2012 Second Annual Composite Repair Users Group Workshop

Meeting held at the Norris Conference Center (Houston, Texas)
Friday, September 7, 2012

Presentation by Chris Alexander

Taking on your toughest technical problems

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2nd Annual Conference & Exhibition

- Welcome and introduction
- Preliminary items
  - Facilities and safety moment
  - Sponsors
  - Information packet (schedule and ballot)
- Today's meeting schedule
- CRUG Mission Statement
- CRUG Board Members
- Presentations

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Today's Meeting Schedule

8:00 to 8:30	**Meet, greet and check-in: *Sponsored by Armor Plate***
8:30 to 8:45	Introductions, welcome and workshop overview - Chris Alexander
8:45 to 9:15	Overview: Ongoing research and lessons learned - Chris Alexander
9:15 to 9:45	Codes and Standards - Franz Worth (Air Logistics)
9:45 - 10:00	**Morning break and booth time: *Sponsored by InduMar Products***
10:00 to 10:30	Advanced composite repair concepts: Reinforcement of axially-aligned notches in pipelines - David Miles (Pipestream, Inc.)
10:30 to 11:00	Inspection of composite materials, microwave technology - Donald MicNicol (Oceaneering)
11:00 to 11:30	Inspection of composite materials: PRCI project overview - Richard Lee (ESR Technology)
11:30 to 11:45	Voting for 2012-2013 Board Members (Ballot Submission) *Door prize give-away*
11:45 to 12:45	**Lunch Break and booth time: *Sponsored by PipeWrap, LLC***
12:45 to 1:15	Regulations in relation to the performance of composite repair systems - Richard Sanders (REServices, LLC)
1:15 to 2:15	**Panel Discussion – Regulations** Max Kieba (PHMSA), Richard Sanders (REServices, LLC), Randy Vaughn (Rail Road Commission of Texas)
2:15 to 3:15	**Panel Discussion – Technology** Michael Keller (The University of Tulsa), Ned Niccolls (Chevron), Mark Piazza (PRCI) / Richard Lee (ESR Technology)
3:15 to 3:45	**Afternoon Break and booth time: *Sponsored by Citadel Technologies***
3:45 to 4:45	**Panel Discussion – Operators** Kevin Coulter (The Dow Chemical Co.), Brent Griffin (Chevron), Stan Parrish (NiSource), Dave Wilson (Phillips 66)
4:45 to 5:00	Wrap-Up, Board Election results, closing comments

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CRUG Mission Statement

The Composite Repair Users Group has been organized to promote the proper use of composite materials and provide education for industry on structurally repairing pipelines, piping, and other pressure containing equipment subject to industry accepted standards.

2011-2012 CRUG Board Members

- Chris Alexander, Stress Engineering, Chair
- Franz Worth, Air Logistics, Vice-Chair
- Jim Souza, Pipe Wrap, LLC, Secretary/Treasurer
- Tommy Precht, Armor Plate, Inc., Public Relations
- Simon Frost, Walker Technical Resources, Compliance
- Julian Bedoya, Stress Engineering, Meeting Organizer
- Shawn Laughlin, Clock Spring, Board Member
- Dit Loyd, WrapMaster, Board Member
- Robert Rettew, Chevron, Board Member
- Satish Kulkarni, Kinder Morgan, Board Member

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Overview: Ongoing research and lessons learned

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Presentation Overview

- Composite repair overview (State of the Art)
- Industry interest as reflected in PRCI studies
- Contribution of composite materials to the integrity management of pipelines
- Case studies
  - Wrinkle bends
  - Branch connections
  - Performance at elevated temperatures
- Looking forward

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State of the Art

- Composite materials have been used to repair high pressure transmission pipelines for more than 20 years
- The key to integrating composite technology is properly designed and installed systems possessing adequate service life
- Performance testing has been an essential element in demonstrating the capacity of composite repair technology

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PRCI Research Programs

- MATR-3-4 Long-term performance (10-year)
- MATR-3-5 Repair of dents
- MATR-3-6 Repair of subsea pipelines/risers
- MATR-3-7 Girth weld reinforcement
- MATV-1-2 Wrinkle bend reinforcement
- MATR-3-9 Re-rating to establish MAOP
- NDE 2-3 NDE & Inspection Techniques Applied to Composite Wrap Repairs
- Future programs (potential)
  - Crack repair and reinforcement
  - Elevated temperature testing

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Composite Repair Past Uses

- Corrosion
- Dents (Plain; dents in seam and girth welds)
- Mechanical damage (dents with gouges)
- Tees, elbows, bends, and branch connections
- Girth welds
- Seam weld defects
- Wrinkle bends (cyclic pressure, bending, and tension)
- Cracks
- Pipe spans
- Hydrotest leak repair
- Re-rating to establish MAOP
- Elevated temperatures
- Offshore pipelines and risers

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Specific Insights

- Case Study #1
  - Topic: Wrinkle bends
  - Loading: Cyclic pressures and bending
- Case Study #2
  - Topic: Branch connections
  - Loading: Static pressure and bending
- Case Study #3
  - Topic: Elevated temperatures
  - Loading: Static pressure and coupon testing

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Case Study #1

Wrinkle Bends

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Project Overview

- Wrinkle bends (WB) were a common means for bending pipeline prior to 1955
- Several failures have occurred during recent times in gas pipelines
- Over the past 3 years SES has formed assessments on WBs for more than seven (7) pipeline companies
- Composite materials have effectively reduced strain in wrinkles
- Loads in testing have included internal pressure, cyclic internal pressure, tension, and bending

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Bending Full-Scale Testing

- March – April 2012
- Testing Goals
  - Produce a high-strain, low cycle failure in low number of cycles
  - Produce a fracture surface similar to actual failures
  - Demonstrate the effectiveness of composite reinforcement
- Samples taken from service
- Testing included the effects of internal pressure and cold temperatures

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Bending Full-Scale Testing

- Pre-test preparation
  - End fixtures fabricated, samples cut, and sand blasted
  - Instrumentation attached (strain gages and displacement transducers)
  - Reinforce one sample with composite wrap
- Testing performed to mimic the sub-scale tests using wrinkle displacements as the guide

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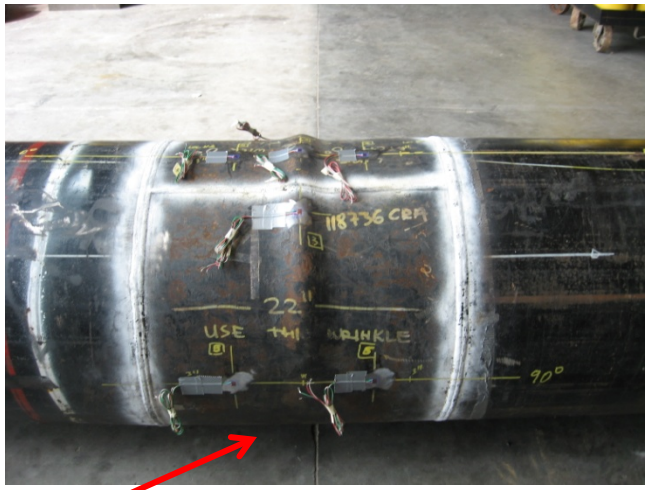
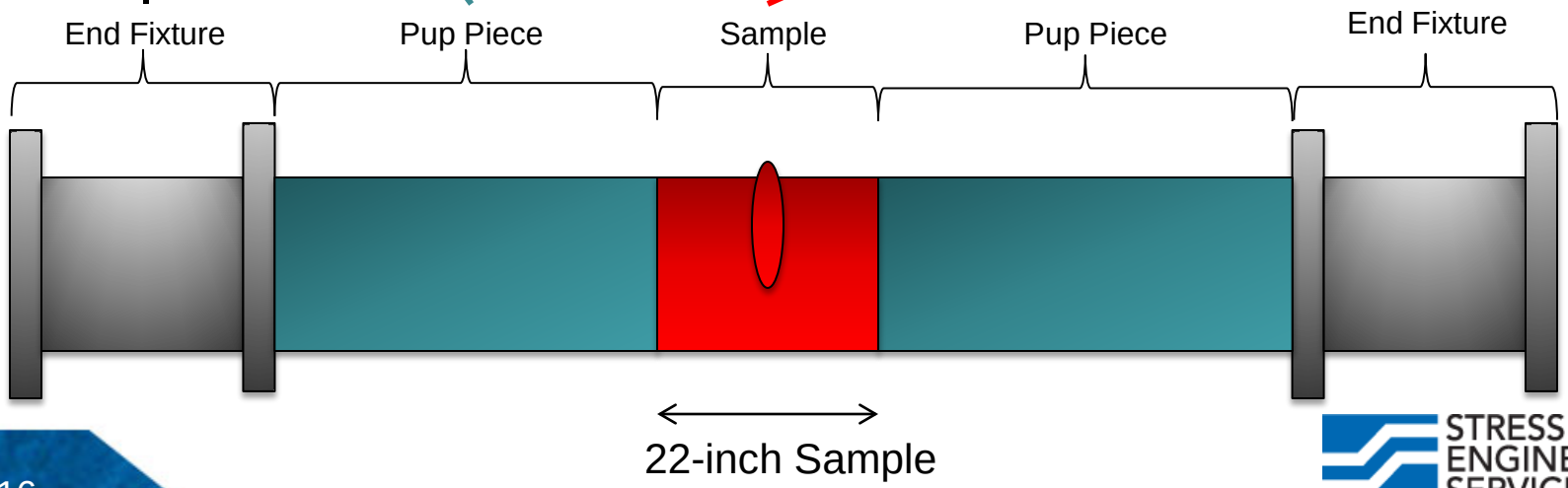
Full-Scale Sample Preparation





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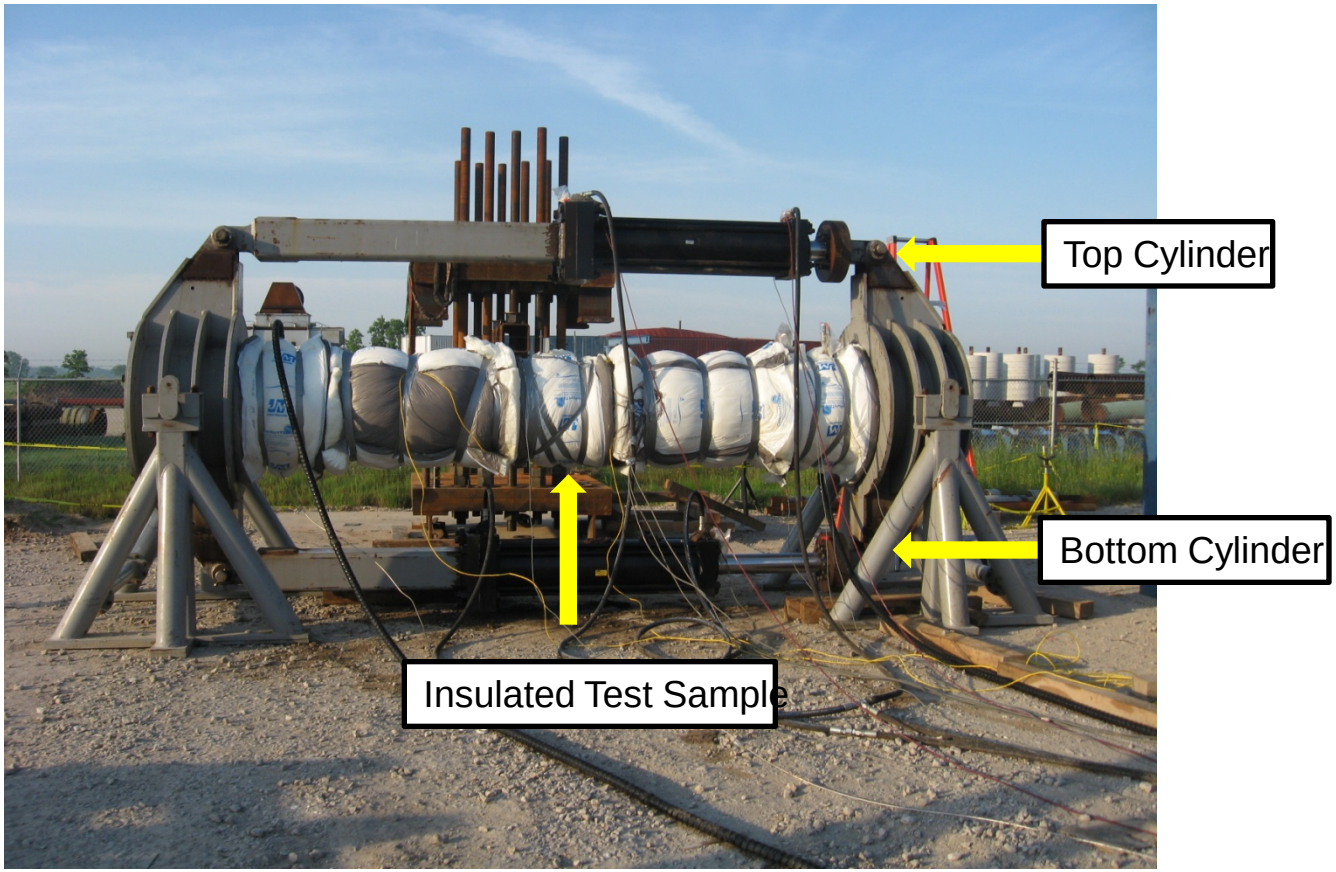
Bending Frame



Full-scale testing wrinkle bend in 24-inch pipe with DSAW running through wrinkle

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Composite Repair Comparison

- Composite sample subjected to **1,031 cycles** before a leak was detected beneath the composite

	Unreinforced Sample	Reinforced Sample
Cycles to Failure	87	1031
Wrinkle Displacements	+0.10-inch -0.10-inch	0.03-inch -0.04-inch
Strain Range at Wrinkle Apex	14000 microstrain (1.4%)	2400 Microstrain (0.24%)
Strain Range at +/-30° on Wrinkle	9000 microstrain (0.9%)	2700 Microstrain (0.27%)
Strain Range at 0° Adjacent to Wrinkle	2870 Microstrain	1900 Microstrain
Strain Range at 180° Adjacent to Wrinkle	1200 Microstrain	1550 Microstrain

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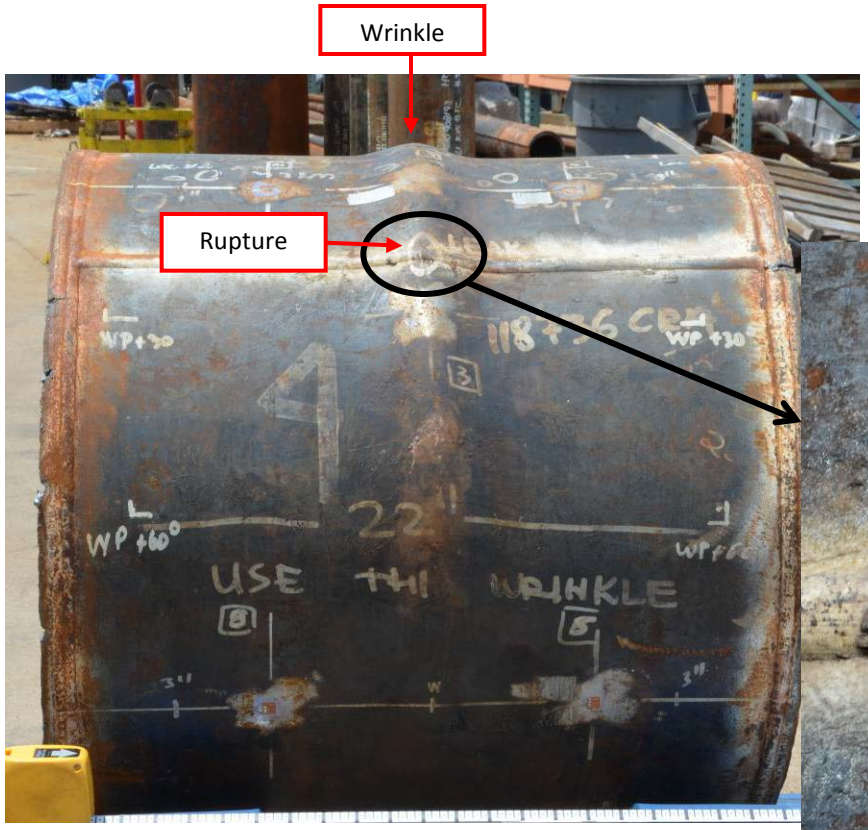
Metallurgy from Test Sample



- Weld metal fracture
- No evidence of yielding

The primary rupture was oriented circumferentially around the apex of the wrinkle

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Case Study #2
Branch Connections

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Branch Connection Testing (1/8)

- Branch connection test samples prepared using 24-inch x 0.250-inch, Grade X70 (run) and 8.625-inch x 0.322-inch, Grade X52 (branch) pipe materials:
  - Two repaired (1 in-plane and 1 out-of-plane)
  - Two unrepaired (1 in-plane and 1 out-of-plane)
- Internal pressure applied, along with the respective bending loads
- Branch connections loaded until gross plastic deformation observed (in unreinforced samples)

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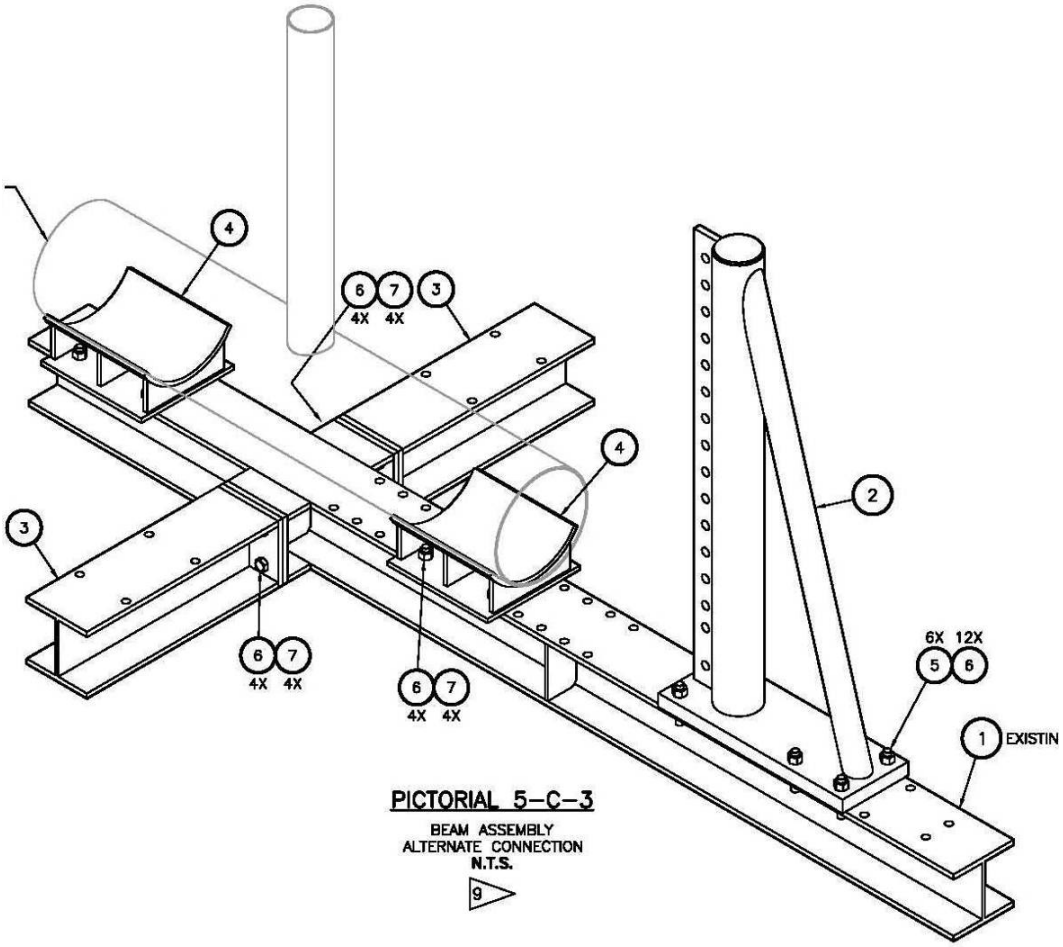
Branch Connection Testing (2/8)



Test Set-up (In-plane Bending)

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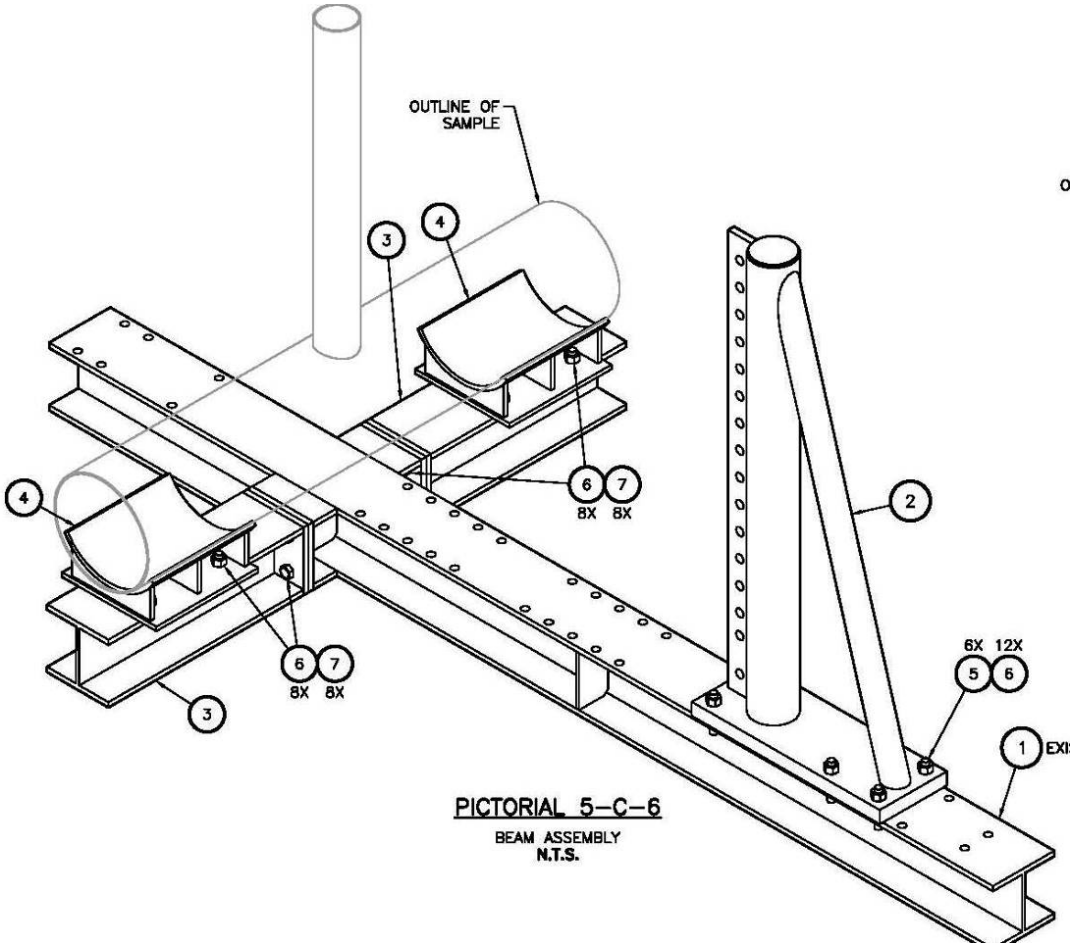
Branch Connection Testing (3/8)



Test Set-up (Out-of-plane Bending)

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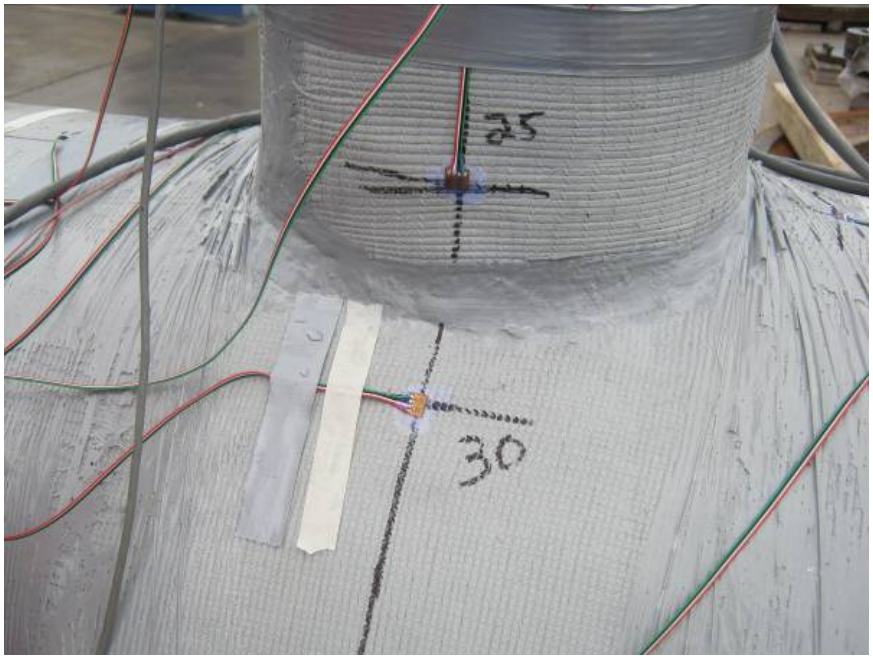
Branch Connection Testing (4/8)



Installation of Armor Plate® Pipe Wrap

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Branch Connection Testing (5/8)

Post-test Comparison (In-plane Bending)

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Branch Connection Testing (6/8)

Post-test Comparison (Out-of-plane Bending)

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Branch Connection Testing (7/8)

Cross-sections cut after testing for in-plane bending sample.

Unreinforced In-plane Sample
(after 13.3 inches at 88.6 kip-ft)

Reinforced In-plane Sample
(after 4.7 inches at 124.0 kip-ft)

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Branch Connection Testing (8/8)

- Considering deflection data, the stiffness increase for the reinforced branch connections in comparison to the unreinforced connections are as follows:
  - In-plane load case: 3.2 times as stiff (75% M_{yield})
  - Out-of-plane load case: 2.4 times as stiff (50% M_{yield})
- At the higher load levels, the composite materials reduced strains in the branch connections by approximately 90%.

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Case Study #3

Performance at Elevated Temperature

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Elevated Temperature Design

- Reduction in strength with increasing temperature must be included in the design process
- Not sufficient to just re-rate performance based on industry recommendations (trust, but verify)
- Observed reductions up to 100°C relative to RT range from 15% to 50%
- Validate final design of corrosion repair at temperature with strain gages measurements in corroded region

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Coupon Tests up to 100°C (1/2)

Temperature (°C)	Sample	Max Crosshead Disp. [in]	Ultimate Load [lbf]	Ultimate Load/Width [lbf/in]	Ultimate Stress [psi]
27	A-A1	0.549	16653	16653	229
	A-B1	0.564	14885	14929	207
	A-B2	0.479	14951	15011	201
60	A-D2*	0.342	10788	11933	155
	A-C4	0.444	13850	15320	207
	A-A7	0.548	15081	15644	211
80	A-D1	0.543	14780	14810	192
	A-C6	0.494	12906	15131	194
	A-C7	0.355	11322	13257	172
100	A-C3*	0.378	9363	9633	125
	A-D6	0.577	13396	13656	169
	A-D7	0.464	14125	14125	193
120					

*Indicates Grip Failure

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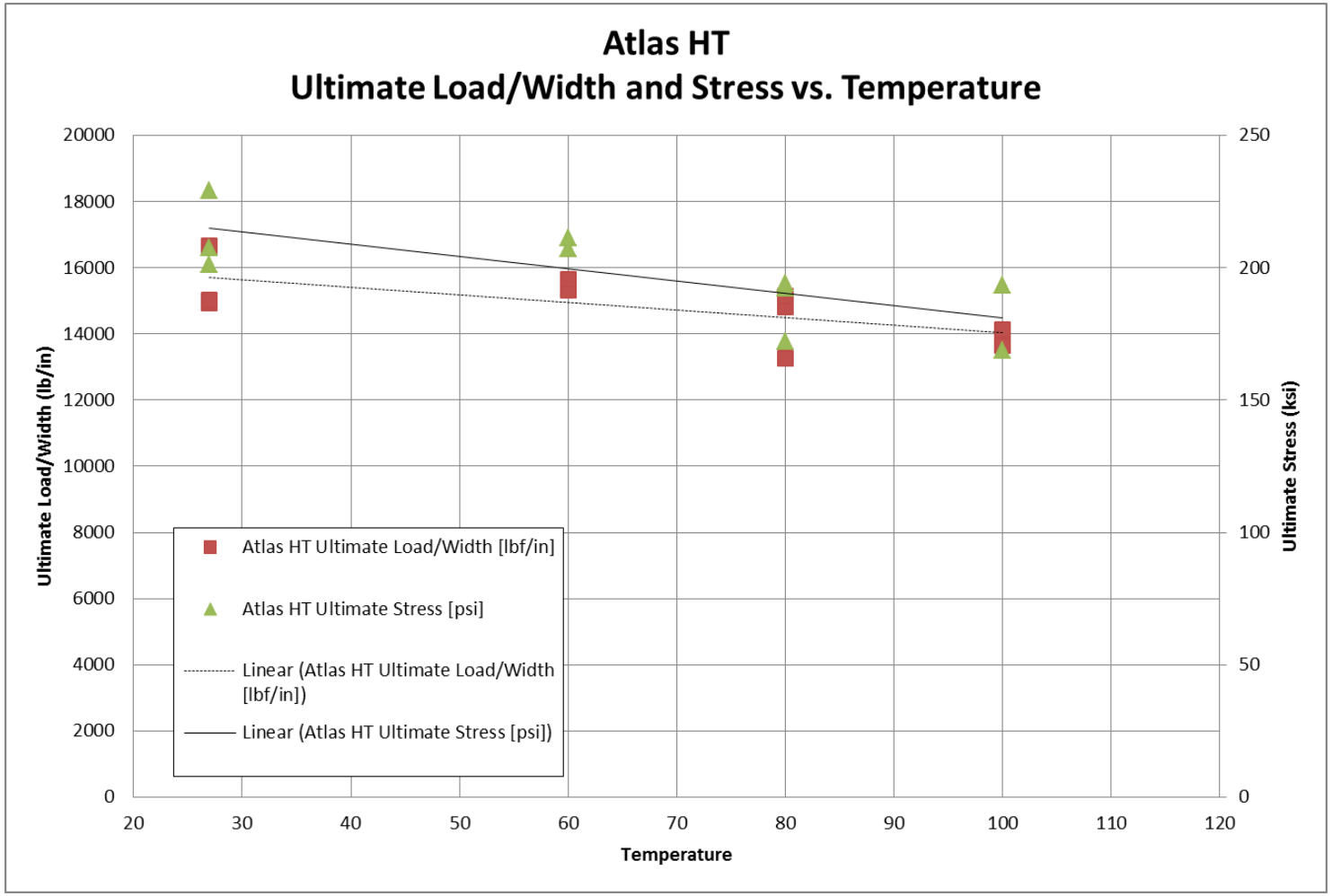
Coupon Tests up to 100°C (2/2)



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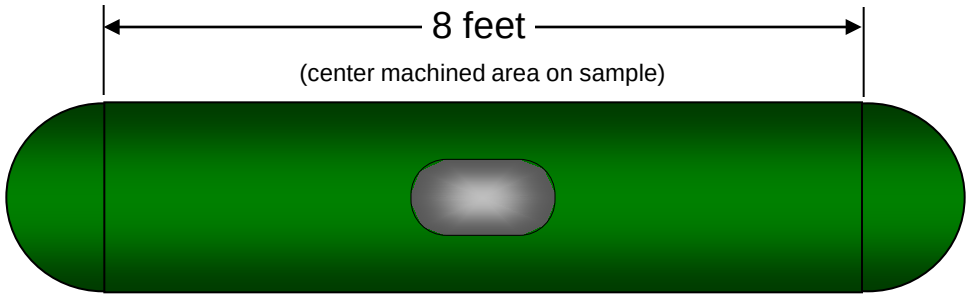
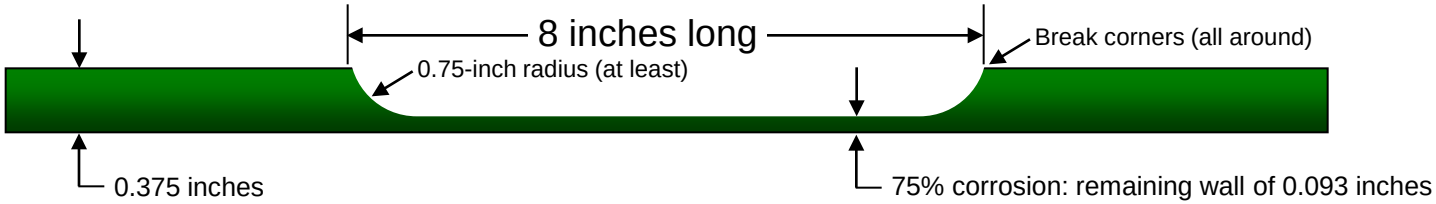
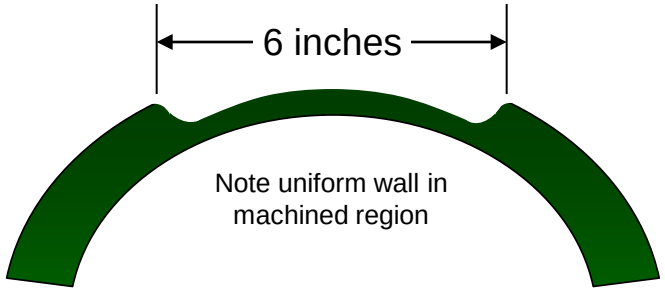
12.75-inch x 0.375-inch, Grade X42 pipe (8-feet long)





NOTE: Perform all machining 180 degrees from longitudinal ERW seam.



Measure wall thickness at 9 locations in the machined area using a UT meter.

Details on machining

(machined area is 8 inches long by 6 inches wide)

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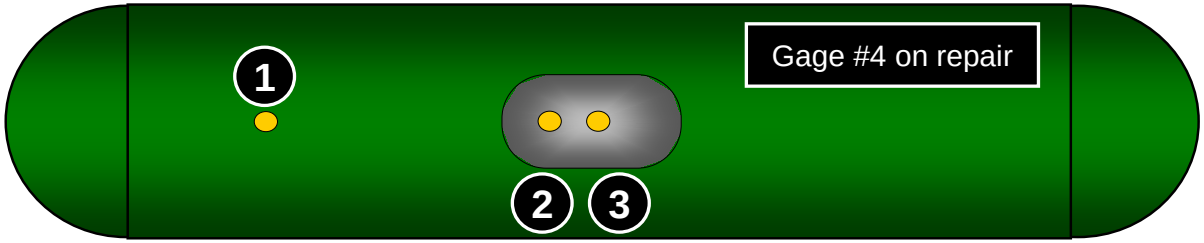
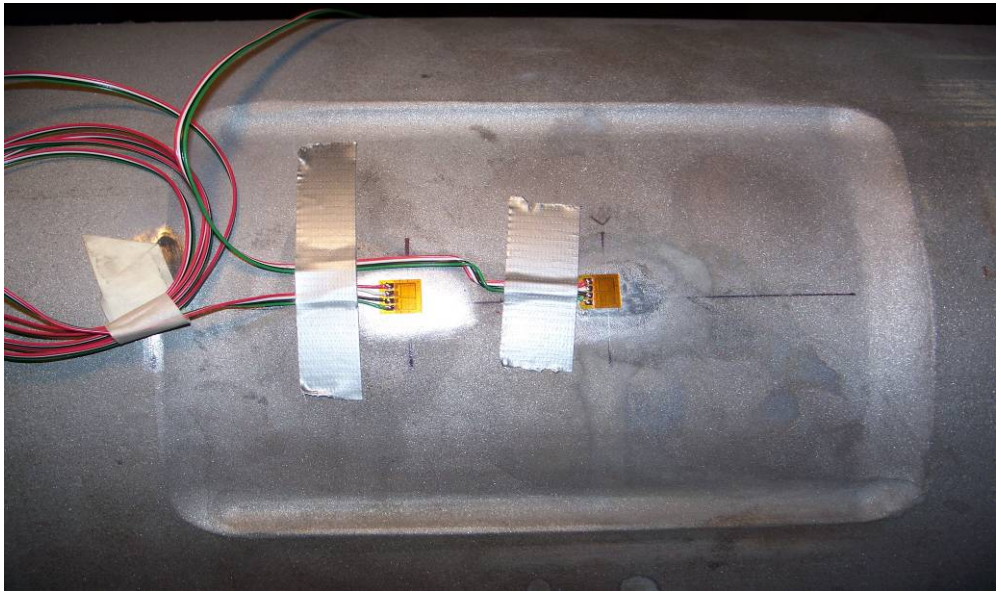
Strain Gage Installation



Location of strain gages installed on the test sample



Photograph of strain gages installed in the machined corrosion region

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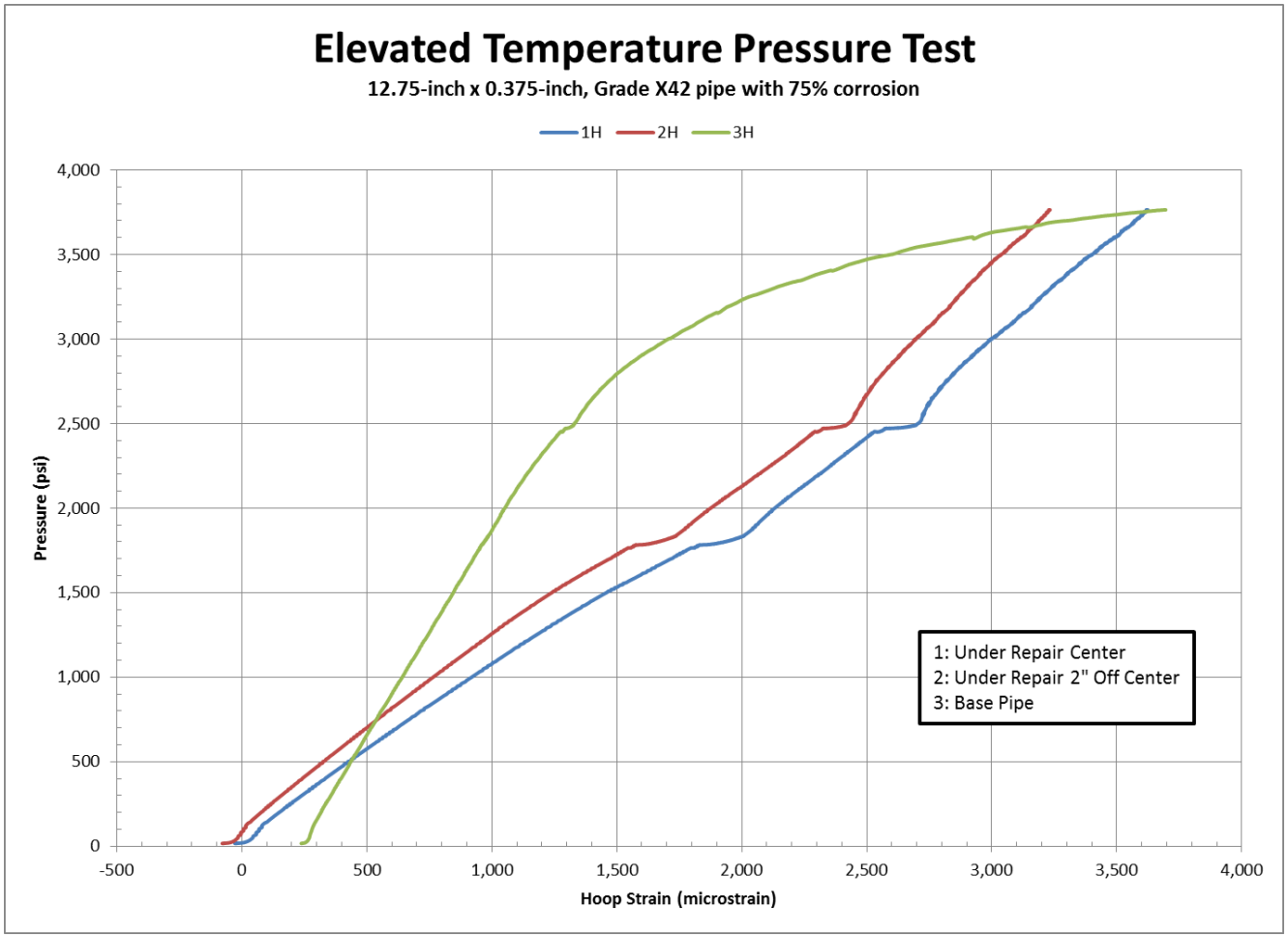
Pressure Test

Measured strains: 0.20% at 72% SMYS and 0.27% at 100% SMYS



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Closing Comments

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Implication of Results and Findings

- Not all composite repair systems perform equally
- Standards such as ASME PCC-2 are essential to ensuring that adequate designs exist
- Composite stiffness is extremely important in fatigue and to reinforce damaged pipe sections (product of Modulus and Thickness)
- When in doubt, conduct tests (especially when testing new applications)
- The intent in testing work is to improve confidence in the performance of composite repair systems
- Quality installation work is essential

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Questions?

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