Today’s Presentation

• State of the Art
• Integrity approach – EB-IMP®
• Past uses of composite materials
• PRCI research efforts on composite materials
• Case studies
  ▪ Branch connections
  ▪ High temperature applications
• The future
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 designing and installing systems that possess adequate service life

• Performance testing has been an essential element in demonstrating the capacity of composite repair technology
The EB-IMP® Process

Gather Data

Level I Evaluation

Level II Evaluation

Level III Evaluation

Fails to Meet Requirements

No Repair is Required

Level IV Evaluation
Use experimental methods to validate previous analysis findings

Level V Evaluation
Develop a repair solution

Make Repair

API 579 steps
Meets requirements

Meets requirements
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
- MATR-3-10 Composite Repair Guideline Document (NEW)

Future programs (potential)
- Crack repair and reinforcement
- Elevated temperature testing
- Effects of pressure during installation
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
Case Study #1
Branch Connections
Branch Connection Testing (1/4)

- 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)
Branch Connection Testing (2/4)

Installation of Armor Plate® Pipe Wrap
Branch Connection Testing (3/4)

Post-test Comparison (In-plane Bending)
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)

In-plane load case: 3.2 times as stiff at 75% \( M_{yield} \)
Case Study #2
Performance at Elevated Temperature
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
# Coupon Tests up to 100°C (1/2)

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<th>Sample</th>
<th>Max Crosshead Disp. [in]</th>
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<th>Ultimate Load/Width [lbf/in]</th>
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*Indicates Grip Failure
Coupon Tests up to 100°C (2/2)

Atlas HT
Ultimate Load/Width and Stress vs. Temperature

- Atlas HT Ultimate Load/Width [lb/in]
- Atlas HT Ultimate Stress [psi]
- Linear (Atlas HT Ultimate Load/Width [lb/in])
- Linear (Atlas HT Ultimate Stress [psi])

Temperature

Ultimate Load/Width (lb/in)

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

- 8 feet long (center machined area on sample)
- 8 inches long
- 0.75-inch radius (at least)
- 0.375 inches
- 75% corrosion: remaining wall of 0.093 inches
- Break corners (all around)
- 0.375 inches
- 6 inches
- Note uniform wall in machined region

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

Details on machining
(machined area is 8 inches long by 6 inches wide)
Pressure Test (75% Corrosion)

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

Elevated Temperature Pressure Test
12.75-inch x 0.375-inch, Grade X42 pipe with 75% corrosion

MAOP 2,524 με
SMYS 3,292 με
MAOP_{min} 1,828 με
MAOP_{max} 3,087 με
SMYS_{min} 2,250 με
SMYS_{max} 4,106 με

Industry-average data for carbon composites

1: Under Repair Center
2: Under Repair 2" Off Center
3: Base Pipe
Closing Comments
The Future

• Standards such as ASME PCC-2 are essential to ensuring that adequate designs exist
• When in doubt, conduct tests (especially when testing new applications) – FUTURE FOCUS
• The intent in testing work is to improve confidence in the performance of composite repair systems
• Quality installation work is essential
Questions?

Dr. Chris Alexander, P.E., Principal
chris.alexander@stress.com
(281) 897-6504 (direct)