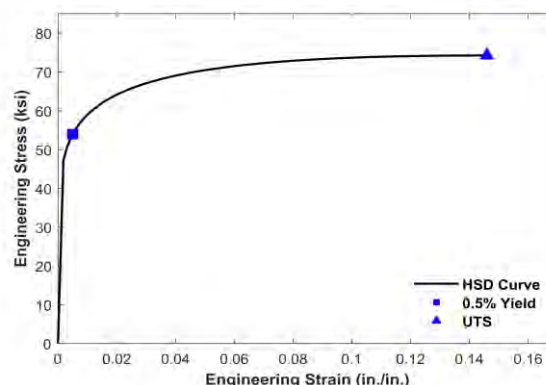
Results

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

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.	190522121501	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

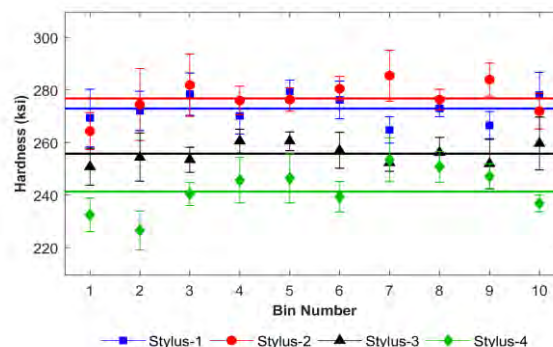
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	15.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	270	268	250	232
2	273	275	255	228
3	278	282	254	241
4	272	276	261	245
5	276	277	262	246
6	277	281	257	240
7	265	285	253	251
8	274	276	256	250
9	266	284	253	247
10	278	272	260	238

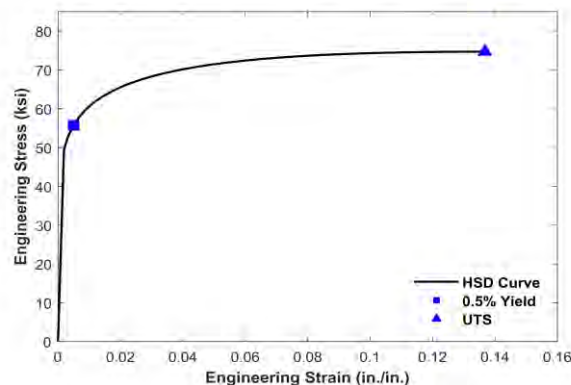


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 55.7). The UTS point is marked with a blue triangle at approximately (0.135, 74.7).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	55.7
UTS	0.135	74.7



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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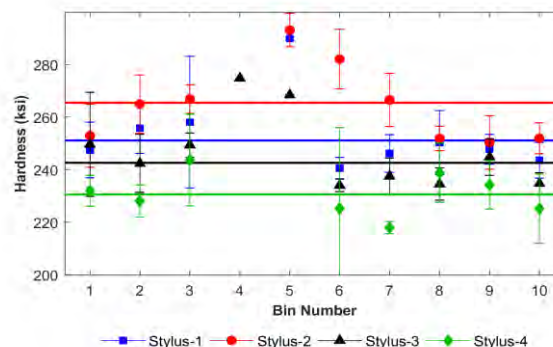
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190522125508	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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)
Stylus-1	251.2	13.99
Stylus-2	265.4	18.02
Stylus-3	242.6	12.79
Stylus-4	230.7	12.79
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.92	0.015
S	Cr	Nb
0.023	0.01	< 0.01
Cu	Al	Mo
0.01	< 0.01	< 0.01
Ni	Si	Ti
0.02	0.01	< 0.01
V	B	
< 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.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>53.8</u>	<u>54.6</u>	<u>50.8</u>	<u>54.1</u>
UTS (ksi)	<u>71.6</u>	<u>71.7</u>	<u>73.7</u>	<u>70.6</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The graph displays the HSD Curve (black line) and the 0.5% Yield point (blue square) and UTS (blue triangle). The Y-axis represents Engineering Stress (ksi) from 0 to 80, and the X-axis represents Engineering Strain (in./in.) from 0 to 0.15. The curve shows a rapid increase in stress up to the yield point, followed by a gradual increase to the UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~54
UTS	~0.13	~73

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.	190530173816	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	256	250	248	226
2	259	258	251	232
3	263	256	250	228
4	258	253	250	228
5	255	254	244	224
6	265	258	245	224
7	267	265	248	226
8	271	262	246	230
9	266	255	245	227
10	265	258	248	219

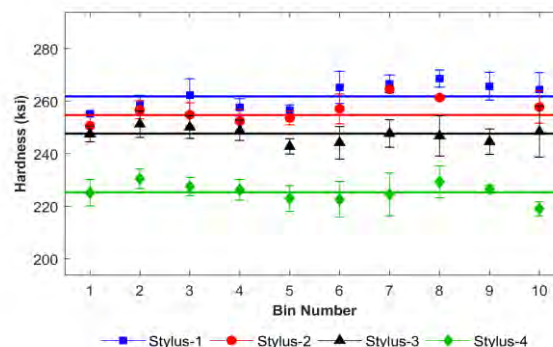
Base Metal Chemical Composition (wt. %)

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.

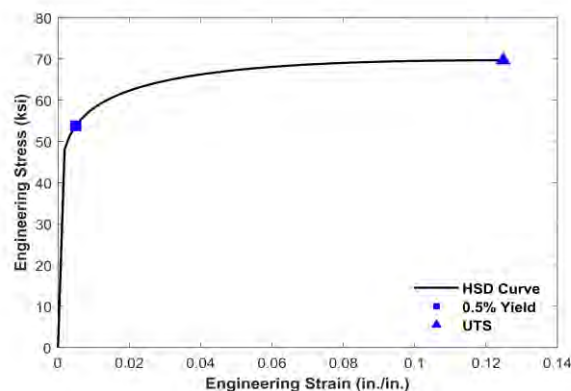


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.14). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 53.8). The UTS point is marked with a blue triangle at approximately (0.125, 70.3).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	53.8
UTS	0.125	70.3



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.	190530190503	REV --
Test Location	Gas Technology Institute			Test Date	5/30/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver. 2.2

HSD Stylus Hardness

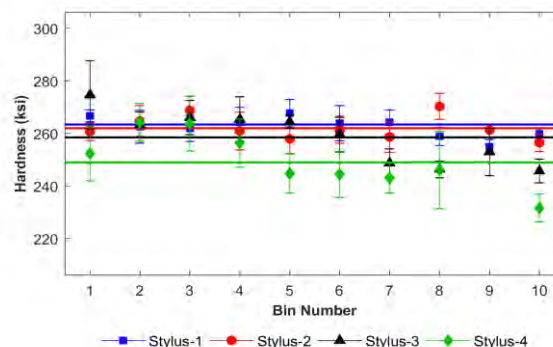
	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	263.3	5.51	50
Stylus-2	262.0	6.50	54
Stylus-3	258.5	11.00	50
Stylus-4	248.9	12.48	53

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)
0.20	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	8.6

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	265	264	275	252
2	263	263	262	260
3	264	265	268	262
4	265	264	265	258
5	268	258	265	245
6	264	262	260	244
7	266	260	258	243
8	260	270	255	247
9	255	261	254	248
10	260	257	245	232

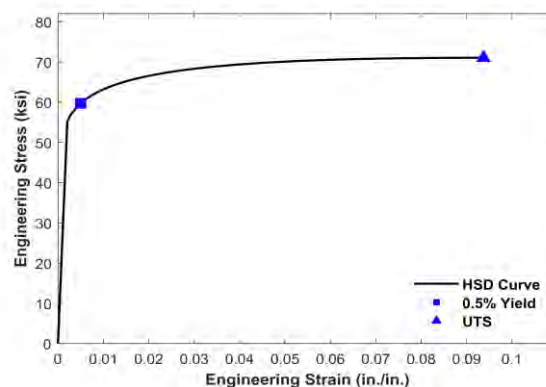


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.1 in./in. in increments of 0.01. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually increases to a peak before leveling off. A blue square marker indicates the 0.5% Yield point at approximately 60 ksi and 0.005 in./in. strain. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 71 ksi and 0.095 in./in. strain.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~60
UTS	~0.095	~71



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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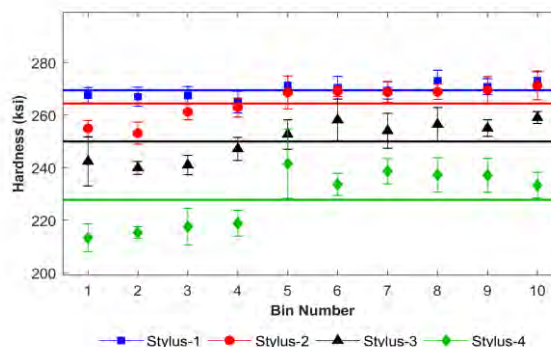
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509133446	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	269.5	4.19
Stylus-2	264.5	7.43
Stylus-3	250.0	8.82
Stylus-4	227.8	12.36
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.28	0.95	0.011
S	Cr	Nb
0.014	0.06	< 0.01
Cu	Al	Mo
< 0.01	< 0.01	0.02
Ni	Si	Ti
0.02	0.01	< 0.01
V	B	
< 0.01	< 0.0005	
Grain Size		mli (μm)
		8.5

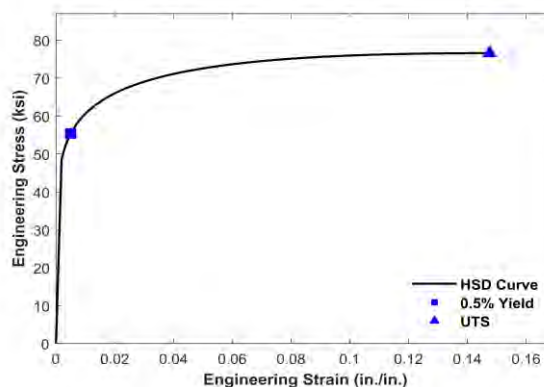


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>	
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					

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 55.4). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.145, 76.6). The legend in the bottom right corner identifies the HSD Curve, 0.5% Yield, and UTS.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	55.4
UTS	~0.145	76.6



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.	190521112949	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	265	260	235	208
2	265	263	235	215
3	265	260	235	212
4	265	260	243	210
5	265	257	241	210
6	265	268	240	215
7	265	261	238	212
8	265	260	242	210
9	265	263	238	212
10	265	265	238	212

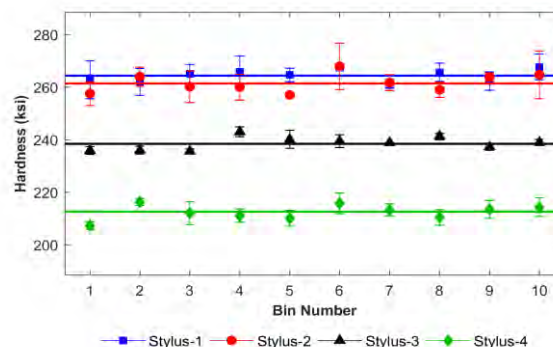
Base Metal Chemical Composition (wt. %)

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.

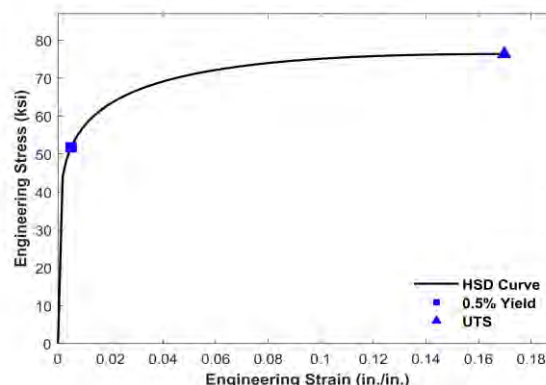


Results

Prediction Ver. <u>H2.4-G2.04-LAB v190728-BLMc</u>				
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>51.8</u>	<u>51.7</u>	<u>51.8</u>	<u>51.8</u>
UTS (ksi)	<u>76.3</u>	<u>76.1</u>	<u>76.5</u>	<u>76.4</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi with increments of 10. The x-axis ranges from 0 to 0.18 in./in. with increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 0.005 in./in. strain and 51.8 ksi stress. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.165 in./in. strain and 76.3 ksi stress.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	51.8
UTS	~0.165	76.3



Comments

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

Parth Patel

Approved:

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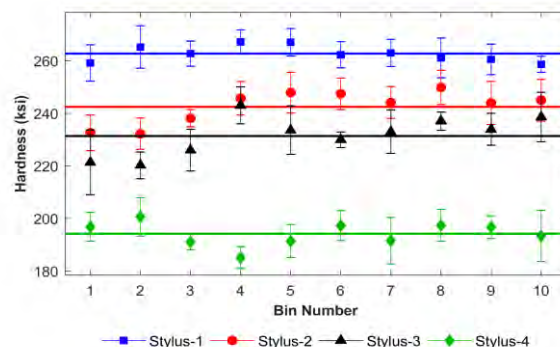
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

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 Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	262.7	6.07
Stylus-2	242.4	8.59
Stylus-3	231.3	10.16
Stylus-4	194.1	6.99
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.25	0.53	0.014
S	Cr	Nb
0.023	0.01	< 0.01
Cu	Al	Mo
0.03	0.02	< 0.01
Ni	Si	Ti
0.01	0.14	< 0.01
V	B	
< 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

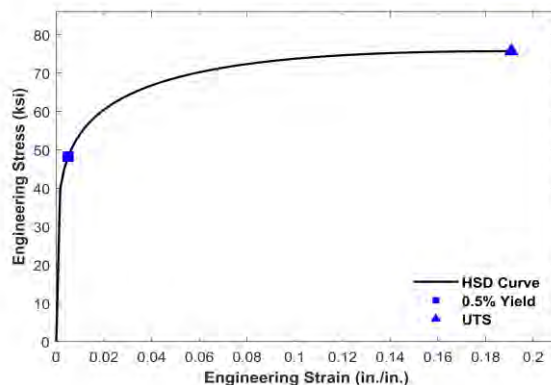
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	48.2	48.2	47.0	49.7
UTS (ksi)	75.7	74.2	77.6	75.2

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).

The graph displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 48.2). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.19, 75.2).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	48.2
UTS	0.19	75.2



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.	190508151049	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	257.0	6.28	65
Stylus-2	248.1	8.18	61
Stylus-3	223.3	5.91	62
Stylus-4	188.8	8.92	60

Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

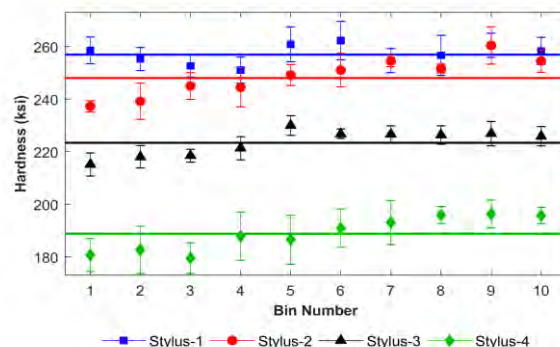
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.25	0.53	0.014	0.023	0.01	< 0.01	0.03	0.02	< 0.01	0.01	0.14	< 0.01	< 0.01	< 0.0005

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.

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	257.0	238.0	218.0	180.0
2	257.0	240.0	218.0	182.0
3	255.0	245.0	218.0	180.0
4	252.0	245.0	222.0	185.0
5	260.0	248.0	232.0	185.0
6	262.0	250.0	228.0	190.0
7	258.0	255.0	228.0	192.0
8	258.0	250.0	228.0	195.0
9	260.0	260.0	228.0	195.0
10	258.0	255.0	225.0	195.0



Results

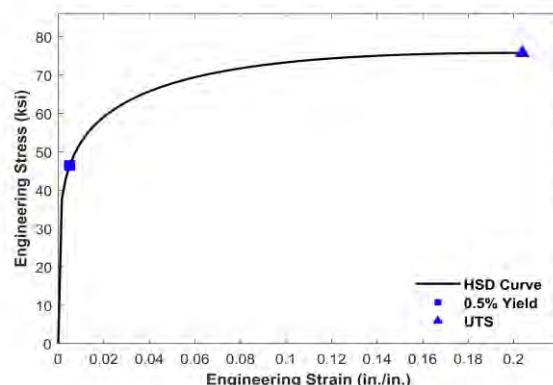
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	46.4	43.7	46.1	48.7
UTS (ksi)	75.8	75.6	76.2	75.9

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).

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10. The x-axis ranges from 0 to 0.2 in increments of 0.02. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.01, 46.4). A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately (0.2, 75.8).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	46.4
UTS	0.2	75.8



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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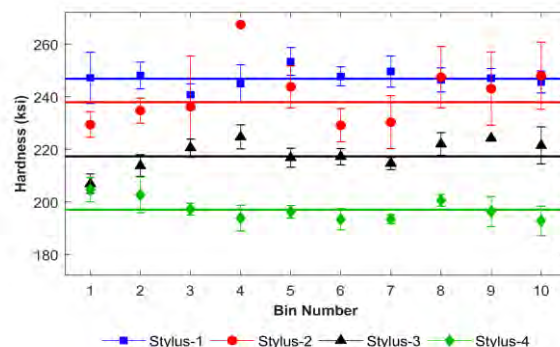
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

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 Plaines, 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						
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)
Stylus-1	246.9	5.85
Stylus-2	238.0	13.17
Stylus-3	217.4	6.44
Stylus-4	197.1	5.51
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.25	0.53	0.014
S	Cr	Nb
0.023	0.01	< 0.01
Cu	Al	Mo
0.03	0.02	< 0.01
Ni	Si	Ti
0.01	0.14	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).

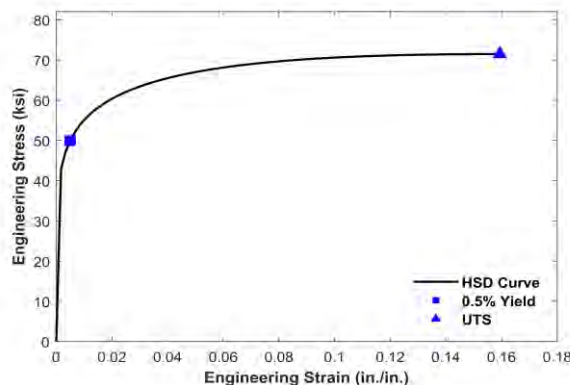
Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend:

- HSD Curve
- 0.5% Yield
- ▲ UTS

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	50.0
UTS	0.16	72.2



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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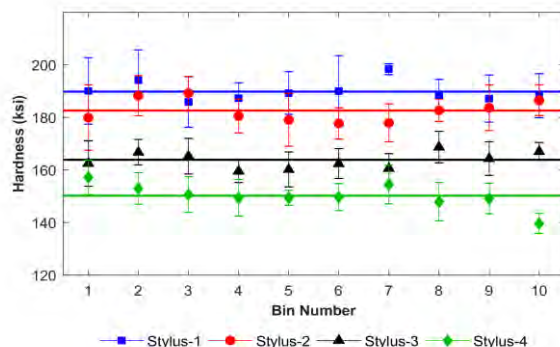
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508160423	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

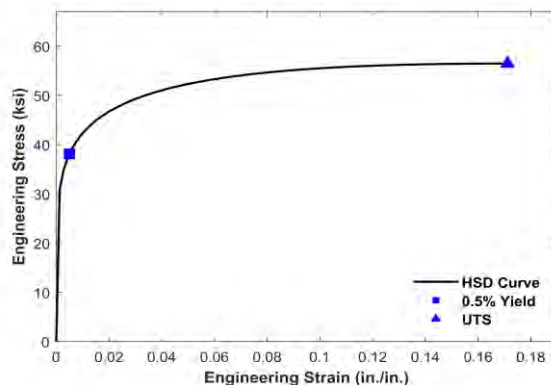
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	189.8	9.22
Stylus-2	182.6	8.36
Stylus-3	163.8	6.28
Stylus-4	150.1	7.14
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.04	0.38	0.029
S	Cr	Nb
0.013	0.02	< 0.01
Cu	Al	Mo
0.03	< 0.01	< 0.01
Ni	Si	Ti
0.03	< 0.01	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	38.1	39.2
UTS (ksi)	56.4	56.5
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).		
HSD Curve		
0.5% Yield		
UTS		



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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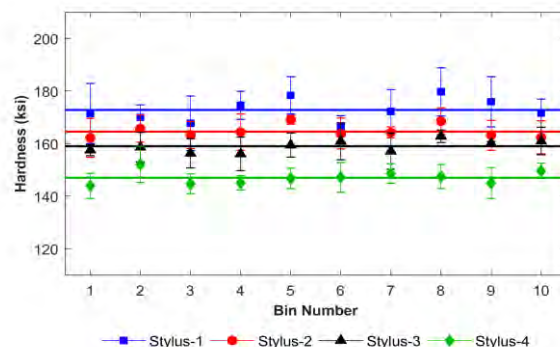
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190521142134	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
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)
Stylus-1	172.7	8.34
Stylus-2	164.5	5.40
Stylus-3	158.9	5.25
Stylus-4	146.9	4.80
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.04	0.38	0.029
S	Cr	Nb
0.013	0.02	< 0.01
Cu	Al	Mo
0.03	< 0.01	< 0.01
Ni	Si	Ti
0.03	< 0.01	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	40.3	40.5	39.9	40.5
UTS (ksi)	52.4	51.7	52.7	52.7

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).

The graph displays Engineering Stress (ksi) on the y-axis (0 to 60) against Engineering Strain (in./in.) on the x-axis (0 to 0.15). A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 40.3). A blue triangle marker indicates the UTS point at approximately (0.12, 52.4). The curve shows a rapid initial increase in stress, followed by a plateau and then a slight rise to the UTS.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	40.3
UTS	0.12	52.4

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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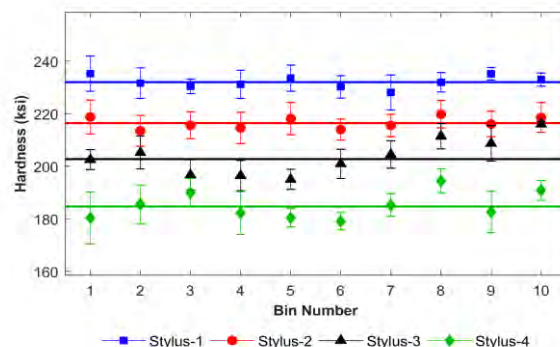
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509175218	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	232.1	4.91
Stylus-2	216.5	5.42
Stylus-3	202.7	7.63
Stylus-4	184.7	7.48
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.20	0.49	0.011
S	Cr	Nb
0.030	0.07	< 0.01
Cu	Al	Mo
0.06	< 0.01	< 0.01
Ni	Si	Ti
0.07	0.12	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	46.9	47.0	45.3	48.6
UTS (ksi)	66.6	66.6	66.6	66.8

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).

The graph displays Engineering Stress (ksi) on the y-axis (0 to 70) against Engineering Strain (in./in.) on the x-axis (0 to 0.18). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.01, 47). The UTS point is marked with a blue triangle at approximately (0.15, 66.8).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~47
UTS	~0.15	~66.8

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.	190508170648	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

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.

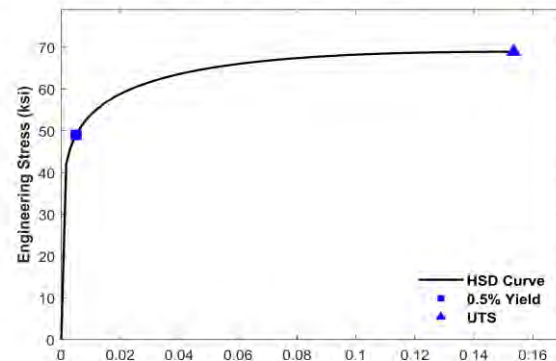
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	49.0	47.5	49.7	49.6
UTS (ksi)	68.9	69.3	68.3	69.2

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).



The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 70) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The curve starts at the origin, rises steeply to a yield point of approximately 49 ksi at 0.01 strain, then continues to a peak of approximately 69 ksi at 0.15 strain. The 0.5% Yield point is marked with a blue square and the UTS point with a blue triangle.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	49.0	0.5% Yield
0.15	69.2	UTS

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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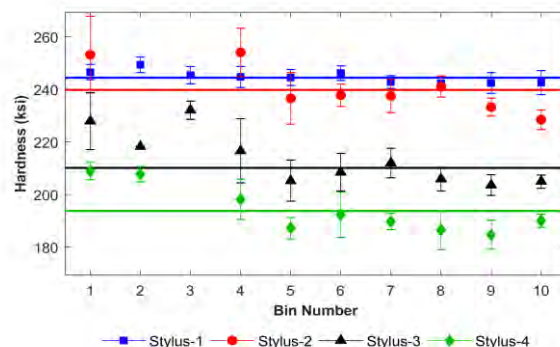
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509133341	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

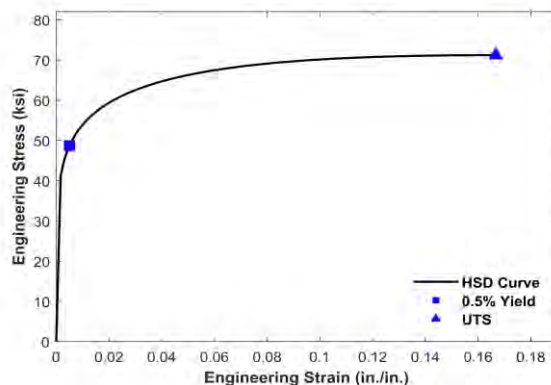
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	244.5	3.61
Stylus-2	239.8	10.60
Stylus-3	210.1	9.68
Stylus-4	193.7	9.89
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.16	0.44	0.013
S	Cr	Nb
0.039	0.13	< 0.01
Cu	Al	Mo
0.07	< 0.01	0.02
Ni	Si	Ti
0.14	0.16	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	48.7	54.7
UTS (ksi)	71.2	72.7
	Subset-2	Subset-3
	48.2	46.7
	71.6	70.7
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

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.	190508124734	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245.2	234.8	210.0	195.9
2	245.2	234.8	210.0	195.9
3	245.2	234.8	215.0	195.9
4	245.2	234.8	215.0	195.9
5	245.2	234.8	210.0	195.9
6	245.2	234.8	215.0	195.9
7	245.2	234.8	210.0	195.9
8	245.2	234.8	220.0	195.9
9	245.2	234.8	225.0	195.9
10	245.2	234.8	225.0	195.9

Base Metal Chemical Composition (wt. %)

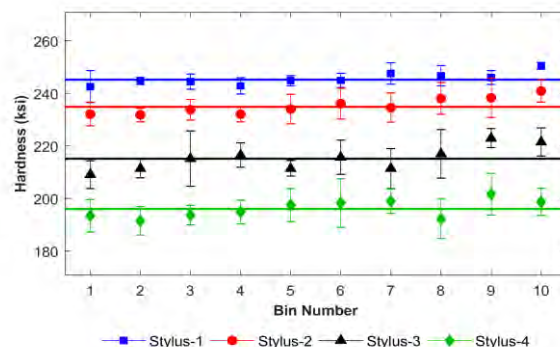
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.16	0.44	0.013	0.039	0.13	< 0.01	0.07	< 0.01	0.02	0.14	0.16	< 0.01	< 0.01	< 0.0005

Grain Size mli (μm)

9.2

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

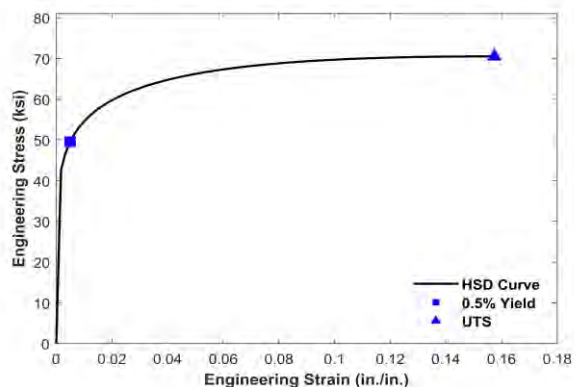
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.



Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	49.6	48.5	49.9	50.2
UTS (ksi)	70.5	70.1	70.2	71.3
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).				

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.01	50.0	0.5% Yield
0.15	71.3	UTS



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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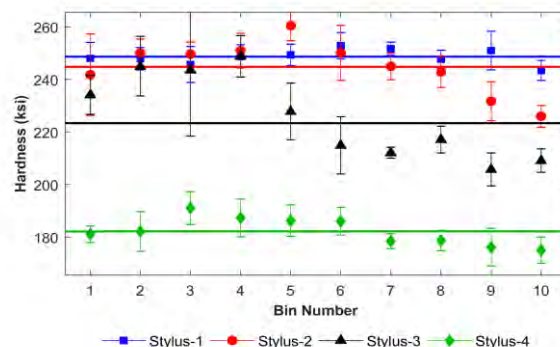
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509130826	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	248.7	5.29
Stylus-2	244.7	12.03
Stylus-3	223.4	16.45
Stylus-4	182.2	7.15
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.22	0.54	0.014
S	Cr	Nb
0.030	0.08	< 0.01
Cu	Al	Mo
0.13	< 0.01	< 0.01
Ni	Si	Ti
0.08	0.14	< 0.01
V	B	
< 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

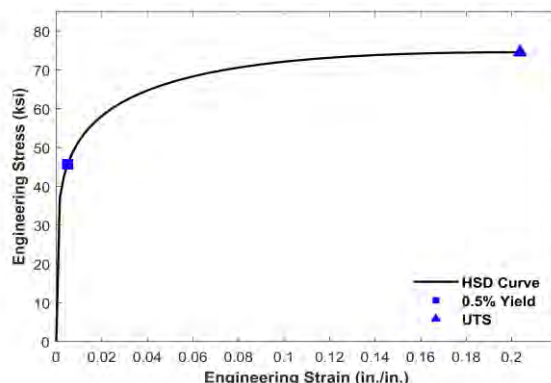
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	45.7	48.5	46.4	43.0
UTS (ksi)	74.5	74.2	75.6	73.8

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).

The graph displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.2). A solid black line represents the HSD Curve. A blue square marks the 0.5% Yield point at approximately (0.01, 45.7). A blue triangle marks the UTS point at approximately (0.2, 74.5).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	45.7
UTS	0.2	74.5



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.	190508133050	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245	243	215	188
2	248	243	218	195
3	245	243	216	195
4	245	240	215	188
5	255	242	217	185
6	258	240	217	185
7	265	242	217	195
8	252	242	220	200
9	252	238	215	188
10	252	238	215	198

Base Metal Chemical Composition (wt. %)

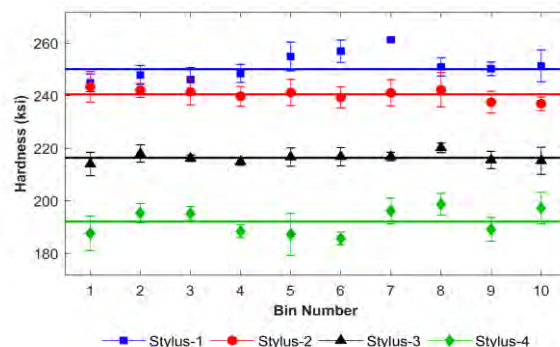
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.22	0.54	0.014	0.030	0.08	< 0.01	0.13	< 0.01	< 0.01	0.08	0.14	< 0.01	< 0.01	< 0.0005

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

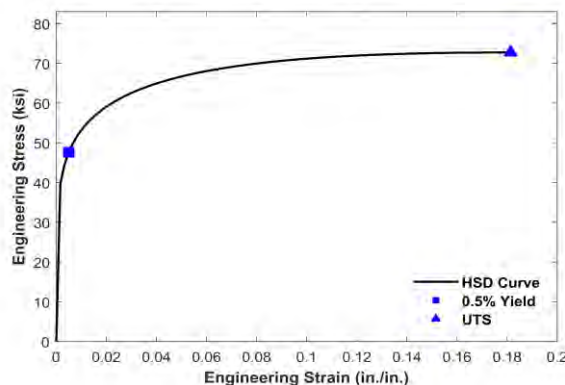
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	47.6	48.4	45.9	48.6
UTS (ksi)	72.7	72.0	73.9	72.5

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).

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.2 in./in. The HSD Curve is a solid black line that starts at the origin, rises steeply to the 0.5% Yield point, and then gradually levels off towards the UTS point. The 0.5% Yield point is marked with a blue square at approximately (0.005, 48). The UTS point is marked with a blue triangle at approximately (0.18, 73).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~48
UTS	~0.18	~73



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.	190509171728	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	243	243	228	200
2	248	248	228	195
3	241	233	206	190
4	237	218	203	180
5	236	214	200	177
6	236	217	204	183
7	247	233	231	186
8	243	228	231	192
9	237	236	218	195
10	239	237	216	189

Base Metal Chemical Composition (wt. %)

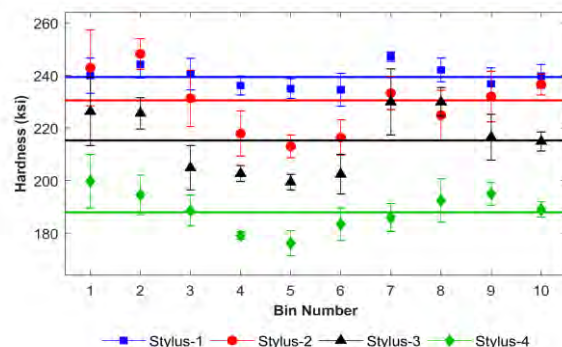
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.43	0.012	0.032	0.07	< 0.01	0.07	< 0.01	< 0.01	0.07	0.11	< 0.01	< 0.01	< 0.0005

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

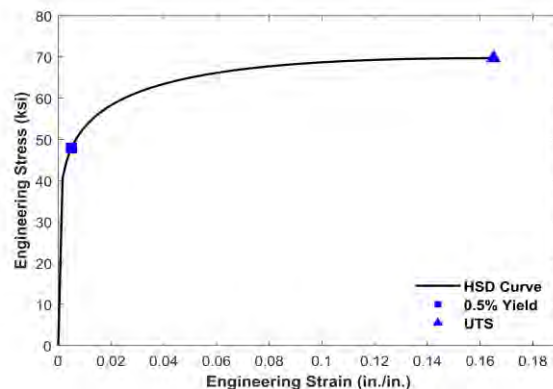
Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	47.9	50.3	44.7	49.6
UTS (ksi)	69.7	70.8	68.1	69.9

The overall results are calculated using the entire sample size.

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

The graph displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.18). A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately (0.005, 48). A blue triangle marker indicates the UTS at approximately (0.165, 71).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~48
UTS	~0.165	~71



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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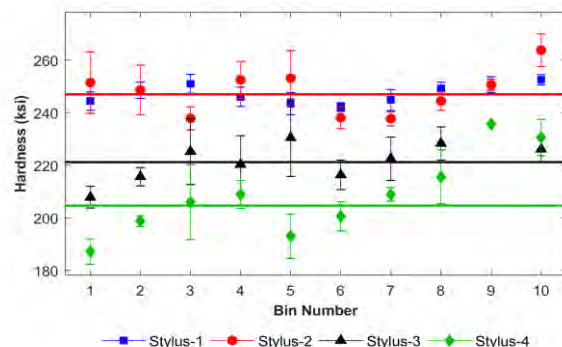
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508122825	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	247.0	4.47
Stylus-2	246.9	9.81
Stylus-3	221.1	10.68
Stylus-4	204.6	14.43
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.19	0.43	0.012
S	Cr	Nb
0.032	0.07	< 0.01
Cu	Al	Mo
0.07	< 0.01	< 0.01
Ni	Si	Ti
0.07	0.11	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	52.6	49.5	51.5	57.4
UTS (ksi)	71.7	72.1	71.6	71.7

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).

The graph displays the Engineering Stress (ksi) on the y-axis (0 to 80) against the Engineering Strain (in./in.) on the x-axis (0 to 0.16). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 52.6). The UTS (Ultimate Tensile Strength) point is marked with a blue triangle at approximately (0.14, 71.7).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	52.6
UTS	0.14	71.7

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.	190521155411	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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.	105-190520	
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	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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245	238	202	188
2	245	240	220	202
3	243	235	220	205
4	238	228	205	192
5	232	222	198	175
6	230	228	195	175
7	232	228	202	180
8	232	225	202	178
9	235	228	205	192
10	232	225	208	208

Base Metal Chemical Composition (wt. %)

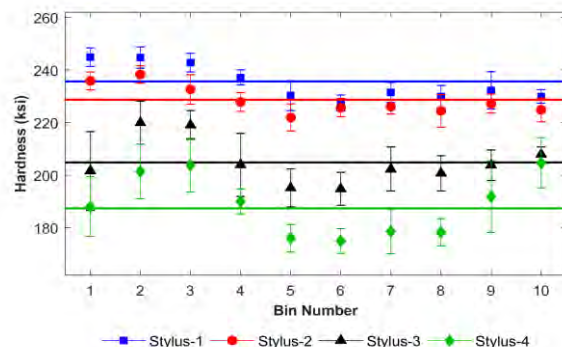
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B
0.19	0.43	0.012	0.032	0.07	< 0.01	0.07	< 0.01	< 0.01	0.07	0.11	< 0.01	< 0.01	< 0.0005

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.



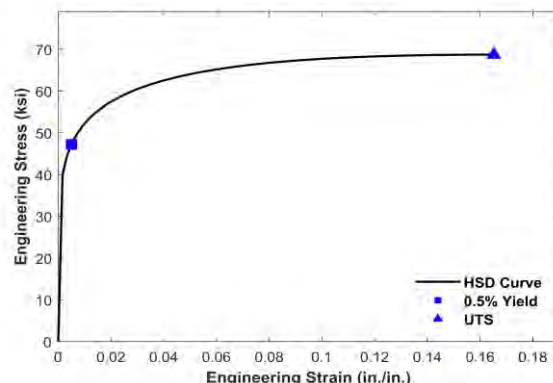
Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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.

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

Engineering Strain (in./in.)	Engineering Stress (ksi)	Point Type
0.005	47.2	0.5% Yield
0.165	68.7	UTS



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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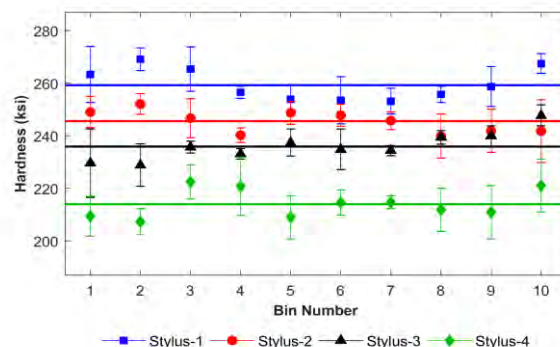
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509154832	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
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)
Stylus-1	259.2	8.27
Stylus-2	245.5	6.94
Stylus-3	235.9	6.76
Stylus-4	214.0	8.57
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.46	0.009
S	Cr	Nb
0.029	0.08	< 0.01
Cu	Al	Mo
0.08	< 0.01	< 0.01
Ni	Si	Ti
0.09	0.15	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).

The graph displays the HSD Curve (black line) and the 0.5% Yield point (blue square) and UTS (blue triangle). The Y-axis represents Engineering Stress (ksi) from 0 to 80, and the X-axis represents Engineering Strain (in./in.) from 0 to 0.15. The 0.5% Yield point is at approximately (0.005, 55.5) and the UTS is at approximately (0.13, 73.7).

Property	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

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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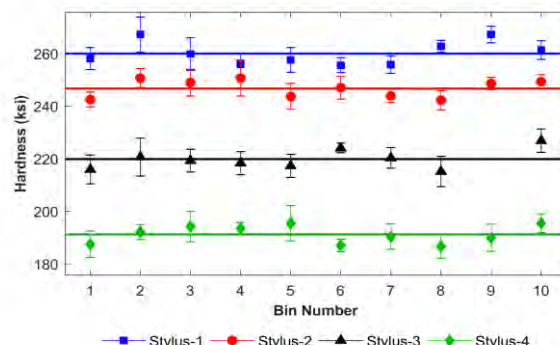
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190509182118	REV --
Test Location	Gas Technology Institute			Test Date	5/9/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

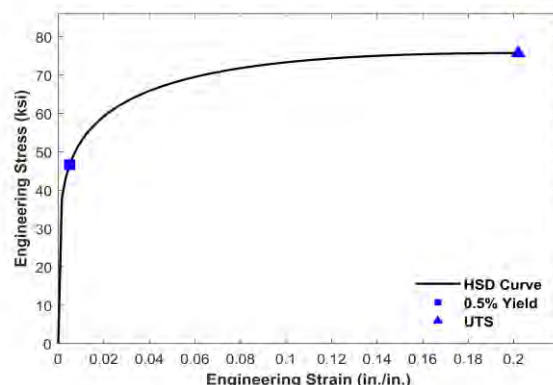
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	260.0	5.85
Stylus-2	246.7	4.91
Stylus-3	219.8	5.75
Stylus-4	191.3	5.31
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.46	0.009
S	Cr	Nb
0.029	0.08	< 0.01
Cu	Al	Mo
0.08	< 0.01	< 0.01
Ni	Si	Ti
0.09	0.15	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	46.6	46.5
UTS (ksi)	75.7	76.0
	Subset-2	Subset-3
	46.9	46.5
	74.9	76.2
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

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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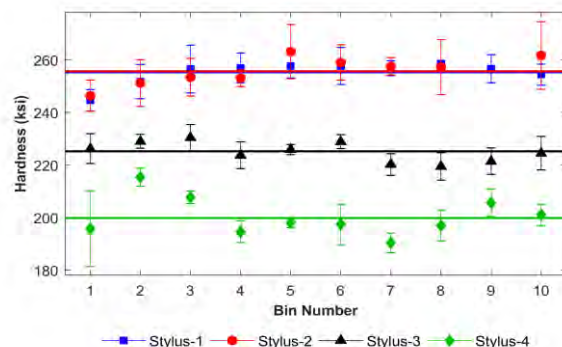
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190528183818	REV --
Test Location	Gas Technology Institute			Test Date	5/28/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

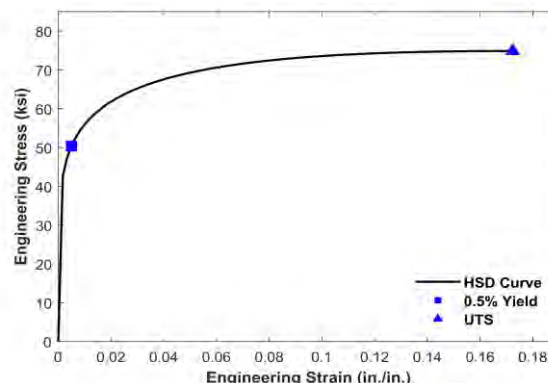
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	255.2	6.35
Stylus-2	255.5	8.70
Stylus-3	225.1	5.51
Stylus-4	199.7	8.73
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.23	0.46	0.009
S	Cr	Nb
0.029	0.08	< 0.01
Cu	Al	Mo
0.08	< 0.01	< 0.01
Ni	Si	Ti
0.09	0.15	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	50.4	53.2
UTS (ksi)	74.9	73.0
	Subset-2	Subset-3
	49.2	49.5
	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

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.	190508174626	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	in		Stylus-1 Serial No.	103-190412	
Profiler Speed	2.16	in/min		Stylus-2 Serial No.	105-190107	
Sampling Rate	1600	Hz		Stylus-3 Serial No.	109-190520	
				Stylus-4 Serial No.	118-190520	

Measurements

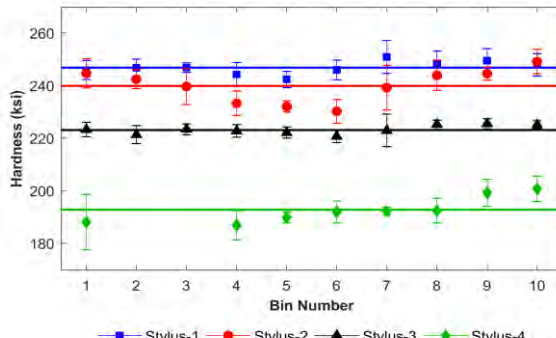
Post-Processing Ver.

2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

Hardness = (Stylus force)/(Contact area)



Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	245	245	225	188
2	245	243	223	
3	245	240	224	
4	244	235	223	187
5	243	233	222	191
6	244	231	221	192
7	245	240	224	192
8	245	244	226	193
9	245	245	226	200
10		245	226	201

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.

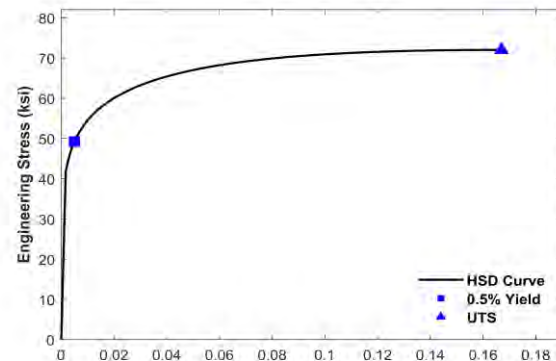
Grain size is measured using the mean-linear-intercept (mli) method through image processing of surface microscopy.

Results

Prediction Ver.	H2.4 v190728			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).



The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.18). The curve starts at the origin, rises steeply to a yield point (blue square) at approximately 49 ksi, then continues to a tensile strength point (blue triangle) at approximately 72 ksi. The 0.5% yield point is marked with a blue square and the UTS point with a blue triangle.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	~49.2
UTS	~0.16	~72.0

Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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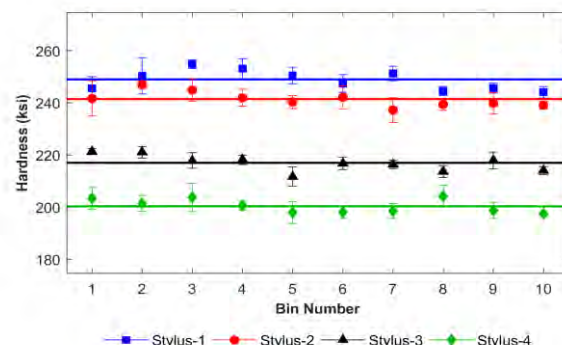
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190529132121	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

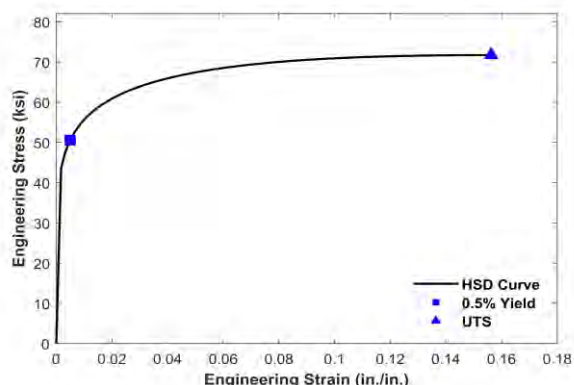
Measurements

Post-Processing Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	249.1	4.91
Stylus-2	241.5	4.51
Stylus-3	217.0	3.69
Stylus-4	200.4	3.96
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.21	0.40	0.011
S	Cr	Nb
0.030	0.06	< 0.01
Cu	Al	Mo
0.07	< 0.01	< 0.01
Ni	Si	Ti
0.09	0.11	< 0.01
V	B	
< 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
0.5% EUL Yield (ksi)	50.6	51.4
UTS (ksi)	71.7	72.3
	Subset-2	Subset-3
	49.9	50.5
	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

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.	190529133848	REV --
Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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	

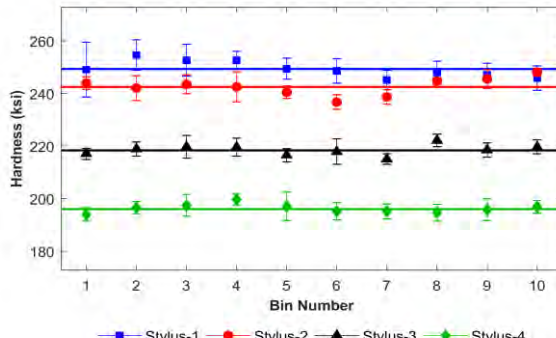
Measurements

Post-Processing 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)



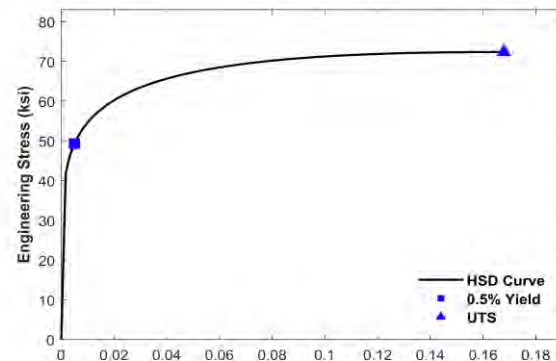
Base Metal Chemical Composition (wt. %)														Grain Size
C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	mli (μm)
0.21	0.40	0.011	0.030	0.06	< 0.01	0.07	< 0.01	< 0.01	0.09	0.11	< 0.01	< 0.01	< 0.0005	10.6

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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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).				



The graph displays the HSD Curve, showing Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.18). The curve starts at the origin, rises steeply to a yield point of approximately 49 ksi at 0.01 strain, then continues to a peak of approximately 72 ksi at 0.16 strain. The 0.5% Yield point is marked with a blue square and the UTS point with a blue triangle.

Engineering Strain (in./in.)	Engineering Stress (ksi)	Property
0.01	49.3	0.5% Yield
0.16	72.3	UTS

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.	190507164705	REV --
Test Location	Gas Technology Institute			Test Date	5/7/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	1.33	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 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

Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	244	226	221	201
2	246	238	217	198
3	244	240	216	195
4	248	245	217	200
5	250	252	219	210
6	258	261	223	215
7	262	262	230	220
8	265	260	238	233
9	267	258	241	240
10	261	243	238	238

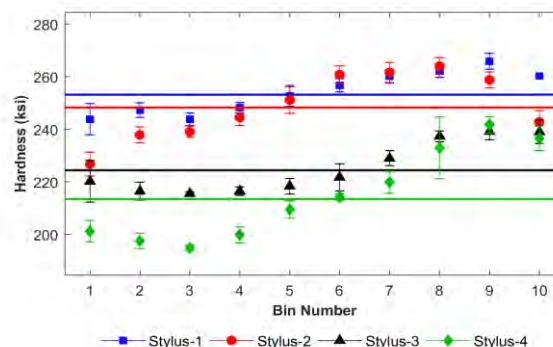
Base Metal Chemical Composition (wt. %)

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.

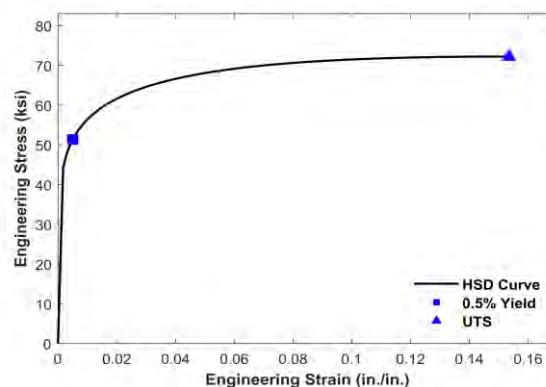


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 in increments of 10, and the x-axis ranges from 0 to 0.16 in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker is placed on the curve at approximately (0.01, 51.3), representing the 0.5% Yield point. A blue triangle marker is placed at the end of the curve at approximately (0.15, 72.2), representing the UTS (Ultimate Tensile Strength) point. A legend in the bottom right corner identifies the black line as the 'HSD Curve', the blue square as '0.5% Yield', and the blue triangle as 'UTS'.

Property	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.01	51.3
UTS	~0.15	72.2



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.	190521125628	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	235.8	235.0	221.8	198.7
2	235.8	235.0	221.8	198.7
3	235.8	235.0	221.8	198.7
4	235.8	235.0	221.8	198.7
5	235.8	235.0	221.8	198.7
6	235.8	235.0	221.8	198.7
7	235.8	235.0	221.8	198.7
8	235.8	235.0	221.8	198.7
9	235.8	235.0	221.8	198.7
10	235.8	235.0	221.8	198.7

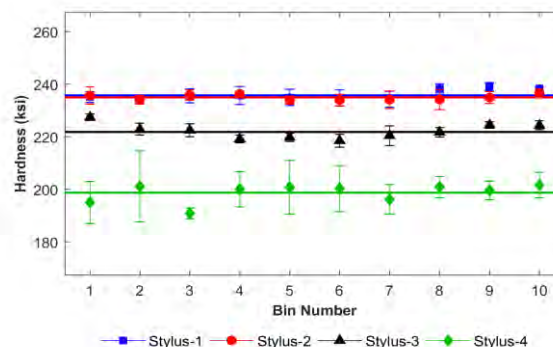
Base Metal Chemical Composition (wt. %)

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.

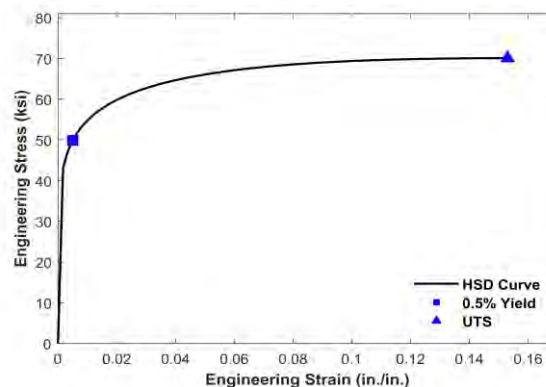


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.005, 50.0). The UTS point is marked with a blue triangle at approximately (0.15, 70.2).

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	50.0
UTS	0.15	70.2



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.	190521162209	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	257.9	4.99	40
Stylus-2	251.9	3.17	35
Stylus-3	226.2	3.82	42
Stylus-4	206.6	3.37	38

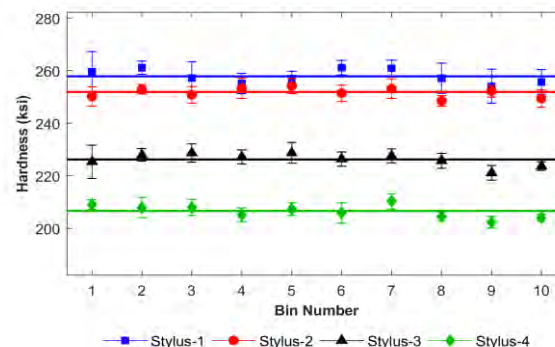
Hardness = (Stylus force)/(Contact area)

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	258	252	225	208
2	258	252	228	208
3	258	252	228	208
4	258	252	225	205
5	258	252	228	208
6	258	252	225	205
7	258	252	228	210
8	258	252	225	205
9	258	252	222	202
10	258	252	225	205

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.9

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

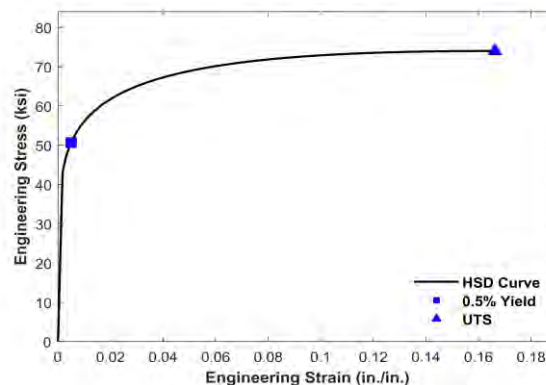


Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi, and the x-axis ranges from 0 to 0.18 in./in. The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately 0.01 in./in. strain and 50.7 ksi stress. The UTS point is marked with a blue triangle at approximately 0.16 in./in. strain and 74.0 ksi stress.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	50.7
UTS	0.16	74.0



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.	190523132044	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

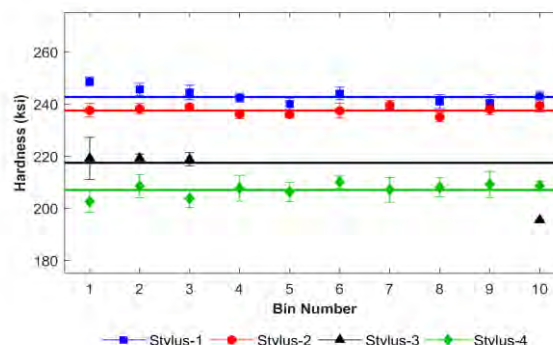
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	248	238	220	203
2	245	239	220	208
3	245	239	220	204
4	243	237	-	208
5	240	237	-	206
6	245	238	-	210
7	-	240	-	208
8	242	236	-	209
9	240	239	-	210
10	243	239	196	209

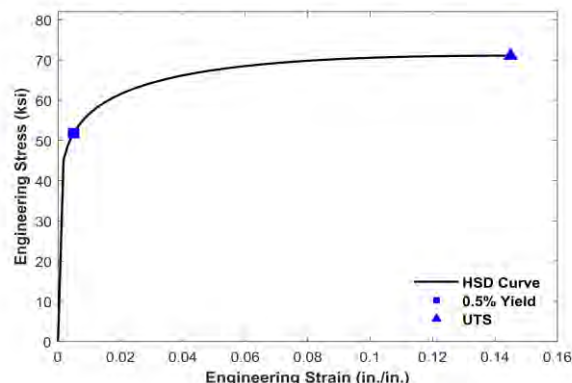


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays Engineering Stress (ksi) on the y-axis (0 to 80) versus Engineering Strain (in./in.) on the x-axis (0 to 0.16). The HSD Curve is a solid black line. The 0.5% Yield point is marked with a blue square at approximately (0.01, 52). The UTS point is marked with a blue triangle at approximately (0.14, 71). The curve rises steeply from the origin, reaches a peak at the UTS point, and then slightly declines.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	51.8
UTS	0.14	71.1



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.	190523133828	REV --
Test Location	Gas Technology Institute			Test Date	5/23/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

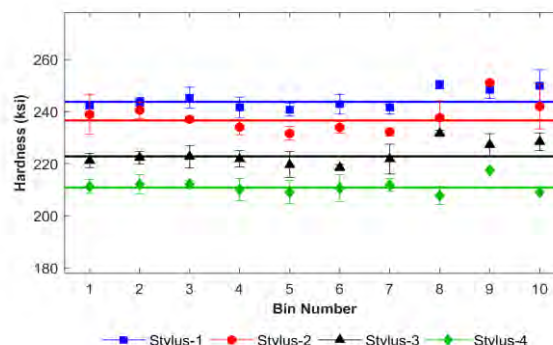
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	7.9

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	244	238	222	211
2	244	241	223	211
3	245	237	224	212
4	242	234	222	210
5	241	232	221	209
6	243	235	220	211
7	242	233	222	212
8	250	238	228	208
9	250	250	228	218
10	250	242	228	210

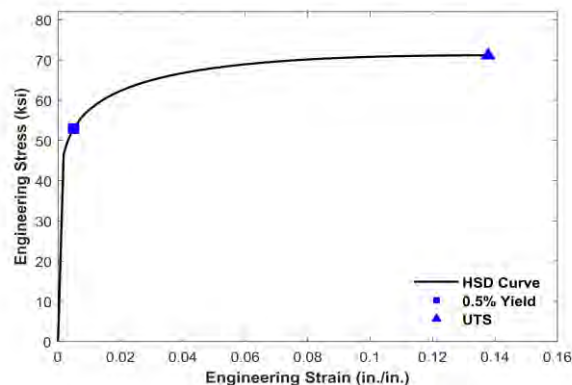


Results

Prediction Ver.	<u>H2.4-G2.04-LAB v190728-BLMc</u>			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
0.5% EUL Yield (ksi)	<u>52.9</u>	<u>53.0</u>	<u>53.0</u>	<u>52.5</u>
UTS (ksi)	<u>71.1</u>	<u>71.3</u>	<u>70.6</u>	<u>71.8</u>
The overall results are calculated using the entire sample size.				
Each subset is calculated using one-third of the measurements				

The stress-strain plot displays the relationship between Engineering Stress (ksi) on the y-axis and Engineering Strain (in./in.) on the x-axis. The y-axis ranges from 0 to 80 ksi in increments of 10, and the x-axis ranges from 0 to 0.16 in./in. in increments of 0.02. A solid black line represents the HSD Curve, which starts at the origin, rises steeply to a yield point, and then gradually levels off towards a peak. A blue square marker indicates the 0.5% Yield point at approximately 0.005 strain and 53 ksi. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 0.135 strain and 71.8 ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	~0.005	~53
UTS	~0.135	~71.8



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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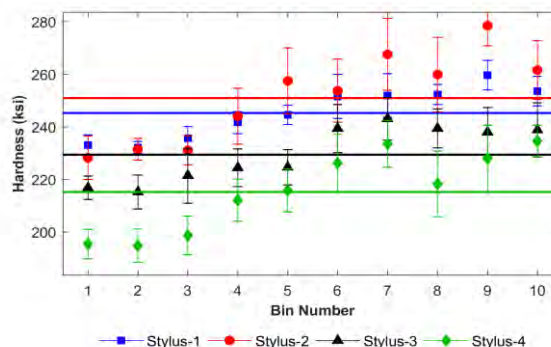
Hardness, Strength, and Ductility (HSD) Tester - Base Metal Report

Testing Information

Customer	Gas Technology Institute	Job ID	GTI19006	Report No.	190508175807	REV --
Test Location	Gas Technology Institute			Test Date	5/8/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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 Ver.	2.2	
HSD Stylus Hardness		
	Average (ksi)	Std. Dev. (ksi)
Stylus-1	245.3	10.41
Stylus-2	250.9	18.86
Stylus-3	229.4	12.74
Stylus-4	215.1	16.87
Hardness = (Stylus force)/(Contact area)		
Base Metal Chemical Composition (wt. %)		
C	Mn	P
0.27	0.71	0.005
S	Cr	Nb
0.024	0.02	< 0.01
Cu	Al	Mo
0.07	< 0.01	< 0.01
Ni	Si	Ti
0.02	0.01	< 0.01
V	B	
< 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			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The graph displays the HSD Curve (Hysteresis Stress-Strain Curve) for the material. The x-axis represents Engineering Strain in in./in., ranging from 0 to 0.16. The y-axis represents Engineering Stress in ksi, ranging from 0 to 80. The curve shows a typical stress-strain behavior with a yield point, a region of strain hardening, and a peak at the Ultimate Tensile Strength (UTS) before fracture. The 0.5% Yield point is marked with a blue square at approximately (0.01, 53.8) ksi. The UTS is marked with a blue triangle at approximately (0.14, 71.8) ksi.

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.01	53.8
UTS	0.14	71.8

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.	190521110246	REV --
Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	

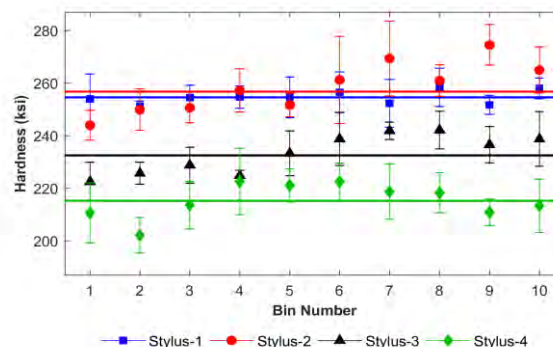
Measurements

Post-Processing Ver. 2.2

HSD Stylus Hardness

	Average (ksi)	Std. Dev. (ksi)	Sample Size
Stylus-1	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

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)
0.27	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	7.8

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

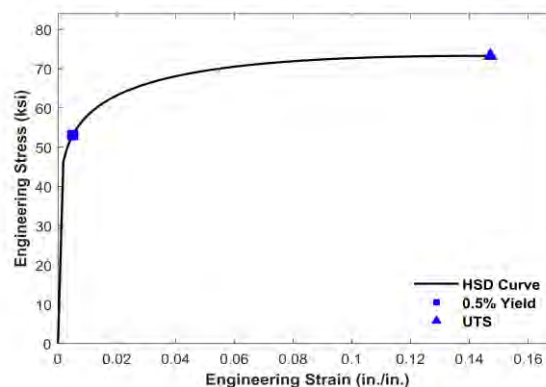
Results

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

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.	190522162951	REV --
Test Location	Gas Technology Institute			Test Date	5/22/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, 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						
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	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

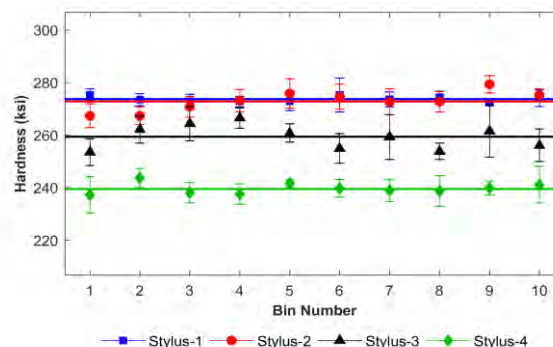
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	8.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	274	273	255	238
2	274	273	262	245
3	274	273	265	238
4	274	273	268	237
5	274	273	262	242
6	274	273	258	240
7	274	273	260	239
8	274	273	255	239
9	274	273	263	240
10	274	273	258	241

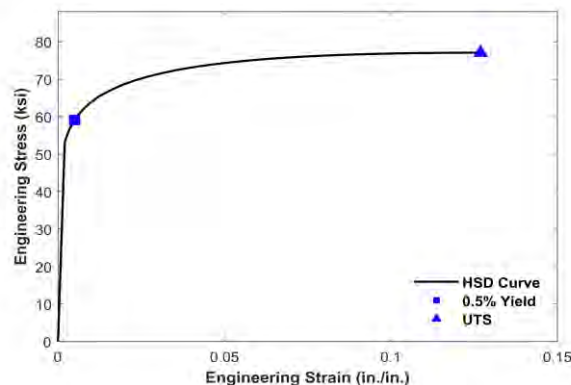


Results

Prediction Ver.		H2.4-G2.04-LAB v190728-BLMc		
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

The plot displays the stress-strain behavior of the material. The y-axis represents Engineering Stress in ksi, ranging from 0 to 80. The x-axis represents Engineering Strain in in./in., ranging from 0 to 0.15. A solid black line represents the HSD Curve. A blue square marker indicates the 0.5% Yield point at approximately 59.1 ksi and 0.001 in./in. strain. A blue triangle marker indicates the UTS (Ultimate Tensile Strength) at approximately 77.0 ksi and 0.12 in./in. strain.

Property	Engineering Stress (ksi)	Engineering Strain (in./in.)
0.5% Yield	59.1	0.001
UTS	77.0	0.12



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Massachusetts Materials Technologies LLC

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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 Plaines, 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						
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	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

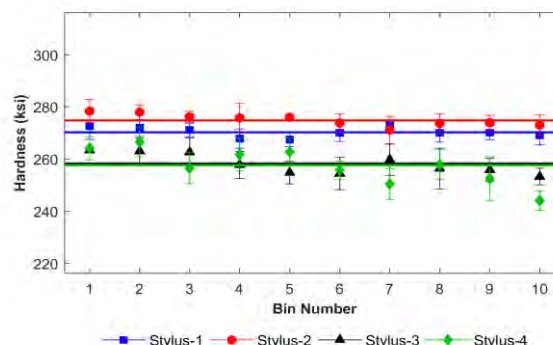
Hardness = (Stylus force)/(Contact area)

Base Metal Chemical Composition (wt. %)

C	Mn	P	S	Cr	Nb	Cu	Al	Mo	Ni	Si	Ti	V	B	Grain Size mli (μm)
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	8.1

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

Bin Number	Stylus-1 (ksi)	Stylus-2 (ksi)	Stylus-3 (ksi)	Stylus-4 (ksi)
1	270.0	278.0	265.0	265.0
2	270.0	278.0	265.0	265.0
3	270.0	276.0	263.0	260.0
4	270.0	276.0	263.0	263.0
5	270.0	276.0	258.0	263.0
6	270.0	274.0	258.0	258.0
7	270.0	272.0	260.0	252.0
8	270.0	274.0	258.0	258.0
9	270.0	274.0	258.0	255.0
10	270.0	272.0	255.0	245.0



Results

Prediction Ver.	H2.4-G2.04-LAB v190728-BLMc			
<u>Tensile Properties</u>	<u>Overall</u>	<u>Subset-1</u>	<u>Subset-2</u>	<u>Subset-3</u>
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				

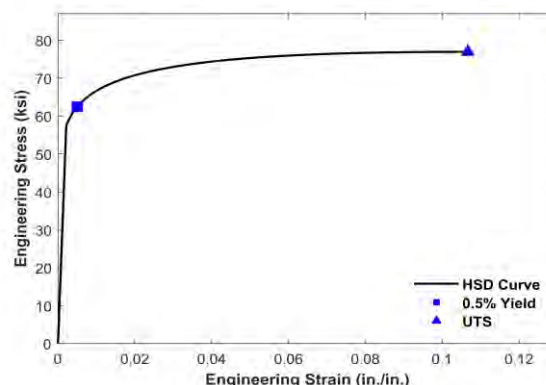
Engineering Stress (ksi)

Engineering Strain (in./in.)

Legend:

- HSD Curve
- 0.5% Yield
- ▲ UTS

Point	Engineering Strain (in./in.)	Engineering Stress (ksi)
0.5% Yield	0.005	62.4
UTS	0.105	76.9
End of Curve (Yellow Star)	0.11	80



Comments

Prepared:	Parth Patel	Approved:	Steven Palkovic, PhD
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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

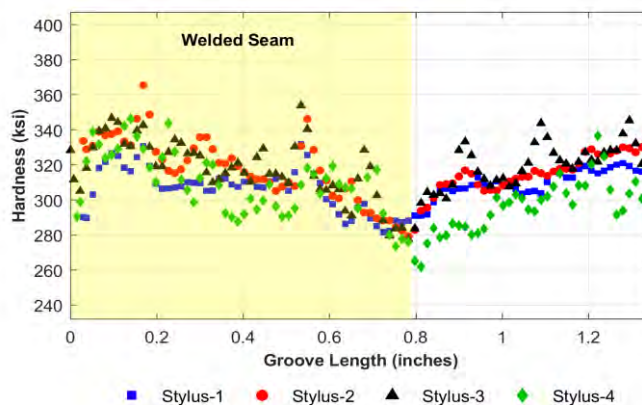
Customer	Gas Technology Institute		Job ID	GTI19006		Report No.	190424165813		REV --
Test Location	Gas Technology Institute					Test Date	4/24/2019		
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	16:58		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	7001-EB7001		
Sample 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

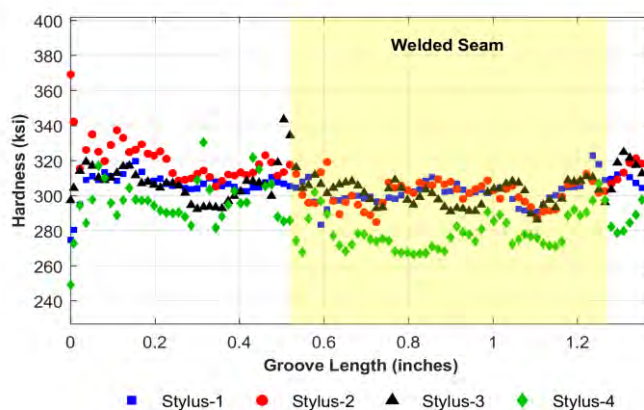
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Test Location	Gas Technology Institute					Test Date	4/24/2019		
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	14:09		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	7001-EB7001		
Sample ID	4		Pipe Size	12 OD x 0.22 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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

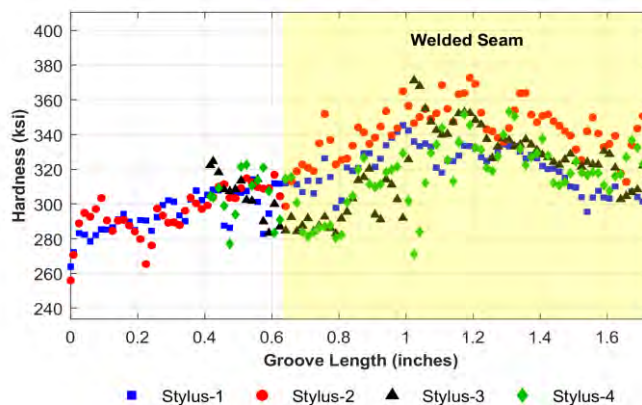
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Test Location	Gas Technology Institute			Test Date	4/25/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	18:00	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	13	Pipe Size	16 OD x 0.22 WT (in)	Operator 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

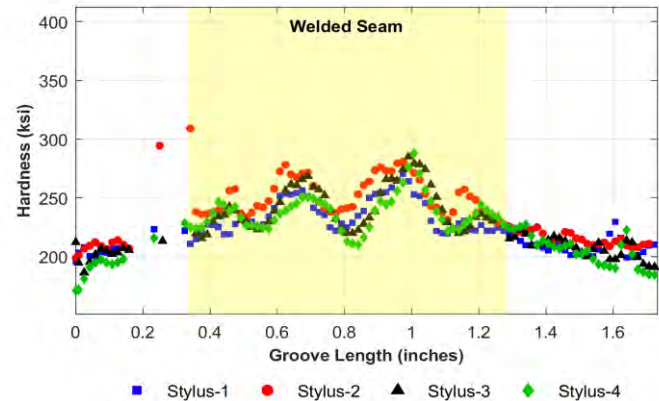
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	13:06	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	35	Pipe Size	12 OD x 0.25 WT (in)	Operator Initials	RP	
Test Name	35-Q1_WD-01_5002-EB5002_190509130623			Sample Type	Cutout	
Sample Description						
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	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
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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

Prepared:

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Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

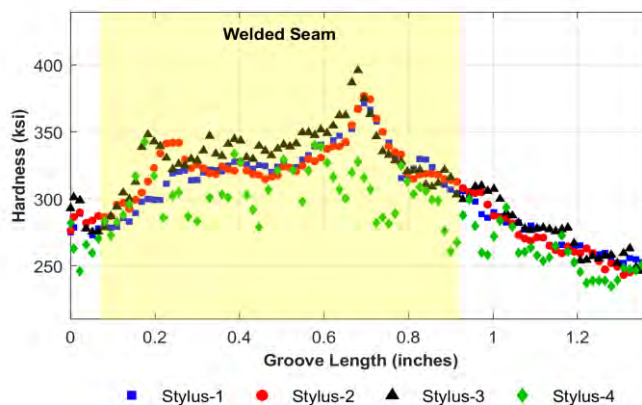
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Test Location	Gas Technology Institute					Test Date	5/23/2019		
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	9:53		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	7001-EB7001		
Sample ID	43		Pipe Size	20 OD x 0.25 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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

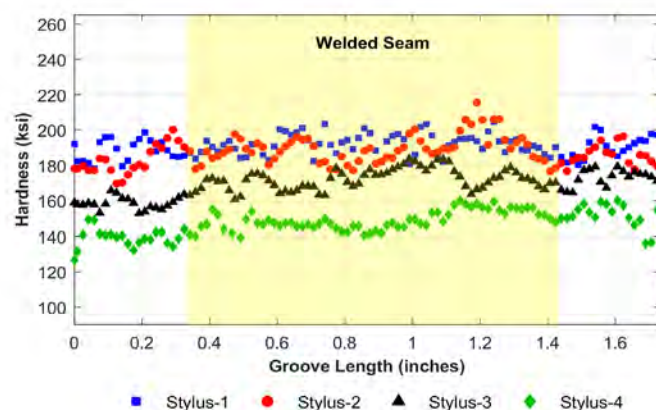
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Test Location	Gas Technology Institute			Test Date	5/21/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	11:23	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	107	Pipe Size	6 OD x 0.24 WT (in)	Operator Initials	RP	
Test Name	107-Q1_WD-01_5002-EB5002_190521112328			Sample Type	Cutout	
Sample Description						
				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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash☒ % 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.

Prepared:

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Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

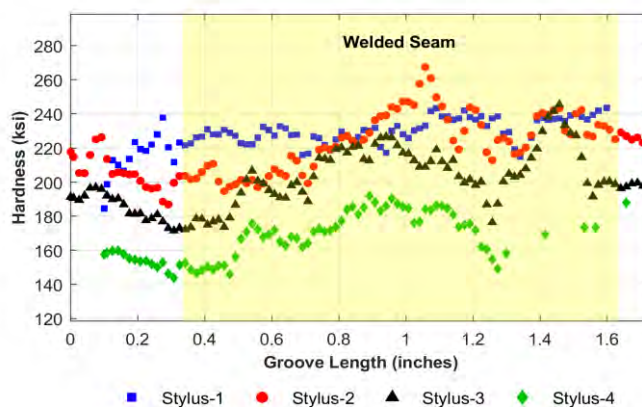
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	17:02	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5001-EB5001	
Sample ID	111	Pipe Size	4 OD x 0.24 WT (in)	Operator Initials	JJ	
Test Name	111-Q1_WD-01_5001-EB5001_190520170244			Sample Type	Cutout	
Sample Description						
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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Waltham, MA 02453

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HSD@byMMT.com

Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

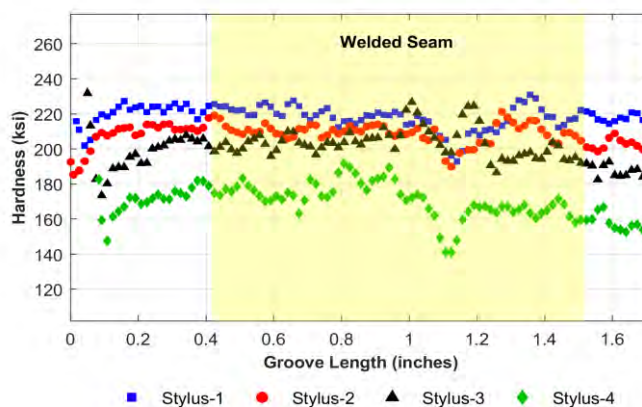
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	15:46		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5001-EB5001		
Sample ID	112		Pipe Size	4 OD x 0.25 WT (in)		Operator Initials	JJ		
Test Name	112-Q1_WD-01_5001-EB5001_190530154646					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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

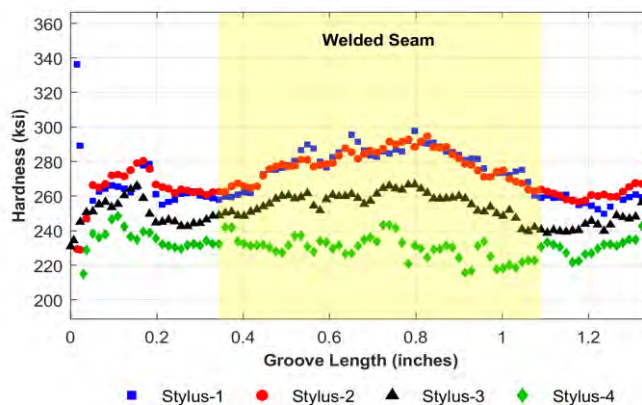
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	16:21	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	113	Pipe Size	6 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	113-Q1_WD-01_7001-EB7001_190506162145			Sample Type	Cutout	
Sample Description						
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	2	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 Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

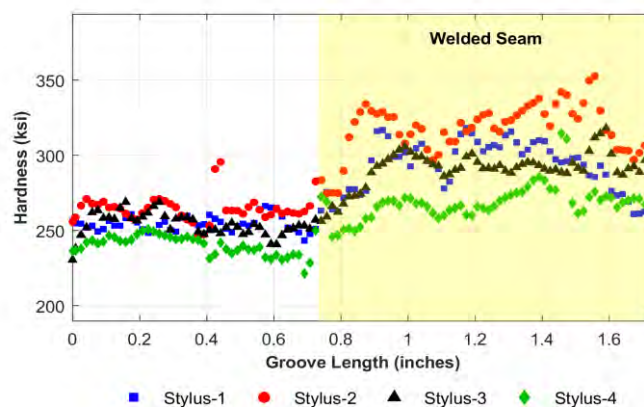
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	14:48		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample ID	114		Pipe Size	8 OD x 0.25 WT (in)		Operator Initials	RP		
Test Name	114-Q1_WD-01_5002-EB5002_190507144827					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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ 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:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

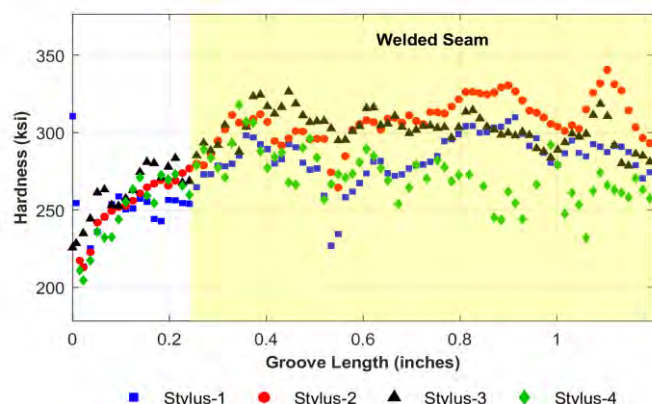
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	16:31	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	7001-EB7001	
Sample ID	115	Pipe Size	8 OD x 0.26 WT (in)	Operator Initials	JJ	
Test Name	115-Q1_WD-02_7001-EB7001_190507163125			Sample Type	Cutout	
Sample Description						
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	2	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 Version: 2.2

HSD Stylus Hardness

	Base Metal Average (ksi)	Weld Zone Average (ksi)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☐ Flash☐ Lap-Welded☐ See Comments☒ ERW [calculated percent probability below]

100 % Low Frequency ERW (LF-ERW)

0 % High Frequency ERW (HF-ERW)

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:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

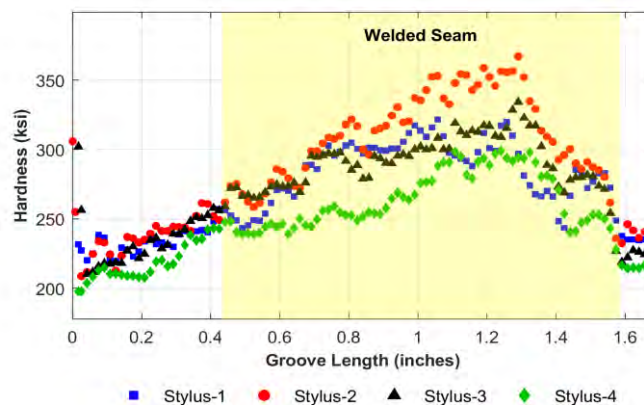
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	13:19			
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5001-EB5001			
Sample ID	116		Pipe Size	8 OD x 0.25 WT (in)		Operator Initials	RP			
Test Name	116-Q1_WD-01_5001-EB5001_190507131912					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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ 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:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

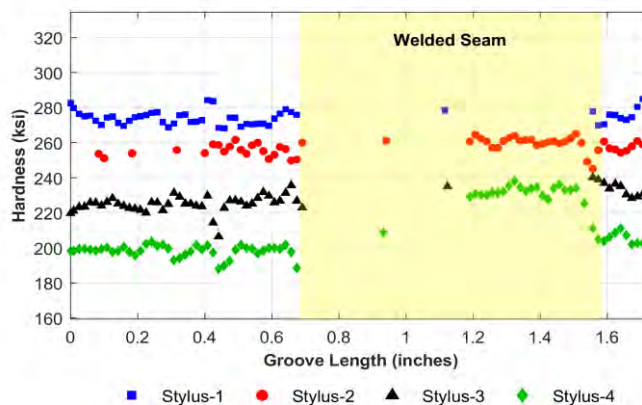
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample ID	119		Pipe Size	10 OD x 0.27 WT (in)		Operator Initials	RP		
Test Name	119-Q1_WD-01_5002-EB5002_190506160545					Sample Type	Cutout		
Sample Description									
						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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Approved:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

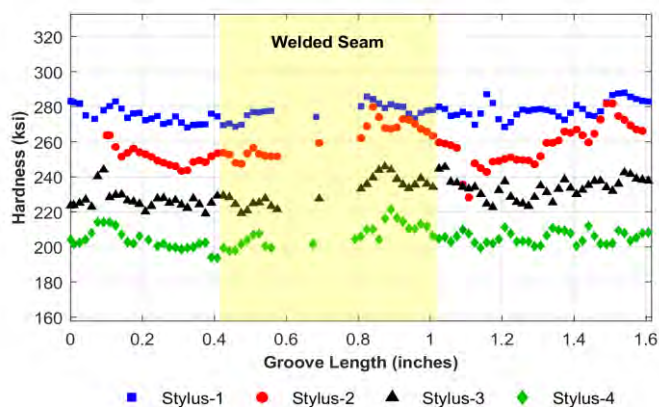
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002			
Sample ID	119		Pipe Size	10 OD x 0.27 WT (in)		Operator Initials	RP			
Test Name	119-Q1_WD-02_5002-EB5002_190506163610					Sample Type	Cutout			
Sample Description										
						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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Approved:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

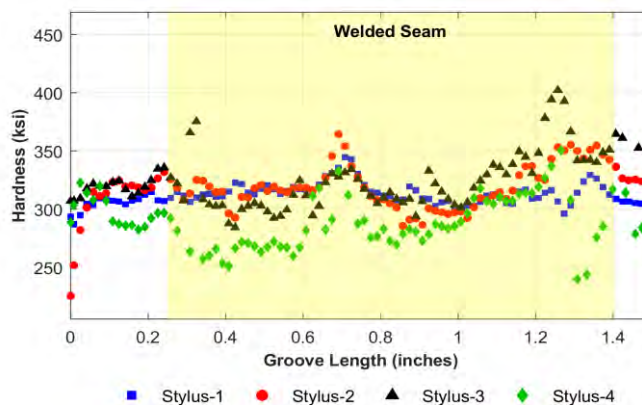
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5001-EB5001		
Sample ID	122		Pipe Size	10 OD x 0.25 WT (in)		Operator Initials	RP		
Test Name	122-Q2_WD-01_5001-EB5001_190506151543					Sample Type	Cutout		
Sample Description									
						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)☒ 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:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

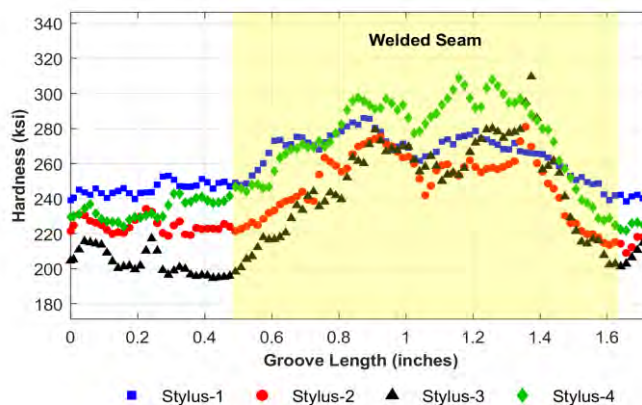
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Sample ID	124		Pipe Size	6 OD x 0.16 WT (in)		Operator Initials	RP		
Test Name	124-Q1_WD-01_5002-EB5002_190520145329					Sample Type	Cutout		
Sample Description									
						LVDT-1 Serial No.	L01-190107		
Surface Finish	2000	Grit				LVDT-2 Serial 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Approved:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

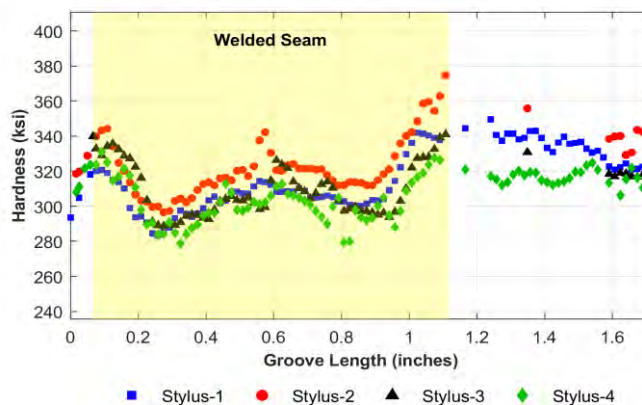
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample ID	125		Pipe Size	10 OD x 0.22 WT (in)		Operator Initials	RP		
Test Name	125-Q1_WD-01_5002-EB5002_190508165340					Sample Type	Cutout		
Sample Description									
						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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

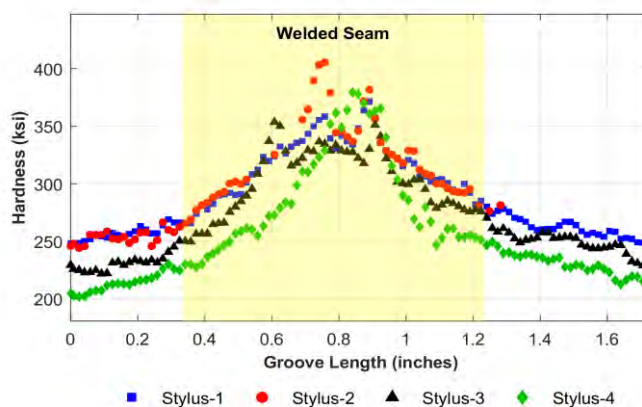
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Test Location	Gas Technology Institute			Test Date	5/29/2019	
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018			Test Time	20:04	
GPS Coordinates	42.020363, -87.921393	Dig ID		HSD Serial No.	5002-EB5002	
Sample ID	130	Pipe Size	4 OD x 0.20 WT (in)	Operator Initials	JJ	
Test Name	130-Q1_WD-01_5002-EB5002_190529200440			Sample Type	Cutout	
Sample Description						
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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ 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:

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Approved:

Steven Palkovic, PhD



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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

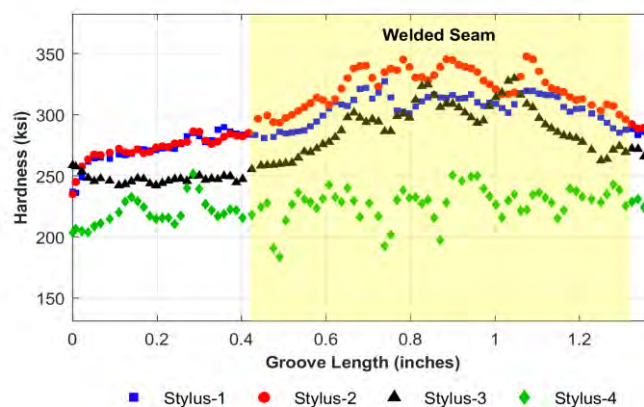
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	7001-EB7001			
Sample ID	133		Pipe Size	8 OD x 0.26 WT (in)		Operator Initials	JJ			
Test Name	133-Q1_WD-01_7001-EB7001_190506173031					Sample Type	Cutout			
Sample Description										
						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)☒ 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

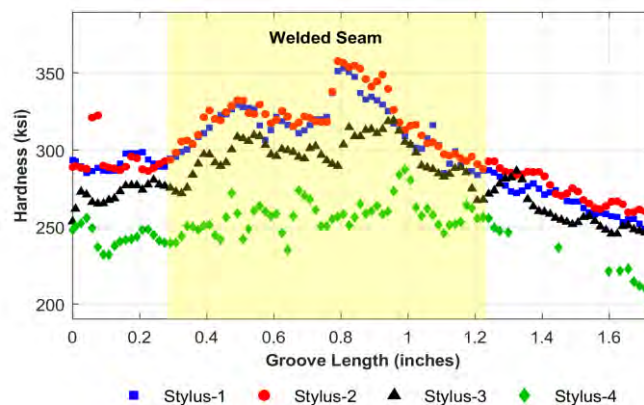
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GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample ID	134		Pipe Size	8 OD x 0.26 WT (in)		Operator Initials	RP		
Test Name	134-Q1_WD-01_5002-EB5002_190507125915					Sample Type	Cutout		
Sample Description									
						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)☒ 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

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

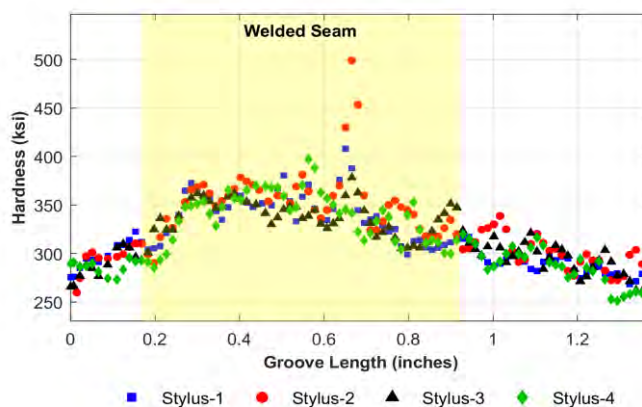
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Sample ID	137	Pipe Size	6 OD x 0.19 WT (in)	Operator Initials	JJ	
Test Name	137-Q1_WD-01_7001-EB7001_190521181409			Sample Type	Cutout	
Sample Description						
Surface Finish	2000	Grit		LVDT-1 Serial No.	L01-190107	
HSD Core Speed	0.117	in/min		LVDT-2 Serial No.	L02-190107	
Travel Distance	2	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 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

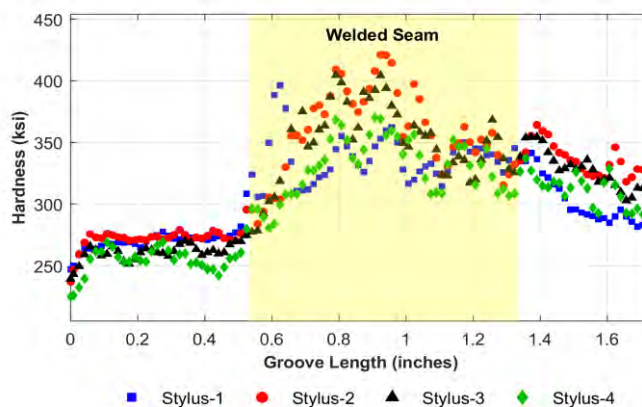
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Sample ID	140		Pipe Size	8 OD x 0.18 WT (in)		Operator Initials	JJ		
Test Name	140-Q1_WD-01_5001-EB5001_190509121335					Sample Type	Cutout		
Sample Description									
						LVDT-1 Serial No.	L01-190107		
Surface Finish	2000	Grit				LVDT-2 Serial 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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ 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

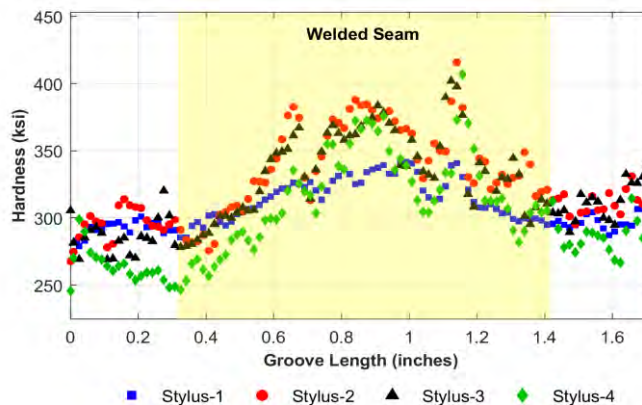
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Sample ID	141		Pipe Size	8 OD x 0.19 WT (in)		Operator Initials	JJ		
Test Name	141-Q2_WD-01_5001-EB5001_190509114427					Sample Type	Cutout		
Sample Description									
						LVDT-1 Serial No.	L01-190107		
Surface Finish	2000	Grit				LVDT-2 Serial 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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

Yasamin Salamat, PhD

Approved:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

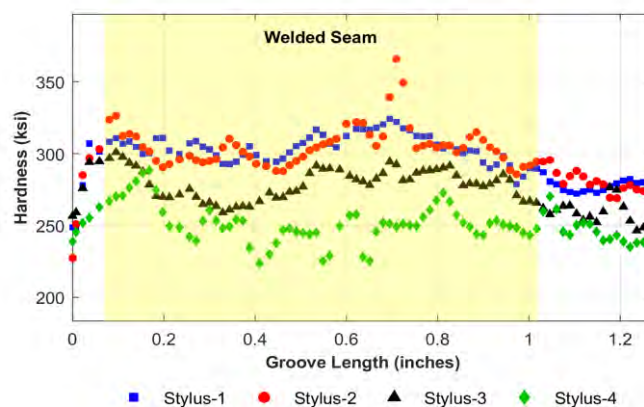
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Sample ID	142		Pipe Size	6 OD x 0.20 WT (in)		Operator Initials	JJ		
Test Name	142-Q1_WD-01_7001-EB7001_190521172639					Sample Type	Cutout		
Sample Description									
						LVDT-1 Serial No.	L01-190107		
Surface Finish	2000	Grit				LVDT-2 Serial 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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

Prepared:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

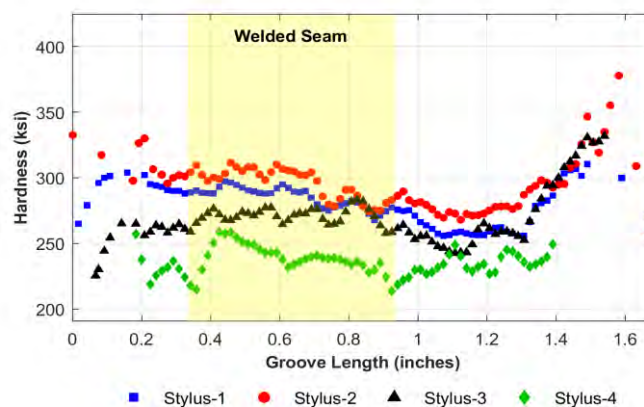
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Sample ID	143		Pipe Size	4 OD x 0.19 WT (in)		Operator Initials	RP		
Test Name	143-Q1_WD-01_5002-EB5002_190523182552					Sample Type	Cutout		
Sample Description									
						LVDT-1 Serial No.	L01-190107		
Surface Finish	2000	Grit				LVDT-2 Serial 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)☒ ERW [calculated percent probability below]☐ Flash % 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

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Approved:

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Hardness, Strength, and Ductility (HSD) Tester - Welded Seam Report

Testing Information

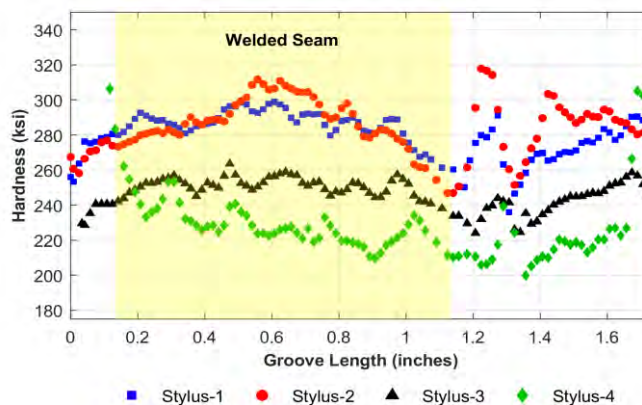
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	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	9:50		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample ID	143		Pipe Size	4 OD x 0.19 WT (in)		Operator Initials	RP		
Test Name	143-Q1_WD-03_5002-EB5002_190524095011					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)	ΔH_s (ksi)	Normalized ΔH_s (%)
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

 ΔH_s : Average change in hardness between base metal and weld regions.Normalized ΔH_s : ΔH_s 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)☒ ERW [calculated percent probability below]☐ Flash % 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

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Testing Information

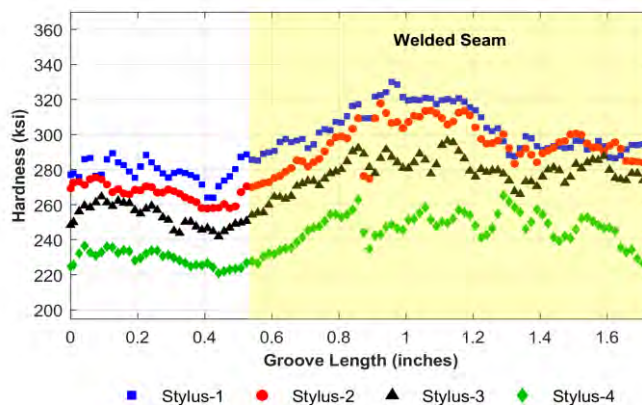
Customer	Gas Technology Institute		Job ID	GTI19006		Report No.	190530142658		REV --
Test Location	Gas Technology Institute					Test Date	5/30/2019		
	1700 S. Mt. Prospect Rd. Des Plaines, IL 60018					Test Time	14:26		
GPS Coordinates	42.020363, -87.921393		Dig ID			HSD Serial No.	5002-EB5002		
Sample 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)☒ ERW [calculated percent probability below]☐ Flash % 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

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