Identifying Knowledge Gaps in Composite Repair Technology

Presentation to the PHMSA R&D Forum

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Taking on your toughest technical problems

STRESS ENGINEERING SERVICES INC.

an employee-owned company

Presentation Overview

- **The Past** - what have we learned?
  - Participants and key players
  - Types of repairs
- **The Present** - Current interests
  - Current research
  - Standards: ASME PCC-2
- **The Future** – where are we headed?
  - Identifying trends and interests
  - Identifying knowledge gaps

The Past

Key Players in Industry

- Operators
  - Those using composite technology
  - Company-specific research programs
- Pipeline Research Council International, Inc.
- Regulators (Federal and State)
- ASME (e.g. PCC-2, B31.4, and B31.8)
- Composite manufacturers and contractors
- Researchers and consultants
- Composite Repair Users Group (CRUG)

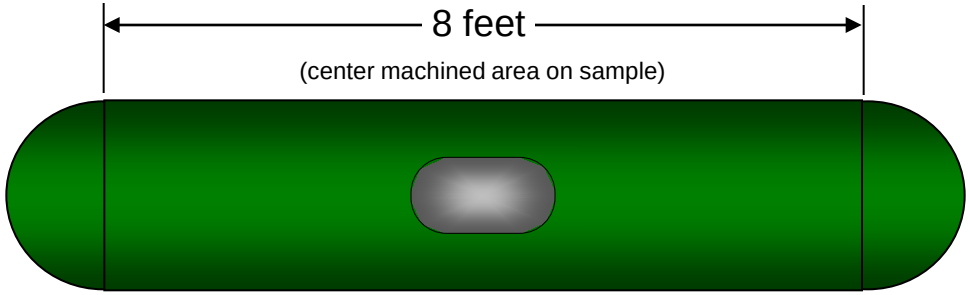
The Past

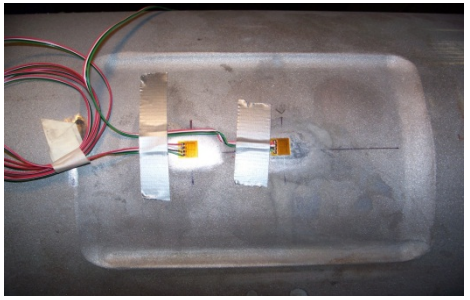
Defects and Types of Repairs

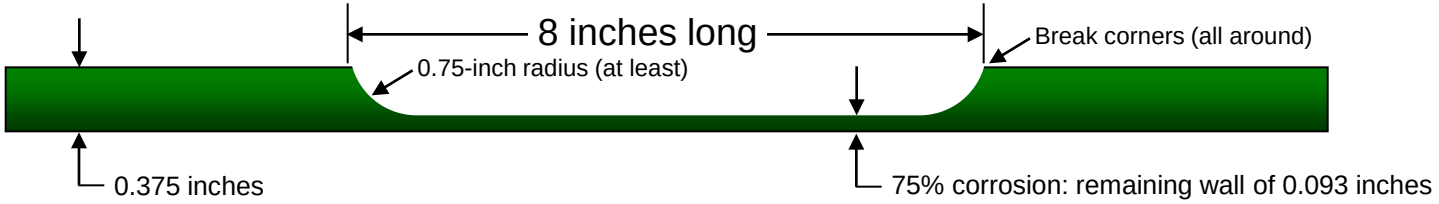
- Corrosion – burst and cyclic pressure fatigue
- Dents and mechanical damage
- Cracks and gouges
- Girth weld reinforcements
- Seam weld reinforcements
- Wrinkle bends
- Branch connections and tees
- Bends and elbows
- Pipe spans
- Subsea pipelines

Destructive Testing has become an integral part of the composite repair assessment process.

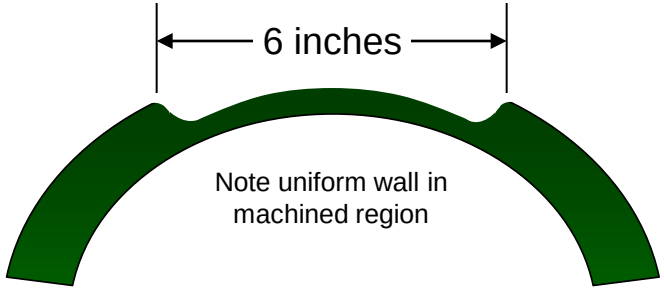
Corroded Pipe Sample







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



Details on machining

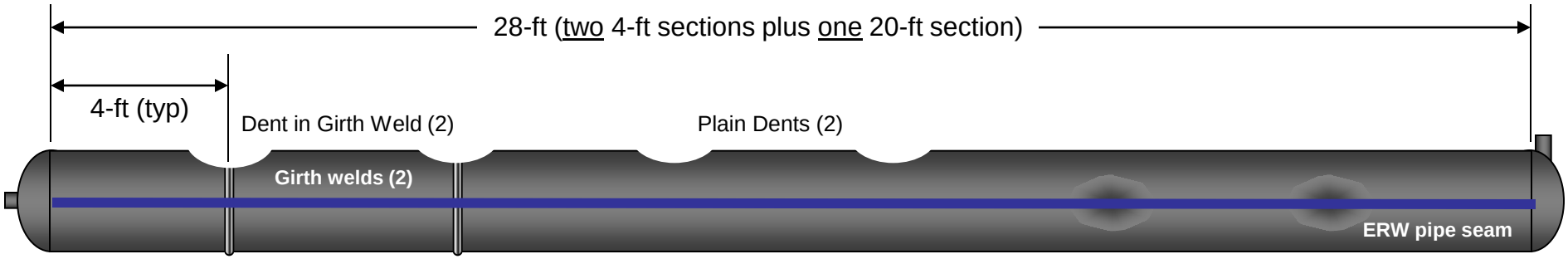
(machined area is 8 inches long by 6 inches wide)

Pressure Cycle Test Results

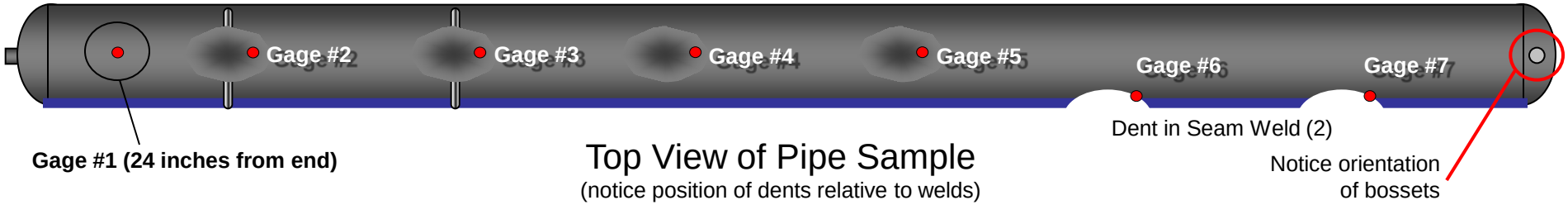
- 12.75-inch x 0.375-inch, Grade X42 pipe pressure cycled at 36% SMYS with 75% deep corrosion
- Results for 8 different systems
  - E-glass system: 19,411 cycles to failure (MIN)
  - E-glass system: 32,848 cycles to failure
  - E-glass system: 129,406 cycles to failure
  - E-glass system: 140,164 cycles to failure
  - E-glass system: 165,127 cycles to failure
  - Carbon system (Pipe #1): 212,888 cycles to failure
  - Carbon system (Pipe #2): 256,344 cycles to failure
  - Carbon system (Pipe #3): 202,903 cycles to failure
  - E-glass system: 259,537 cycles to failure
  - Carbon system (Pipe #4): 532,776 cycles (run out, no failure)
  - Hybrid steel/Epoxy system: 655,749 cycles to failure
  - Hybrid steel/E-glass system: 767,816 cycles to failure (MAX)

Dented Pipeline Samples – Strain Gage Locations

Samples fabricated using 12.75-inch x 0.188-inch, Grade X42 pipe material

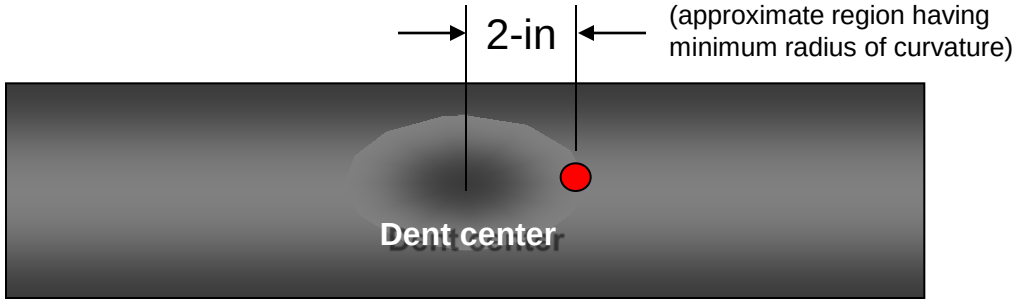


Side View of Pipe Sample (6 defects total)



Top View of Pipe Sample

(notice position of dents relative to welds)



Close-up View of Dented Region

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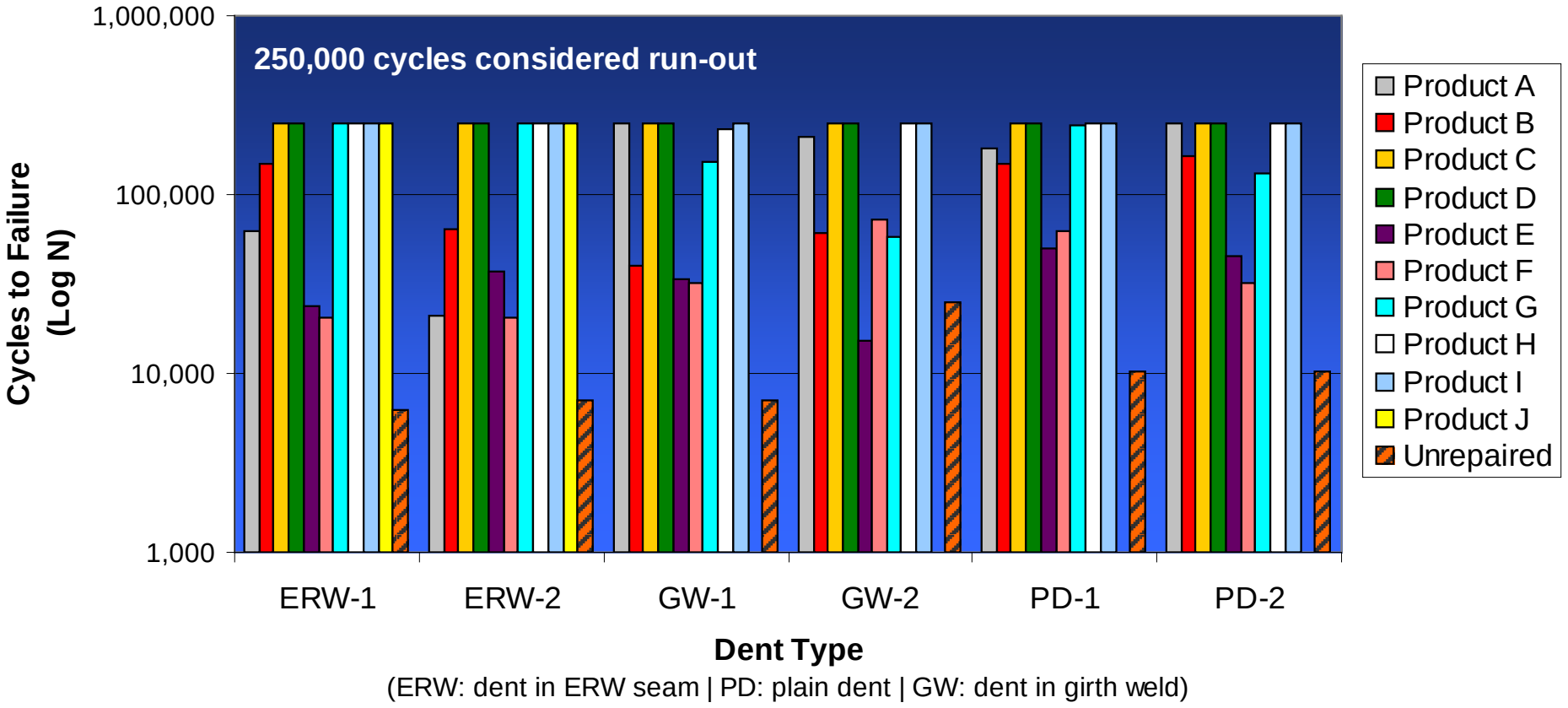
Cycles to Failure of Composite Repaired Dents

Dents initially 15% of OD installed on a 12.75-inch x 0.188-inch, Grade X42 pipe using a 4-inch end cap. Dents installed with 72%SMYS pressure in pipe and cycled to failure at $\Delta\sigma$ = 72% SMYS.



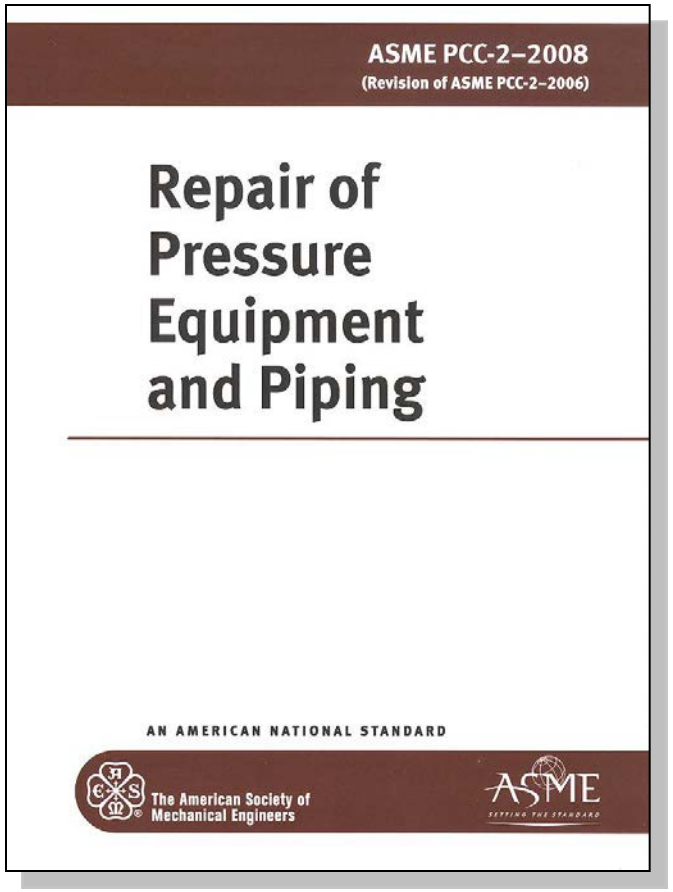
(ERW: dent in ERW seam | PD: plain dent | GW: dent in girth weld)

One system was pressure cycled to 358,470 cycles after which the ERW seam failed.

The Present

Industry Standards

- ASME PCC-2 (and ISO 24817)
- Part 4 – *Nonmetallic and Bonded Repairs*
- Quality control of materials and installation is essential
- Key benefit to industry is uniformity and designating minimum design requirements



The Present

Current research efforts

- Repair of pipelines at elevated temperatures (160F and up)
- Repair of subsea pipelines
- Assessment of various inspection technologies
- Repair of wrinkle bends
- Repair of cracks
- Re-rating pipelines

The Future

Trends and Interests

- Great interest in **elevated temperature** applications and performance
- Inspection technology
  - Identifying flaws
  - Correlating flaws with performance
- **New products** from existing manufacturers
- Using composite materials to **establish MAOP**
- Repair versus pipe replacement
- Effects of **internal pressure** during installation

The Future

Identifying Knowledge Gaps

- **Inspection technology** – tremendous need to correlate flaws with performance
- What constitutes an **acceptable design** (minimum performance criteria)?
- **Environmental/aging effects** including moisture, sustained loads, and temperature
- Standardization of **codes** and **regulations**
- Means for evaluating and adopting new composite **technology** for new **applications**