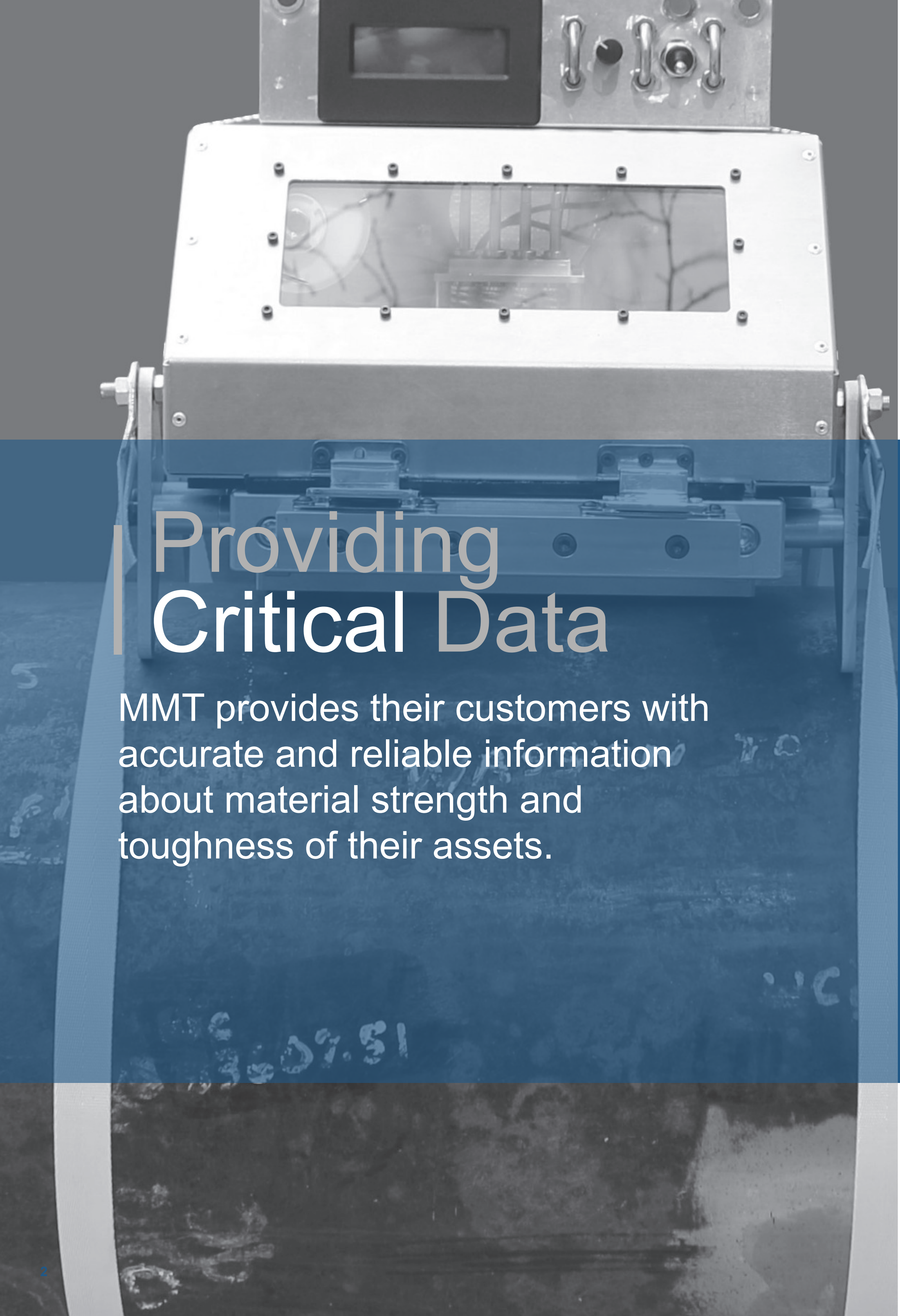
**Massachusetts
Materials
Technologies LLC**

HSD Tester

Nondestructive Material Verification



Providing Critical Data

MMT provides their customers with accurate and reliable information about material strength and toughness of their assets.

Why Operators Choose MMT

Providing Data to Ensure Safe Operation

Thickness & Crack Data

Yield Strength & Toughness

Safe operation requires two types of data, pipe geometry and material properties. There are many technologies that collect thickness, crack size, and other geometric records, but only a few that measure material properties. MMT is one of the few solutions that provides critical strength data to complete material records.

Cost Effective Technologies

NO Service Interruption

Pipeline integrity management is expensive, requiring decisions that consider the costs of service interruption, pipeline replacement, and potential catastrophic failure. MMT offers a cost effective solution that is nondestructive and practical, requiring no service interruption. Ultimately, embracing MMT's solutions across the industry will reduce cost by life extension, eliminate service interruptions, and reduce the risk of major failures and incidents.

Complementary to In-Line Inspections

ILI + NDT = Safer Operation

In-line inspection (ILI) provides key data for pipeline surveying, identifies "weak links," and groups similar pipes. Nondestructive Testing (NDT) provides accurate strength measurements for an exposed pipe joint. Combining ILI and NDT methods could produce accurate and reliable datasets for more efficient use of pipeline integrity budgets.

Nondestructive Material Verification

Material verification is an essential practice for all industries to obtain critical material property data to ensure safety, meet all government regulations, maintain proper records, and expand the lifetime of existing assets.

The Hardness, Strength and Ductility (HSD) Tester is a portable, nondestructive testing (NDT) instrument for metals that accurately and reliably measures the yield strength and identifies the longitudinal welded seam type of pipelines without service interruptions or expensive cutouts.

The HSD Tester will support the need to extend the life of old pipelines and to perform quality control of new assets.

Innovative Technology
Transforming the Industry

Portable

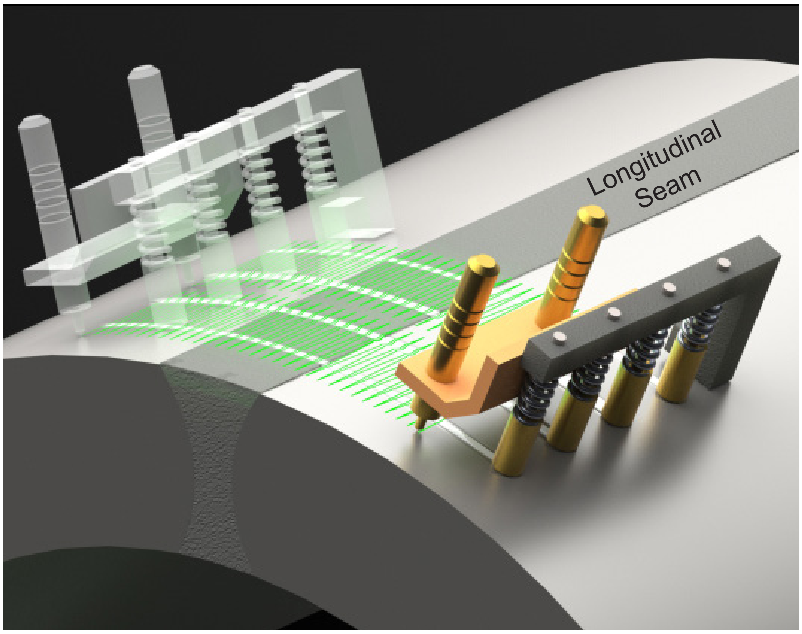
Designed to test on pipes ranging from 4 to 60 inches in diameter. Field personnel are equipped to complete any job, including in-ditch testing of oil and gas pipelines. Testing of fittings, tanks, and flat plates is also available.

Nondestructive

The HSD Tester leaves multiple grooves on the pipe surface with a depth of less than 0.002 inches (50 μm). The groove geometry is shallow and spherical so there is a limited stress concentration around the deformed area. Grooves can be buffed from the surface after testing if long-term fatigue performance is a concern.

Accurate

The performance and capabilities of the HSD Tester have been demonstrated through testing on more than 50 integrity digs and an internal database of 124 steel pipe joints. Testing has been performed on pipes of varying vintage and fabrication, including seamless, electric resistance welded (ERW), double submerged arc welded (DSAW), and flash welded construction. Comparing the accuracy of tensile strength prediction of the HSD Tester with laboratory tensile testing for 124 pipe samples, the yield strength is within +10% to -15% with over **90%** confidence, and the ultimate tensile strength is within +10% and -10% with over **95%** confidence.



During a test, four styluses generate grooves on the pipe surface that are measured through contact profilometry.

Material Grade Determination

The HSD Tester implements a process called frictional sliding, where multiple styluses deform the pipe surface to generate shallow grooves and measure the material response.

Hardness

A profiling tool measures the width and depth of each groove. This geometry, in addition to the force applied to each stylus, is used to calculate the hardness that indicates a material's resistance to permanent deformation.

Representative Stress & Strain

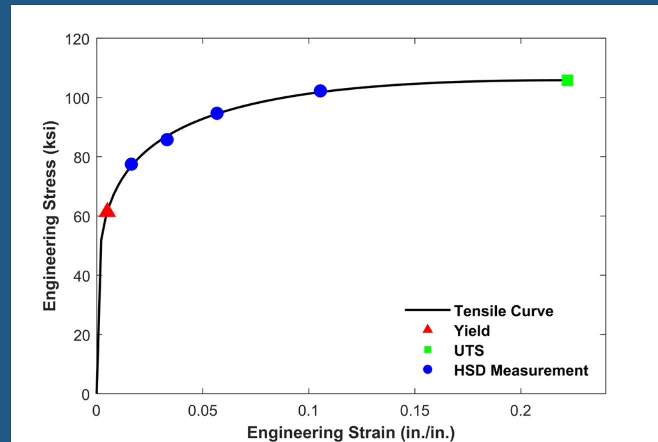
The material response for each stylus is used to calculate the representative stress and strain, relating the frictional sliding measurement to an equivalent tensile value.

Engineering Stress-Strain Curve

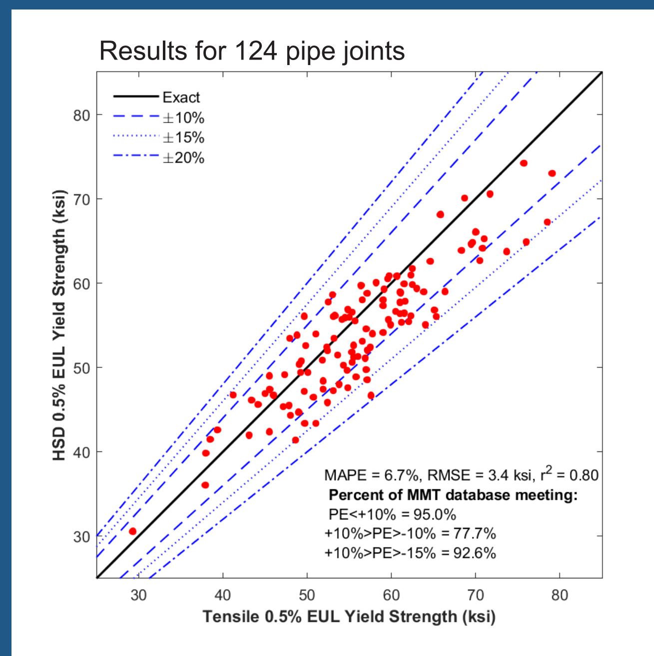
A complete stress-strain curve is fit to individual stylus measurement, allowing for determination of the tensile strength properties. This includes:

- 0.2% offset yield strength
- 0.5% elongation under load (EUL) yield strength
- Ultimate tensile strength (UTS)
- Strain hardening exponent (n)
- Power law strength coefficient (K)

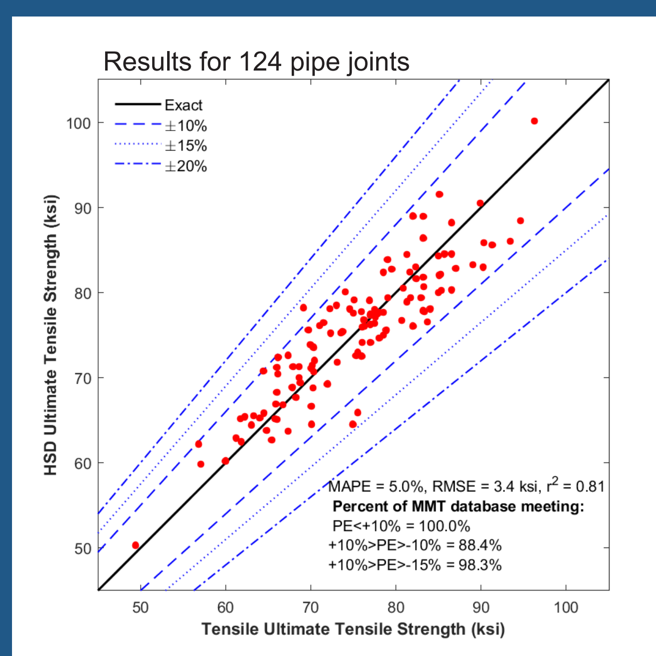
Measured Material Response



Yield Strength Performance



Ultimate Tensile Strength Performance

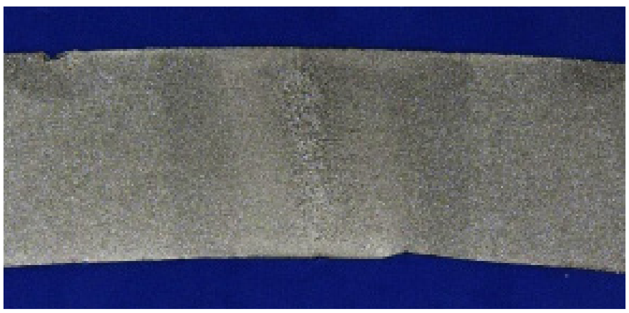


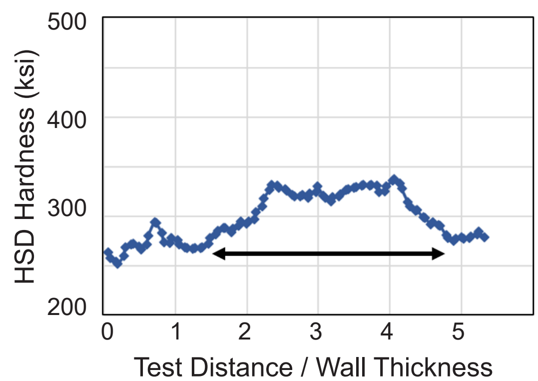
Welded Seam Identification

The HSD Tester scans over a longitudinal welded seam and identifies the fabrication process. The seam type is determined through the analysis of the hardness variation across the weld. The number of local increases in hardness associated with the presence of heat-affected-zones, magnitude of local hardness increases, and the overall size of the affected area all provide data that can be used to classify the weld fabrication process such as Low Frequency or High Frequency Electric-Resistance Welds (LF-ERW or HF-ERW), Double-Submerged Arc Welds (DSAW), Flash Welds, and the presence of post-weld-heat-treatment (PWHT).

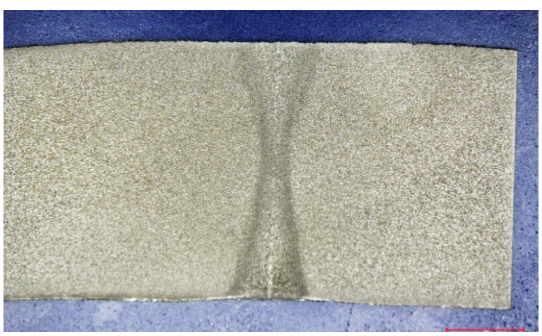
Seam Cross Section | HSD Measured Response

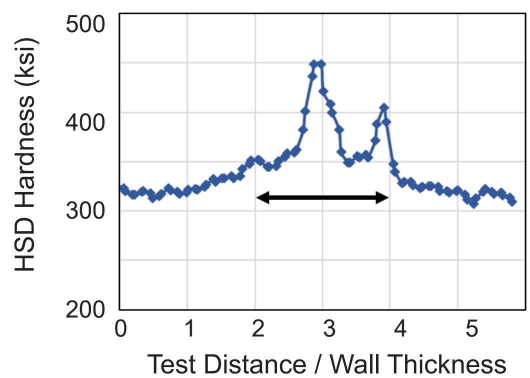
Low Frequency Electric-Resistance Welds (LF-ERW)



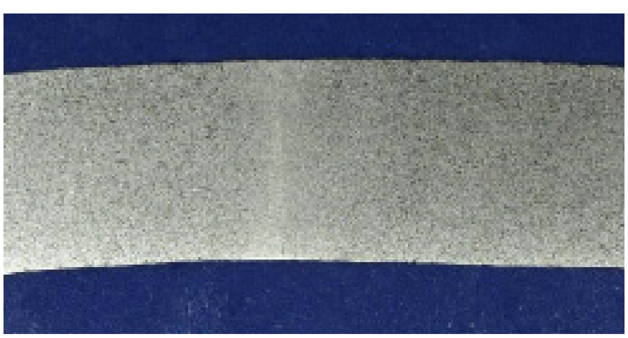


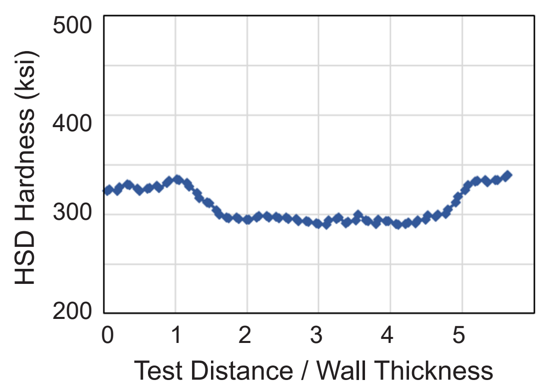
High Frequency Electric-Resistance Welds (HF-ERW)





Normailized Seam (Post-Weld-Heat-Treatment)



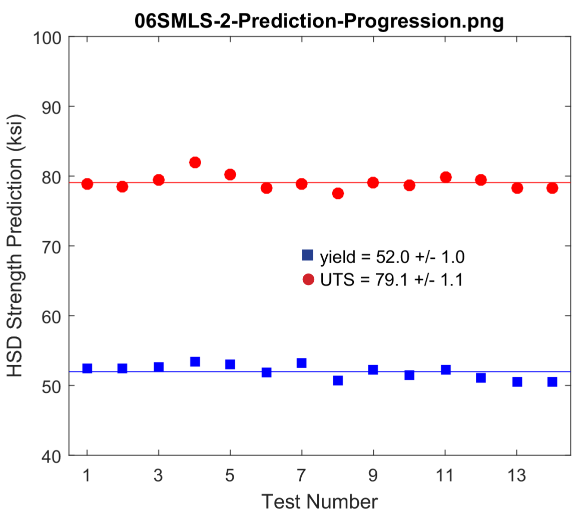


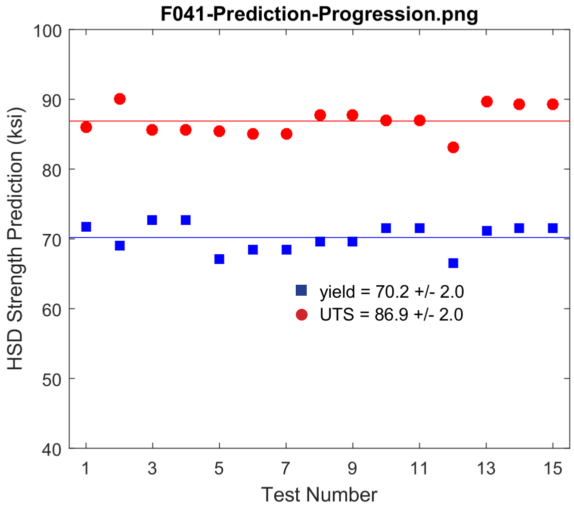
HSD Tester Performance

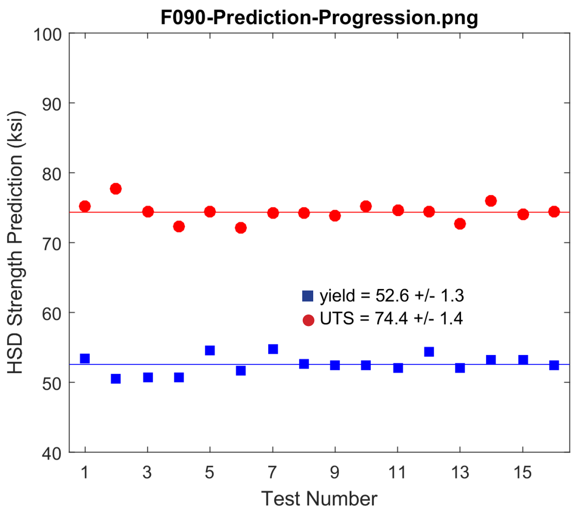
Repeatability

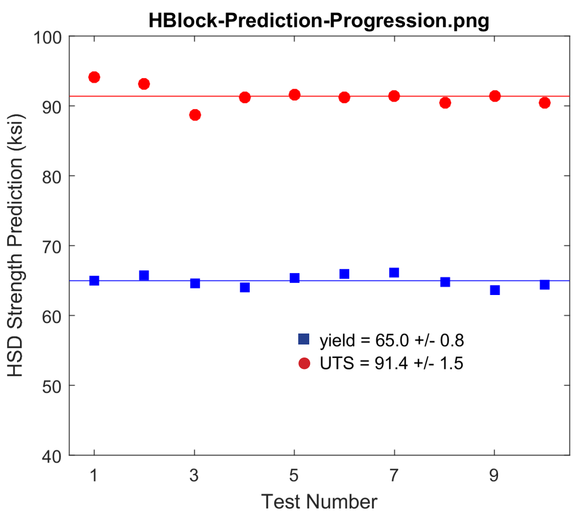
The consistency of the HSD Tester can be assessed by monitoring tensile strength measurements on the same material over time. The plots below provide examples of repeatability for four homogeneous steel materials of varying grade and composition which have been tested 10 or more times. A homogeneous material has uniform strength properties throughout the specimen that allows for a direct comparison between the HSD surface measurements and the full wall thickness tensile coupon. The tests shown in the four plots of Fig.1 were performed by different technicians, using two different HSD Tester units, and were performed over the course of three months. The small scatter and standard deviation for yield strength and ultimate tensile strength indicates the high repeatability of the HSD Tester and method.

Fig 1. Repeatability of tensile strength predictions for 4 homogeneous steel materials. The mean and standard deviation of the 0.5% EUL yield strength and ultimate tensile strength (UTS) for the tests is shown.





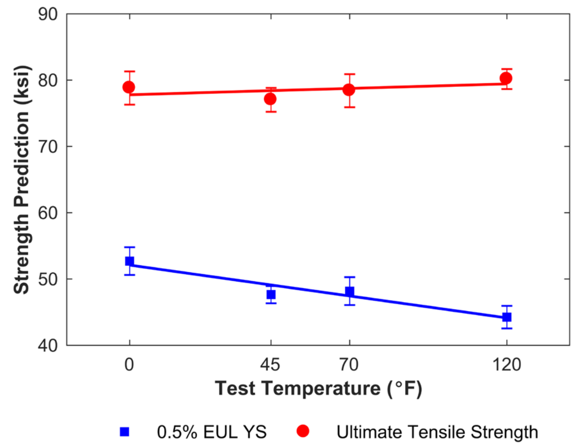




Influence of Environmental Temperatures

In-ditch material verification is conducted at temperatures that can reach extreme conditions. Temperature testing has been conducted to assess its influence on the HSD Tester measurement. A homogeneous steel plate was tested at temperatures of 0°F, 45°F, 70°F and 120°F (-17.8°C, 7.2°C, 21.1°C and 48.9°C). The results in Fig. 2 indicate that the yield strength shows a linear decrease with increasing temperatures, whereas the UTS is not strongly influenced. These observations are consistent with expectations for the response of steel materials to a range of temperatures.

Fig 2. Effect of temperature on the yield and UTS measurement of the HSD Tester.



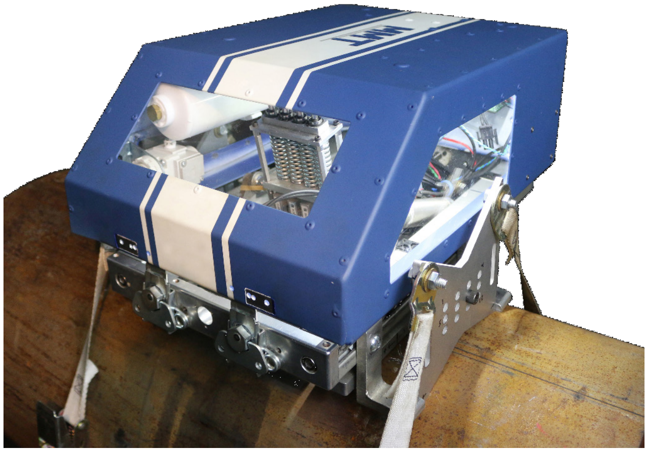
The All-in-One Solution

The HSD Tester is a technology that meets all the standards demanded by the industry. It is the only solution that accurately and reliably measures the yield strength and identifies the longitudinal welded seam type of pipelines at an efficient cost and in a timely manner without the need for service interruptions or expensive cutouts.

	MMT HSD Tester	Indentation	Hydrotesting & Cutouts
Nondestructive	✓	✓	✗
Accuracy	✓ Best (and needed)	✓ Accepted by some	✓
Cost Effective	✓	✓	✗
Time Saving	✓	✓	✗
Seam Identification	✓	✗	✓

Valuable Data for Pipeline Integrity Management

The HSD Tester presents the opportunity for complete material records at an affordable cost. The information the HSD Tester can provide is needed to ensure safe operation of pipelines and meet all government regulations. Major costs associated with service interruption, pipeline replacement, hydrostatic pressure testing, and catastrophic failure can be avoided by implementing this cost-effective solution. No alternative method exists for longitudinal seam determination.



Technical Specifications

Weight	28.6 lbs / 12.95 kg
Dimension	19 in x 9 in x 13.5 in (L x H x D) 48.26 cm x 22.86 cm x 34.29 cm
Power	120V
Test Duration	10 minutes
Test Distance	1.33 inches / 3.38 cm
Computer Unit	Microsoft Windows

Highlights and Applications

Low Cost

- No service interruptions
- No expensive cutouts

Portable

- Ready to use in-ditch
- Capable to test on pipes, fittings, and plates

New Asset Verification

- Confirm manufactured material properties

Old Asset Verification

- Complete missing material testing records (MTR)

Full Data Service

MMT provides field personnel equipped to complete any on-site job, including in-ditch testing of oil and gas pipelines.

Hardness, Strength, and Ductility (HSD) Tester

MMT tests two regions for each pipe joint including one centered on the longitudinal seam for ERW pipes.

Chemical Composition through Spark OES or Burr Samples

Spark Optical Emission Spectroscopy (OES) - A spectrometer capable of identifying chemical composition and analyzing key elements.

Burr Samples - MMT removes burr shavings from the surface of the pipe, no more than 0.005” into the surface. Samples are sent to a laboratory for testing, combustion analysis is used to measure carbon content and Iductively Coupled Plasma OES is used for all other elements.

Metallographic Grain Size

Average grain size is measured using the mean-linear-intercept (mli) method with surface microscopy of the etched microstructure.

Contact Information

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