Nondestructive Measurements of Tensile and Fracture Toughness

By
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ABI® Overview

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What It Is

Automated Ball Indentation® (ABI®)

- ABI® is a nondestructive mechanical testing technique for determining Tensile and Fracture Toughness Properties
- It is based on progressive indentation with intermediate partial unloadings until the maximum depth (maximum strain) is reached, and then the indenter is fully unloaded.
- The ABI® test is a macroscopic (bulk) technique that measures the properties on a small volume of material.

Determining Pipe Grade According to API 5L

Three values are required

- Specified Minimum Yield Strength (SMYS)
- Specified Minimum Tensile Strength (SMTS)
- Maximum Ratio of SMYS/SMTS

Table 1 Tensile Requirements According to API Specification 5L for Line Pipe

Grade	Yield Strength Minimum		Ultimate Tensile Strength, Minimum		Yield to Tensile Ratio (max.)
	PSI	MPa	PSI	MPa	
A25	25,000	(172)	45,000	(310)	0.93
A	30,000	(207)	48000	(331)	0.93
B	35,000	(241)	60,000	(413)	0.93
X42	42,000	(289)	60,000	(413)	0.93
X46	46,000	(317)	63,000	(434)	0.93
X52	52,000	(358)	66,000	(455)	0.93
X56	56,000	(386)	71,000	(489)	0.93
60	60,000	(413)	75,000	(517)	0.93
X65	65,000	(448)	77,000	(530)	0.93
X70	70,000	(482)	82,000	(565)	0.93
X80	80,000	(551)	90,000	(620)	0.93

Determining MAOP

MOAP = (Factors of safety x SMYS x t)/ (OD)

The use of the ABI®-measured key tensile properties for undocumented pipeline sections allows for the calculation of an accurate and less-conservative maximum safe operating pressure.

SMYS

Pipe Thickness (t)

Pipe Outer Diameter (OD)

Key Benefits

Stress-Strain Microprobe® (SSM)

Nondestructive

- The ABI® technique is ideal for testing in-service components where cutting samples is either too costly or impractical – such as pipelines
- The spherical indentations produced on the pipe surface are shallow, smooth depressions with no sharp edges or stress concentration sites

Efficient

- ABI®-measured yield and ultimate strength values in minutes for fast grade determination
- Tests are performed on in-service pipelines so there is no costly transmission loss or downtime

Select ABI Users

Sandia National Laboratories
NASA
Oak Ridge National Laboratory
PGW
Chevron
BR Petrobras
PG&E Pacific Gas and Electric Company
Y12
TransCanada In business to deliver
Westinghouse
bp
DTE Energy
ConocoPhillips
KAERI Korea Atomic Energy Research Institute
Columbia Pipeline Group
DuPont
Los Alamos National Laboratory EST. 1943
KRISS Korea Research Institute of Standards and Science
ExxonMobil
Shell Global Solutions
eDF
UC San Diego
Shadong University 1901
Statoil
Northern Natural Gas A MidAmerican Energy Holdings Company

*Several of the listed clients listed contracted services or purchased equipment from Advanced Technology Corporation. ABI Services is the services arm of ATC, but operates as a separate legal entity.

Applications

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Applications

Oil and Gas Pipelines

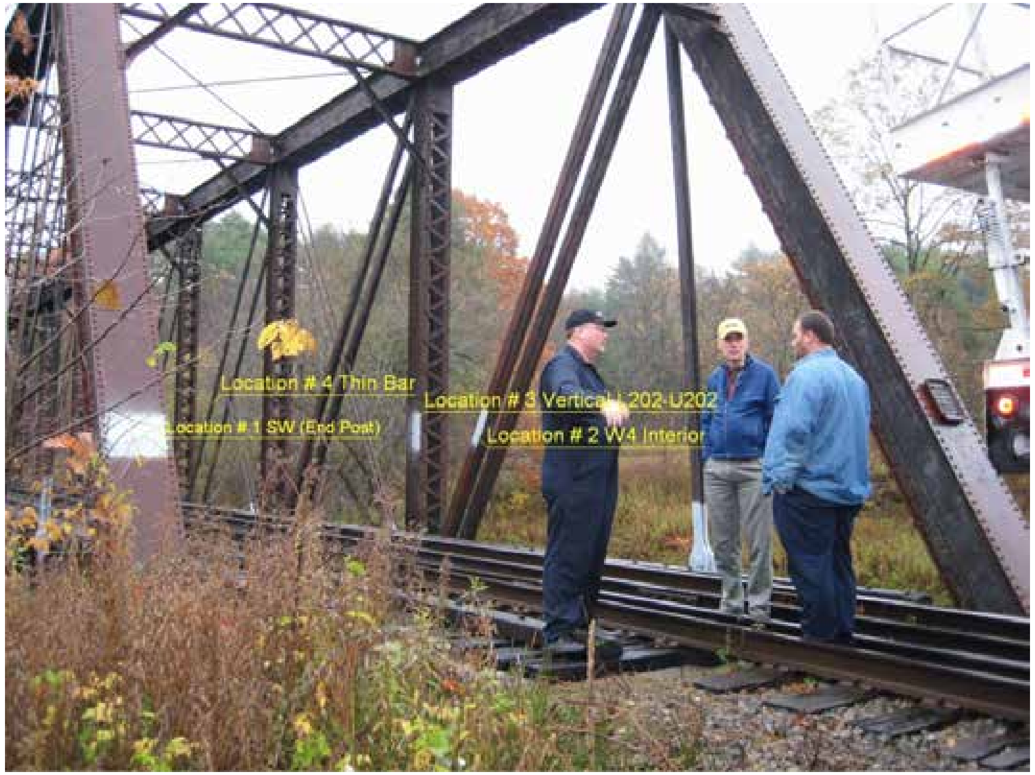
Other Field Applications

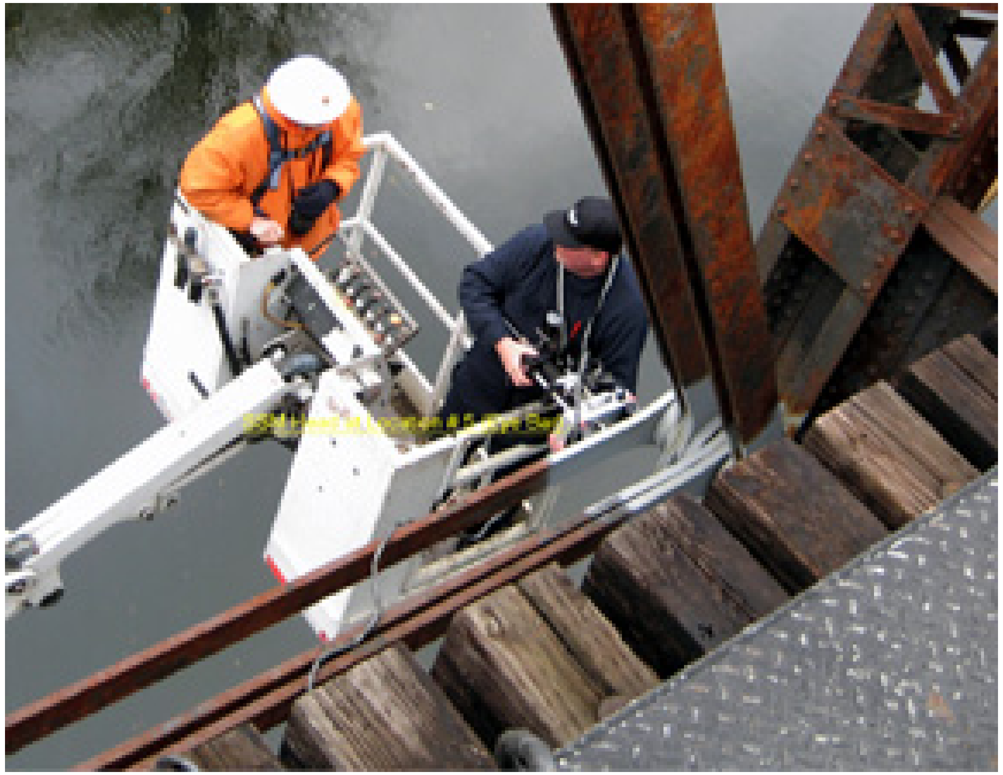
Storage Vessels

Forgings

Other Field Applications

Bridges





Capabilities

2” OD and larger pipes

7” long sections and larger

Bends/elbows

T-fittings

Compression station piping

Case Studies

Case Study: Determining Pipe Grade

Client X: Determining pipe grade following an acquisition

To determine the pipe grade based on the ABI®-measured yield strength (YS) and tensile strength (TS) values (average value minus one standard deviation from 3-5 ABI tests) and comparing them to the API 5L specified minimum YS and TS values per each pipe grade (SMYS and STS and the maximum allowable ratio of YS/TS).

The majority of in-situ ABI® tests were conducted on pipelines sections with unknown grades (material certificates were lost due to merger and acquisitions, staff retirements, or replacement of corroded or damaged joints with undocumented ones that meet only outer diameter values).

Case Study: Determining MAOP with Varying Wall Thickness

Client Y: Wall thickness changed, but the data showed the MAOP did not have to be lowered

A smart-pig MFL tool run discovered a 50’ pipe joint (12” outer diameter) with a reported wall thickness of 0.281” while the rest of the pipeline had a wall thickness of 0.312” of Grade X52. It was obvious that the uniformly reduced thickness was not due to corrosion but, most likely, because the original joint was replaced due to severe localized corrosion (the pipe joint was located in a swamp area).

The in-situ ABI® tests confirmed that the joint met Grade X65 for the mechanical properties requirements; hence, the MAOP of the line did not need to be lowered since the increased Grade of X65 (instead of X52) compensated for the reduced thickness. The MAOP is a function of three parameters (SMYS x wall thickness / pipe outer diameter), in addition to the various mandatory factors of safety. This case study demonstrates the complementary abilities of using in-line inspection and in-situ ABI® testing.

Case Study: Preventing a Tank Fracture

Client Z: Preventing a tank fracture when inserting a new nozzle

The client needed to determine the fracture toughness of a storage tank wall before cutting a plug for a new nozzle/outlet fabrication to ensure no brittle fracture could occur during the modification. ABI® testing provided the client with the tank wall mechanical properties to achieve the modification safely.

Case Study: Verifying properties after a fire

Client T: After a fire, safely placing a $12M petrochemical vessel back in service

To verify tensile, ductility, and fracture toughness following a fire accident in a petro-chemical pressure vessel that lasted 30 minutes at an unknown, high temperature. Fortunately, this undocumented vessel (8 to 14-inch thick forging) manufactured in the 1950s was ABI® tested, in-situ, six-months prior to the fire incident to establish its base properties.

Following the fire accident, the resultant new values of ductility and fracture toughness measured by the ABI® tests were within 95% of the pre-fire properties and the $12M vessel was placed back in service safely.

How It Works

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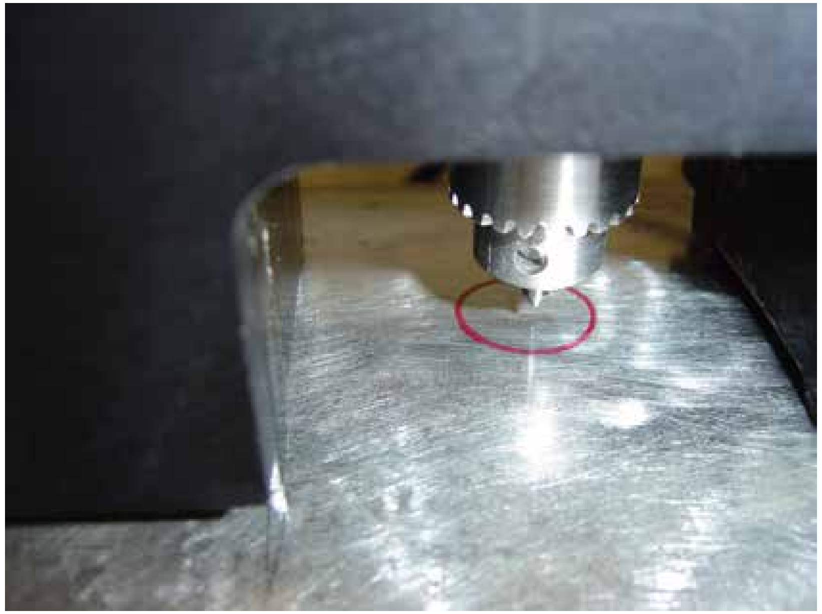
How it Works

Automated Ball Indentation® (ABI®)

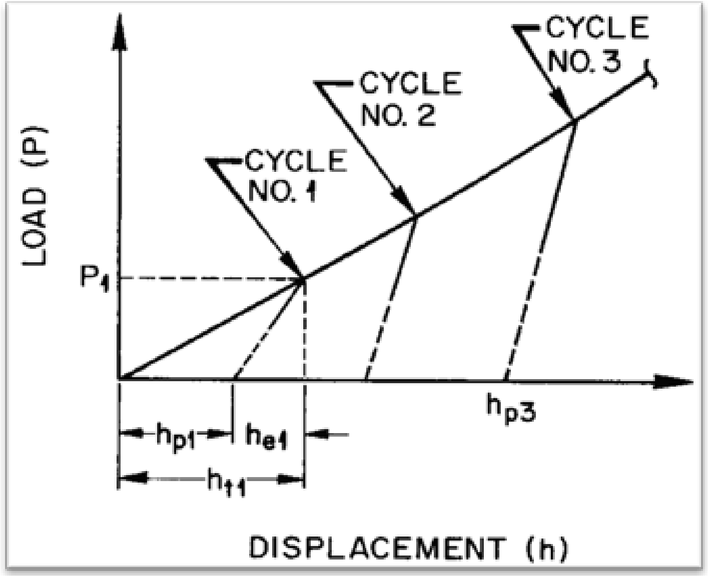


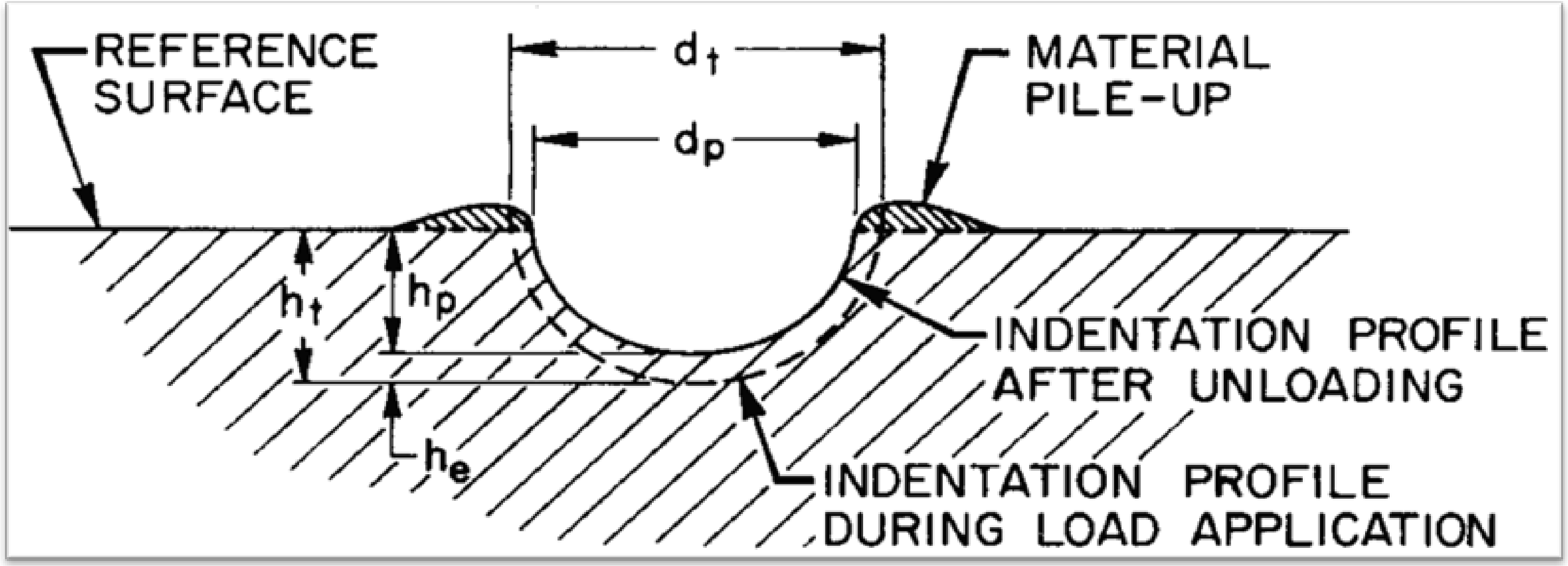
A nondestructive, spherical indentation shown to scale

- Ball indentations are shallow, with smooth edges and produce compressive stresses in the material that retard crack initiation
- The remaining ABI® depression is similar to one from shot-peening or sand blasting.

How it Works

ABI® Progressive Cyclic Loading with Multiple Partial Unloadings of Ball Indenter into Material





How it Works

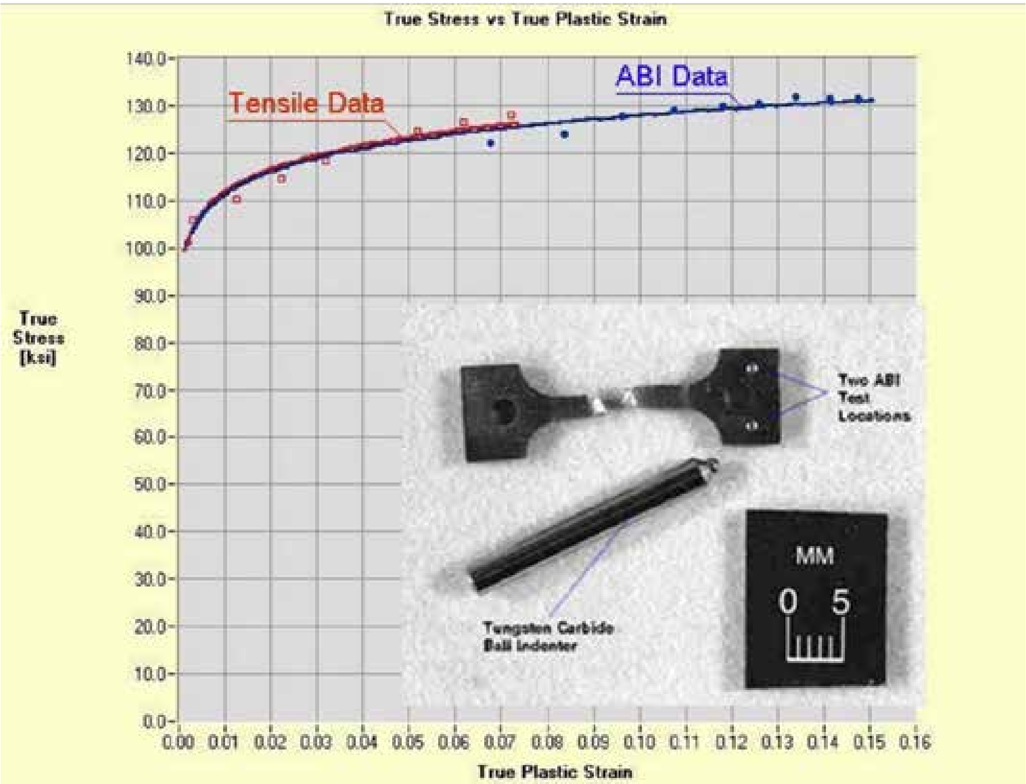
Calculation of Stress-Strain Curves

	Tensile Test	ABI® Test
Data Parameters	(1) Tensile Load, (2) Sample Extension	(1) Compressive Load, (2) Progressive Indentation Depth
Stress	Load / Cross-Sectional Area	Load/ Effective Indentation Size
Strain	DL / L_o	Constant x (Indentation diameter / Indenter diameter)

How it Works

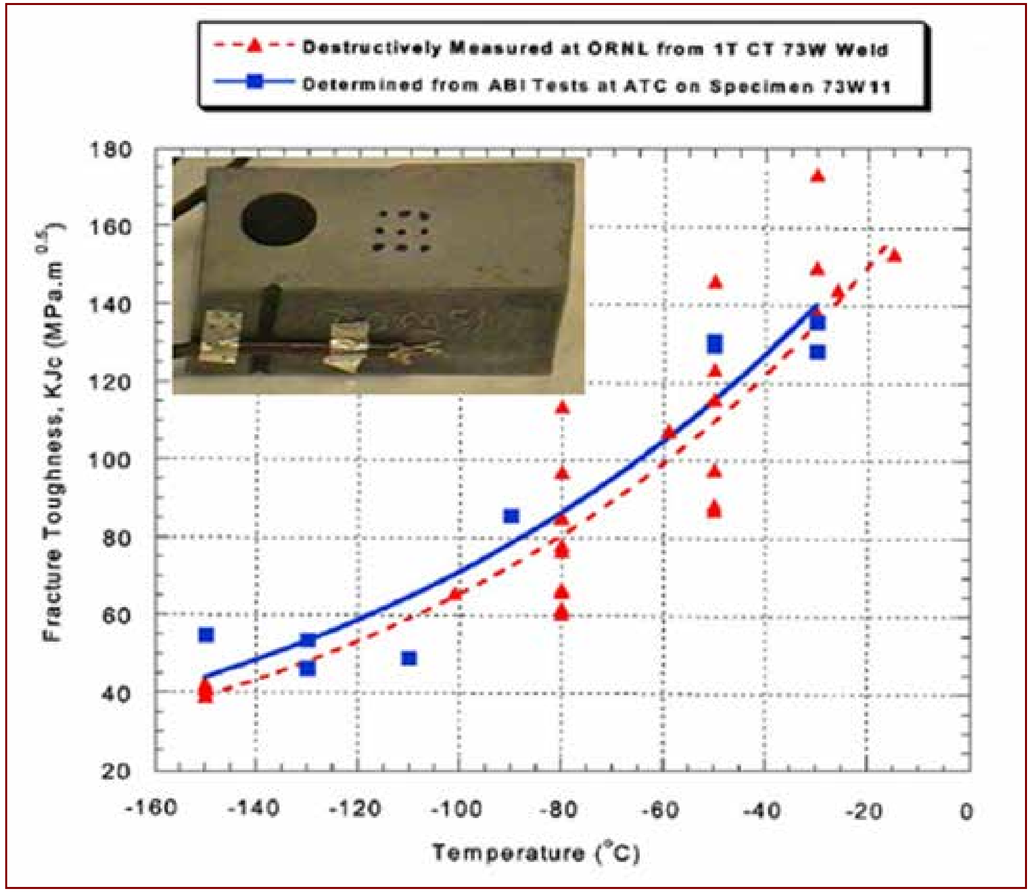
Stress-Strain Curves from ABI® and Tensile Tests on a High-Strength Steel Sample

- The ABI®-measured True- Stress versus True- Plastic-Strain curve is in excellent agreement with the curve from the destructive tensile test on a high strength material.



In-Situ/Nondestructive Measurement of Fracture Toughness

Comparison between nondestructively ABI®-measured $(K_{Jc})^{ABI}$ and destructive 1T CT fracture toughness test results of 73W Weld of Oak Ridge National Laboratory (ORNL)



Resources

Resources

In-Situ Measurement of Pipeline Mechanical Properties Using Stress-Strain Microprobe - Validation of Data for Increased Confidence & Accuracy
http://prci.org

www.abiservices-usa.com

Video demonstration link: www.abiservices-usa.com/videos

Thank you.

Any Questions?