STRESS ENGINEERING SERVICES INC. ESTABLISHED 1972

FITNESS FOR SERVICE ENGINEERING PRACTICE

ASSESSING THE USE OF COMPOSITE MATERIALS IN REPAIRING AND REINFORCING OFFSHORE RISER PIPES

Presented to the

Regional Operations Technology Assessment Committee (ROTAC) Meeting

Minerals Management Service (Pacific OCS Region)

OTRC Presentation

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Presentation Outline

- Review of current composite repair state of the art
- Joint Industry Project (JIP) Program
  - Task overview and schedule
  - Manufacturer participation
  - Analysis phase
  - Testing phase
  - Guideline development
- Closing comments

Uses of Composite Materials
(repair and structural reinforcement)

- Metal wall loss (due to corrosion)
- Plain dents
- Mechanical damage (dents with a gouge)
- Re-rating pipeline system to achieve higher operating pressures
- Corrosion repair and replacement
  - Under insulation coating (UIC)
  - Wear-resistant coatings (e.g. saddles)
  - Underwater coatings

Types of Composite Repairs

(used to repair pipeline systems)

- **Wet lay-up systems** (e.g. Armor Plate Pipe Wrap, Diamond Wrap, Aquawrap, Comptek)
  - Monolithic
  - Can be applied to non-straight geometries
  - Versatility in range of epoxy products (e.g. underwater, high temperature, etc.)
- **Layered systems** (e.g. Clock Spring and PermaWrap)
  - First widely-used composite repair system
  - Layered repair system
  - Limited to repair of straight pipes

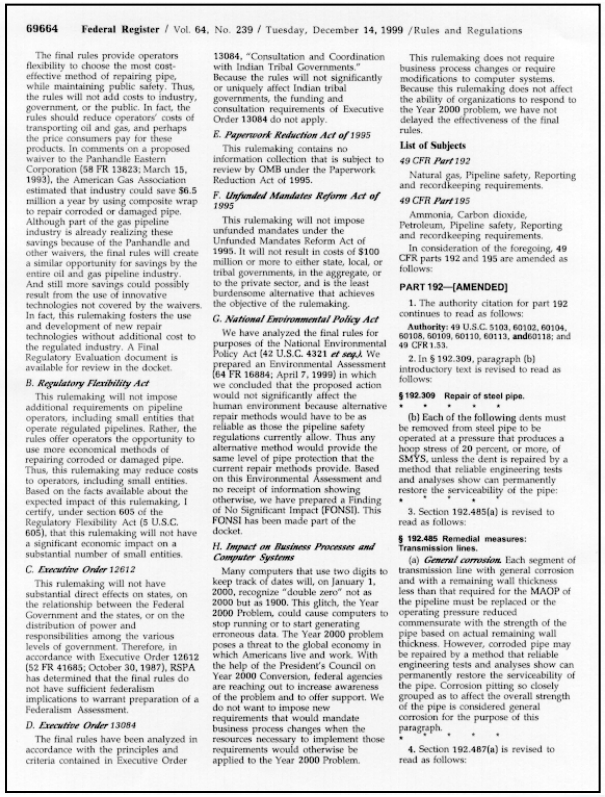
Government Regulations

(from the U.S. Department of Transportation)

On January 13, 2000, ***Pipeline Safety: Gas and Hazardous Liquid Pipeline Repair***, was issued by the RSPA of the Department of Transportation, went into effect.

According to this document, the requirement for repairing corroded and dents in pipelines is as follows,

...repaired by a method that reliable engineering tests and analyses show can permanently restore the serviceability of the pipe.



69664 **Federal Register** / Vol. 64, No. 239 / Tuesday, December 14, 1999 /Rules and Regulations

The final rules provide operators flexibility to choose the most cost-effective method of repairing pipe, while maintaining public safety. Thus, the rules will not add costs to industry, government, or the public. In fact, the rules should reduce operators' costs of transporting oil and gas, and perhaps the price consumers pay for these products. In comments on a proposed waiver to the Panhandle Eastern Corporation (58 FR 13823; March 15, 1993), the American Gas Association estimated that industry could save $6.5 million a year by using composite wrap to repair corroded or damaged pipe. Although part of the gas pipeline industry is already realizing these savings because of the Panhandle and other waivers, the final rules will create a similar opportunity for savings by the entire oil and gas pipeline industry. And still more savings could possibly result from the use of innovative technologies not covered by the waivers. In fact, this rulemaking fosters the use and development of new repair technologies without additional cost to the regulated industry. A Final Regulatory Evaluation document is available for review in the docket.

B. Regulatory Flexibility Act

This rulemaking will not impose additional requirements on pipeline operators, including small entities that operate regulated pipelines. Rather, the rules offer operators the opportunity to use more economical methods of repairing corroded or damaged pipe. Thus, this rulemaking may reduce costs to operators, including small entities. Based on the facts available about the expected impact of this rulemaking, I certify, under section 605 of the Regulatory Flexibility Act (5 U.S.C. 605), that this rulemaking will not have a significant economic impact on a substantial number of small entities.

C. Executive Order 12612

This rulemaking will not have substantial direct effects on states, on the relationship between the Federal Government and the states, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 12612 (52 FR 41685; October 30, 1987), RSPA has determined that the final rules do not have sufficient federalism implications to warrant preparation of a Federalism Assessment.

D. Executive Order 13084

The final rules have been analyzed in accordance with the principles and criteria contained in Executive Order 13084, "Consultation and Coordination with Indian Tribal Governments." Because the rules will not significantly or uniquely affect Indian tribal governments, the funding and consultation requirements of Executive Order 13084 do not apply.

E. Paperwork Reduction Act of 1995

This rulemaking contains no information collection that is subject to review by OMB under the Paperwork Reduction Act of 1995.

F. Unfunded Mandates Reform Act of 1995

This rulemaking will not impose unfunded mandates under the Unfunded Mandates Reform Act of 1995. It will not result in costs of $100 million or more to either state, local, or tribal governments, in the aggregate, or to the private sector, and is the least burdensome alternative that achieves the objective of the rulemaking.

G. National Environmental Policy Act

We have analyzed the final rules for purposes of the National Environmental Policy Act (42 U.S.C. 4321 *et seq.*). We prepared an Environmental Assessment (64 FR 16884; April 7, 1999) in which we concluded that the proposed action would not significantly affect the human environment because alternative repair methods would have to be as reliable as those the pipeline safety regulations currently allow. Thus any alternative method would provide the same level of pipe protection that the current repair methods provide. Based on this Environmental Assessment and no receipt of information showing otherwise, we have prepared a Finding of No Significant Impact (FONSI). This FONSI has been made part of the docket.

H. Impact on Business Processes and Computer Systems

Many computers that use two digits to keep track of dates will, on January 1, 2000, recognize "double zero" not as 2000 but as 1900. This glitch, the Year 2000 Problem, could cause computers to stop running or to start generating erroneous data. The Year 2000 problem poses a threat to the global economy in which Americans live and work. With the help of the President's Council on Year 2000 Conversion, federal agencies are reaching out to increase awareness of the problem and to offer support. We do not want to impose new requirements that would mandate business process changes when the resources necessary to implement those requirements would otherwise be applied to the Year 2000 Problem.

This rulemaking does not require business process changes or require modifications to computer systems. Because this rulemaking does not affect the ability of organizations to respond to the Year 2000 problem, we have not delayed the effectiveness of the final rules.

List of Subjects

49 CFR Part 192

Natural gas, Pipeline safety, Reporting and recordkeeping requirements.

49 CFR Part 195

Ammonia, Carbon dioxide, Petroleum, Pipeline safety, Reporting and recordkeeping requirements.

In consideration of the foregoing, 49 CFR parts 192 and 195 are amended as follows:

PART 192—[AMENDED]

1. The authority citation for part 192 continues to read as follows:

Authority: 49 U.S.C. 5103, 60102, 60104, 60108, 60109, 60110, 60113, and60118; and 49 CFR 1.53.

2. In § 192.309, paragraph (b) introductory text is revised to read as follows:

§ 192.309 Repair of steel pipe.

* * * * *

(b) Each of the following dents must be removed from steel pipe to be operated at a pressure that produces a hoop stress of 20 percent, or more, of SMYS, unless the dent is repaired by a method that reliable engineering tests and analyses show can permanently restore the serviceability of the pipe:

* * * * *

3. Section 192.485(a) is revised to read as follows:

§ 192.485 Remedial measures: Transmission lines.

(a) ***General corrosion.*** Each segment of transmission line with general corrosion and with a remaining wall thickness less than that required for the MAOP of the pipeline must be replaced or the operating pressure reduced commensurate with the strength of the pipe based on actual remaining wall thickness. However, corroded pipe may be repaired by a method that reliable engineering tests and analyses show can permanently restore the serviceability of the pipe. Corrosion pitting so closely grouped as to affect the overall strength of the pipe is considered general corrosion for the purpose of this paragraph.

* * * * *

4. Section 192.487(a) is revised to read as follows:

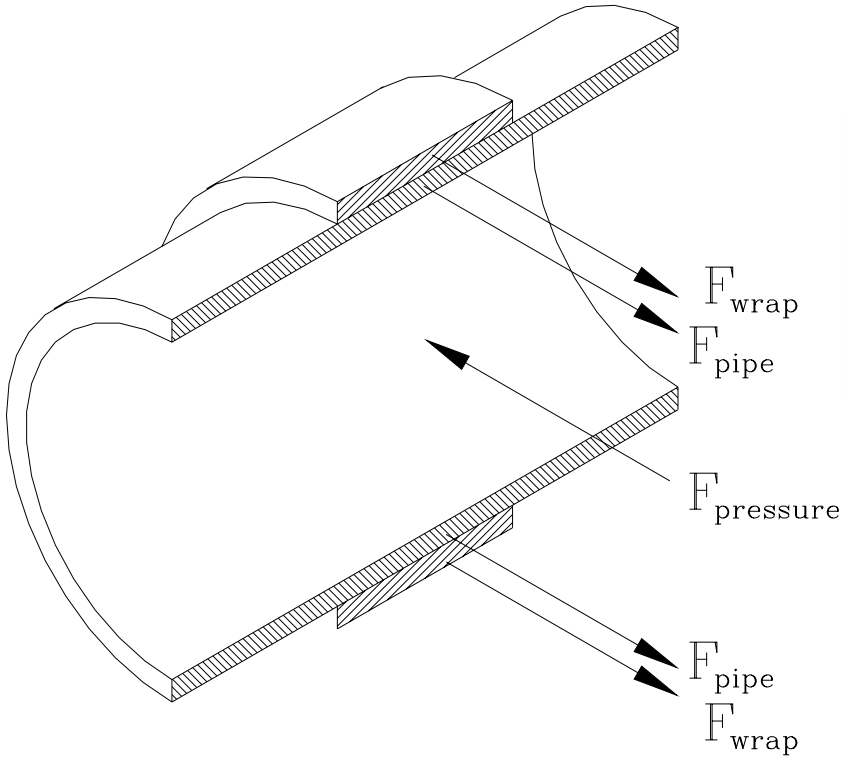
Page from the RSPA-98-4733 document

Guidelines for Evaluation of Composite Repair Methods

The **basic fundamental issues** for evaluating composite repair methods are as follows:

- Strength of the composite material
- Environmental effects (e.g. cathodic disbondment, temperature, acids and alkalines)
- Effects of pressure (both static and cyclic)
- Mechanics of load transfer from pipe to wrap
- Long-term performance issues
- Consistency in application and quality control in manufacturing

Mechanics of Composite Repair Methods



Equation defining burst pressure

$$P_{burst} = \frac{\sigma_{ult_{pipe}} \cdot t_{pipe} + \sigma_{ult_{wrap}} \cdot t_{wrap}}{r_{inside}}$$

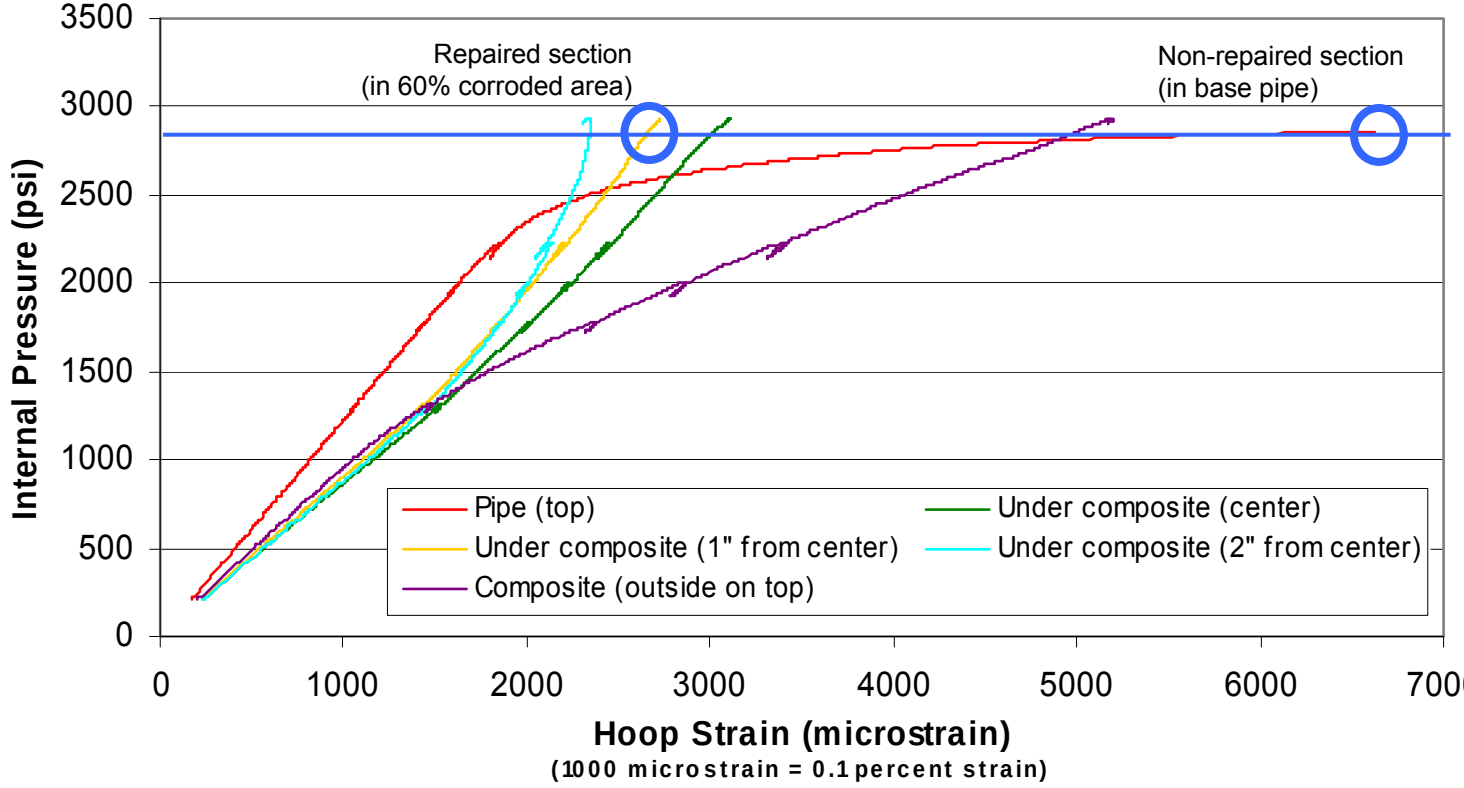
P = Internal pressure
σ = Material failure stress
t = Thickness of material
r = Radius of pipe

Note:
The above calculation is based on thin-wall shell theory and is not applicable for thick-walled pipes with diameter to wall thickness ratios less than 20.

Pipe-to-Composite Load Transfer
(Hoop Strain During Pressurization)

Hoop Strain as a Function of Internal Pressure

Comptek epoxy resin composite repair system (Sample #2)
12.75-in x 0.219-in, Grade X52 pipe w ith 60 percent corrosion
Burst pressure of 2,931 psi (in unrepaired section of test sample)



Observations on Current Composite Repair Methods

- For more than 10 years, the pipeline industry has been making repairs using composite materials
- A significant body of research exists addressing a variety of repair types
- The missing link in most of the composite repair systems is long-term test data (especially in terms of the adhesive systems)

JIP Program

- Elements of the program
  - Task overview and schedule
  - Manufacturer participation
  - Analysis phase
  - Testing phase
  - Guideline development

Task Overview and Schedule

Tasks	Year 2006								Year 2007	
	May	June	July	August	September	October	November	December	January	February
Task 1 - Information gathering stage (review current state of the art)										
Task 2 - Determining typical riser loads										
Task 3 - Document range of existing limitations										
Task 4 - Identify optimization opportunities and FEA of repair systems										
Task 5 - Testing phase and evaluation of current systems										
Task 6 - Complete documenttation and preparation of final report										

Completed task

Incomplete task OR task in-progress

- **Task 1** - Information gathering stage
- **Task 2** - Anticipated loads
- **Task 3** - Document range of limitations of existing technology
- **Task 4** - Identify opportunities and concepts for emerging technologies (includes analysis efforts based on finite elements)
- **Task 5** – Full-scale testing
- **Task 6** - Final report and documentation

Analysis Phase

- Simulation of repair considering loads acquired during Task 2
- Finite element analysis employing specific composite properties and elastic-plastic material properties for steel riser pipes
- Limit analysis methods will be used to capture the lower bound plastic collapse load and corresponding design load

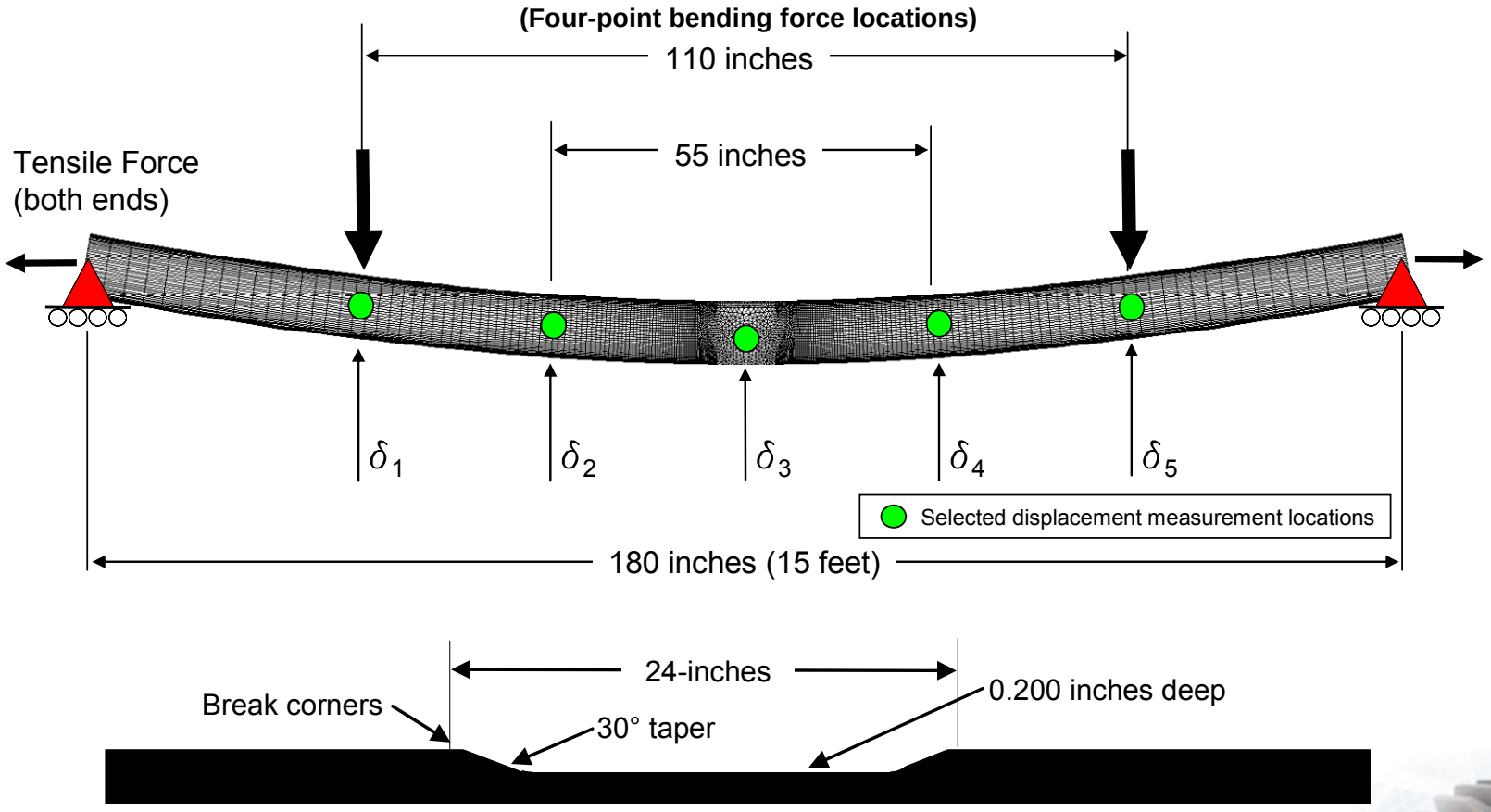
Testing Phase

- Full-scale testing using loads acquired during Task 2 (8-inch NPS pipe)
- Three test samples integrate 50% corrosion
  - 8-ft long Internal **pressure** sample (see NOTE)
  - 8-ft long Pressure and **tension**
  - 15-ft long Pressure, tension, and **bending**
- Strain gages installed in corroded areas beneath repairs
- In testing limit analysis methods used to capture the lower bound plastic collapse load

NOTE: Test variables shown in **BOLD RED** is the one incrementally increased to capture the lower bound collapse load

Testing Details

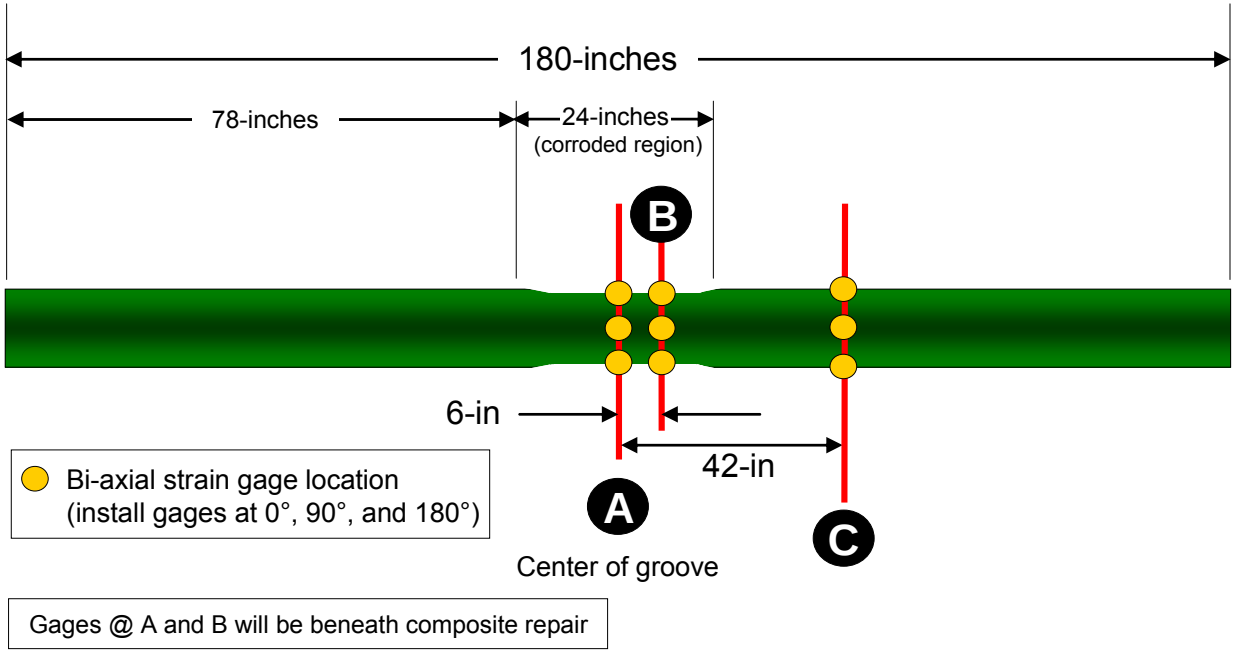
(Sample loading and defect configuration)

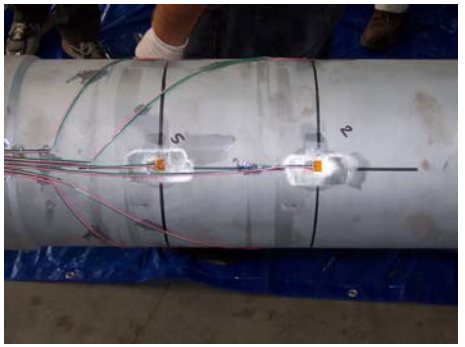


Simulated corrosion on outside surface of pipe (circumferential groove)

Testing Details

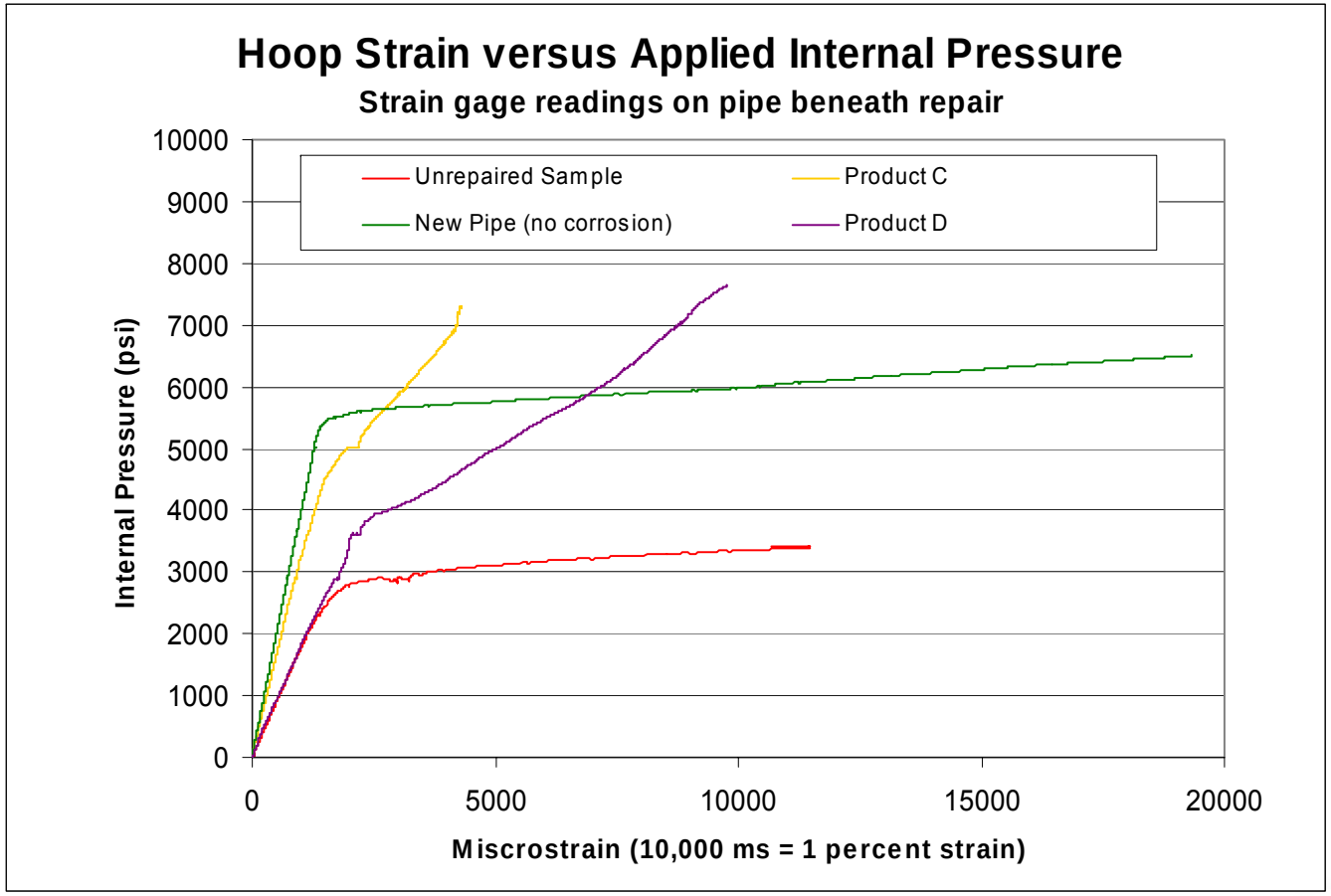
(Strain gage details – 12 per sample)





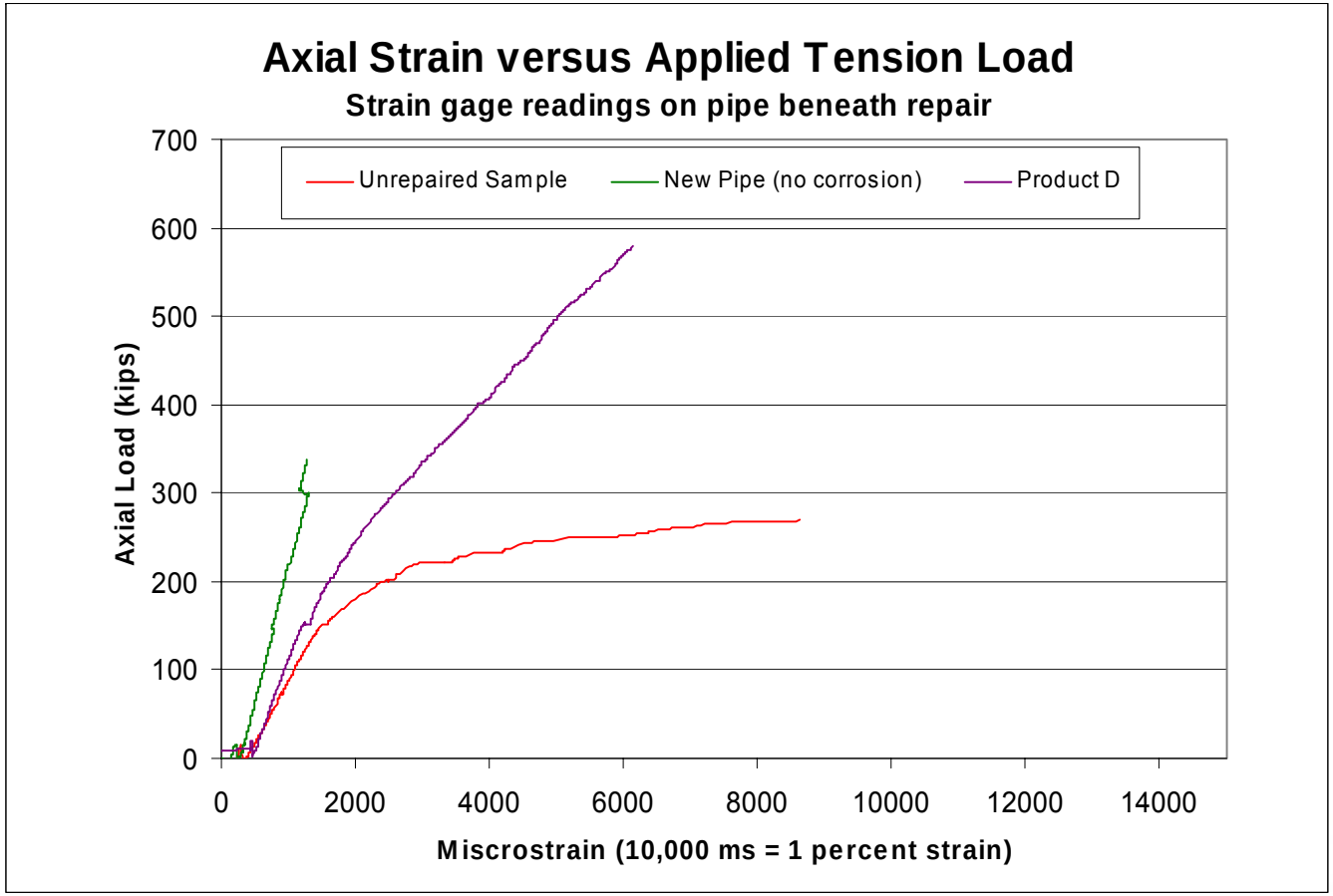
Preliminary Test Results

(Burst pressure sample)



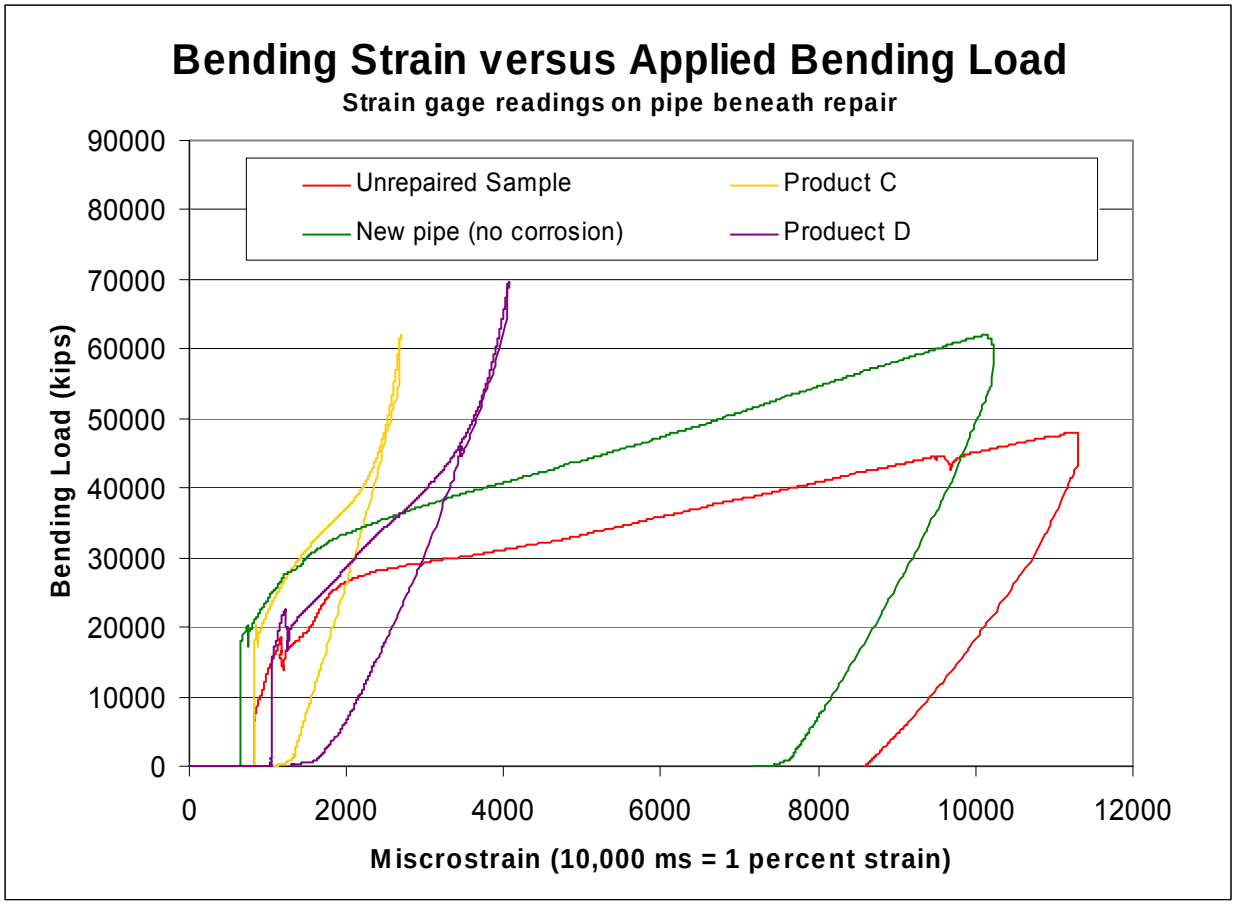
Preliminary Test Results

(Tension loading sample)



Preliminary Test Results

(Bending load sample)



Repair System Development

- Integrating riser loads
- Expected results for the different load requirements
  - Internal pressure
  - Axial tension
  - Bending
- Essential elements relative to design repair requirements
- Consider riser loads subject to API RP 1111 design stress limits
- Addressing and qualifying potential upset conditions

Path Forward Activities

Under MMS-OTRC Sponsorhip ***Composite Repair Methods for Steel Pipes*** *(PR# 558-39300 - Dr. Ozden O. Ochoa) the following research tasks are underway*

- Implement computational FEA models to validate tests
- Identify & demonstrate “structurally optimized” composite repair concept
- Develop guidelines for MMS with regards to using composite materials to repair offshore risers