Development of Selective Seam Weld Corrosion Test Method

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Background

- Part of a PHMSA Funded Program
- Overall Objective – Identify actions that can be used by operators to eliminate longitudinal seam weld failures in electric resistance welded (ERW) line pipe

Background

- Manufacturing defects associated with ERW line pipe
  - Lack of fusion defects
  - Hook cracks
  - Plate misalignment
  - Under trim and over trim
  - Electrical contact marks

Background

- In-service growth mechanisms
  - Selective Seam Weld Corrosion (SSWC)
  - Fatigue/corrosion fatigue
    - Hook cracks
    - Misalignment
    - Under trim
    - SSWC
    - Lack of fusion defects

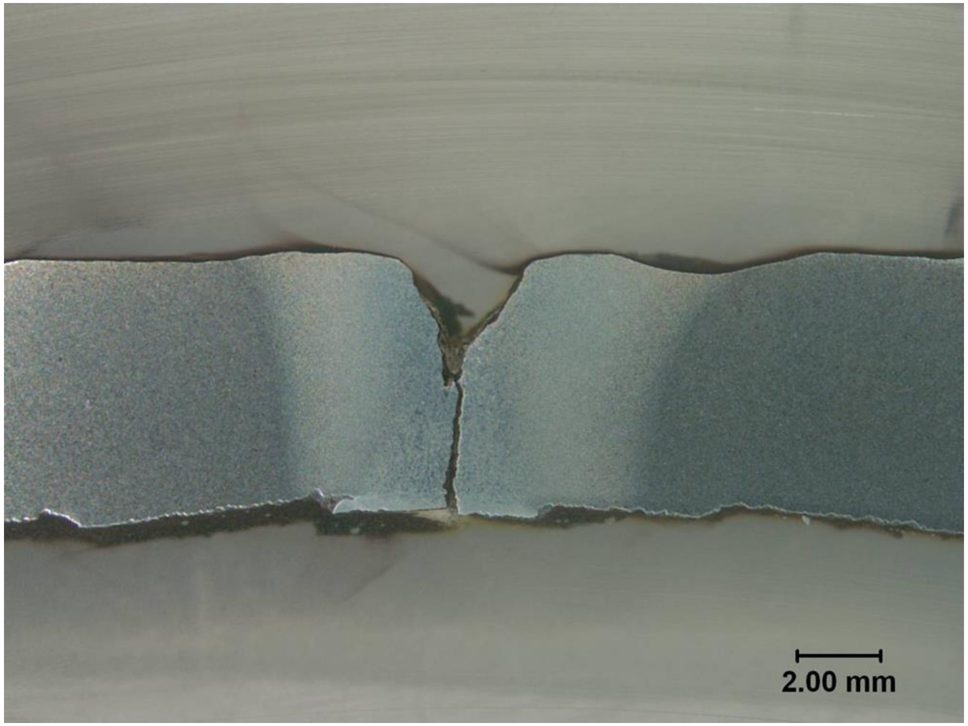
Background

- Contributing factors in service failures
  - In-service growth mechanisms
  - Difficulty in detecting and sizing defects
  - Low and variable toughness at ERW seams

Selective Seam Weld Corrosion

- Selective corrosion along bond line/HAZ of seam weld of ERW line pipe
- Possible causes
  - Galvanic effect
  - Difference in corrosion kinetics
  - Combination

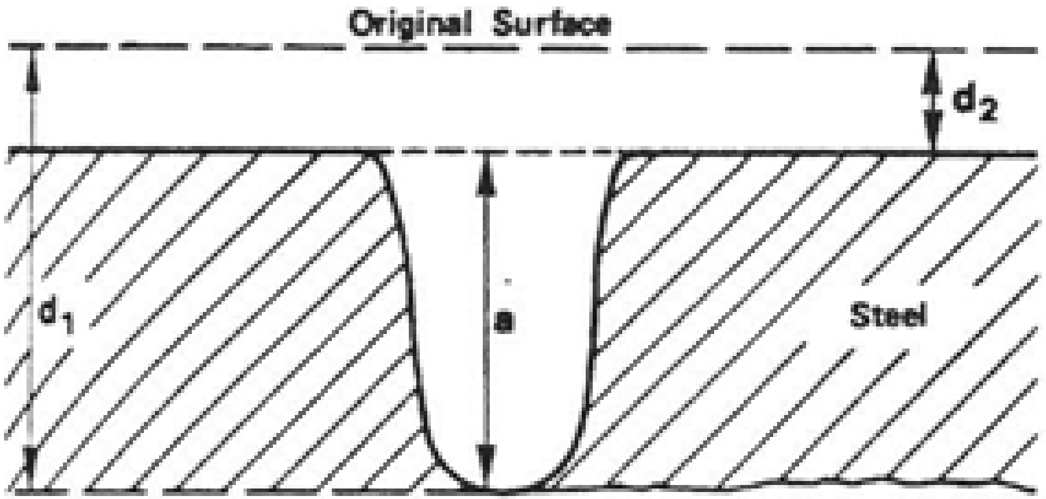
SSWC Failure of Petroleum Pipeline



Photomicrograph of Failed Seam Weld

Severity of SSWC

- Grooving Factor
  - $\alpha = d_1/d_2 = 1 + a/d_2$



Selective Seam Weld Corrosion

- Traditional corrosion testing
  - Potentiostatic or galvanostatic polarization of welded samples
    - 3.5% aqueous NaCl
    - Several weeks
  - Measure severity of grooving corrosion
- Slow and destructive

Project Objective

- Develop test method to quantify SSWC susceptibility of ERW seams
  - Non-destructive
  - Field-deployable
    - Operating pipelines
  - Reliable
  - Rapid

Approach

- Identified ERW pipe joints that are susceptible to SSWC
  - Potentiostatic tests in 3.5% NaCl
    - 0 mV SCE for two weeks
  - Measured grooving factor α
- Local corrosion potential
- Local Linear Polarization Resistance (LPR)

Surface Preparation

- Remove external coating
- Clean surface with solvent
- Abrade area (2 in^2)
  - To 600 grit finish
- Re-clean with solvent

Corrosion Potential Measurements

- Looked for potential differences between weld and base metal (BM)
- Copper/copper sulfate reference electrode
- Small wetted sponge to isolate measurement to weld or BM
- High impedance voltmeter

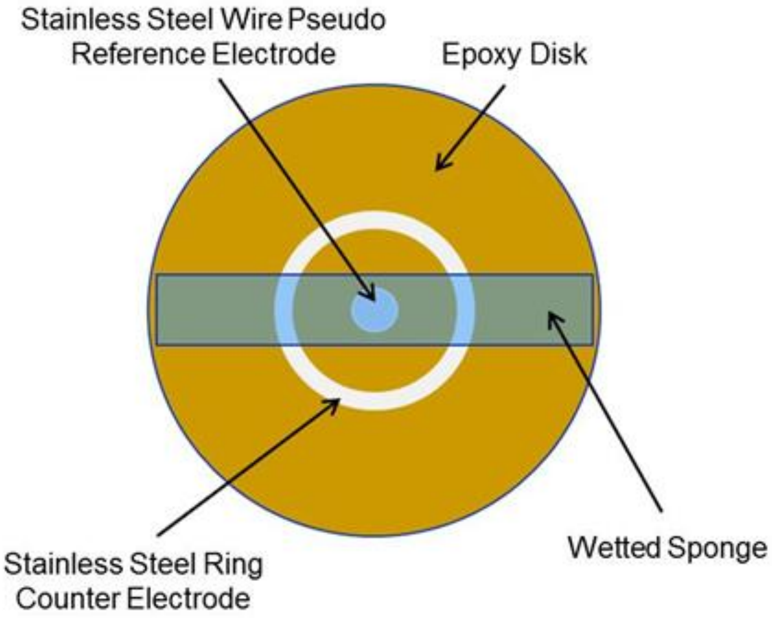
LPR Measurements

- Standard technique for measuring the corrosion rate (ASTM G96)
  - Polarize sample ±10-30 mV (ΔV)
  - Measure ensuing current density (i)
  - $R_p = \Delta V/i$
  - Corrosion Rate α $1/R_p$

LPR Measurements

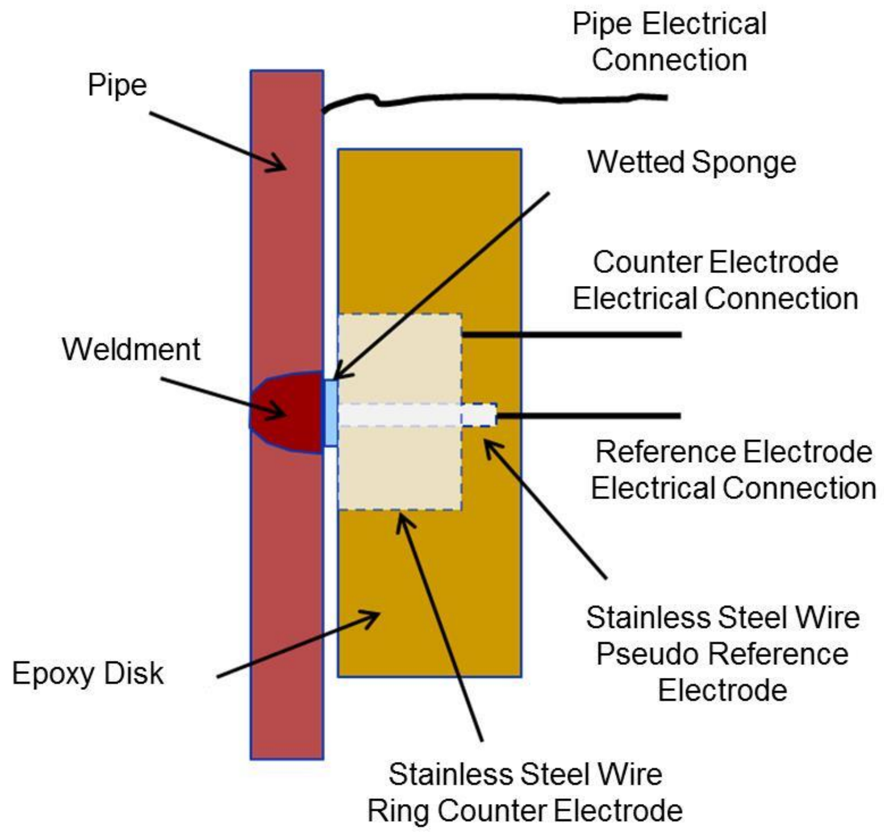
- Limited test environment to small weldment region - Barnacle cell

Plan View



Barnacle Cell

Cross Section View



Variables in Study

- Pipe steel
  - 7 pipe steels
- Wetting solution
  - 3.5 % aqueous NaCl
  - Tap water
  - 1000 ppm $NaSO_4$
  - Sports drink

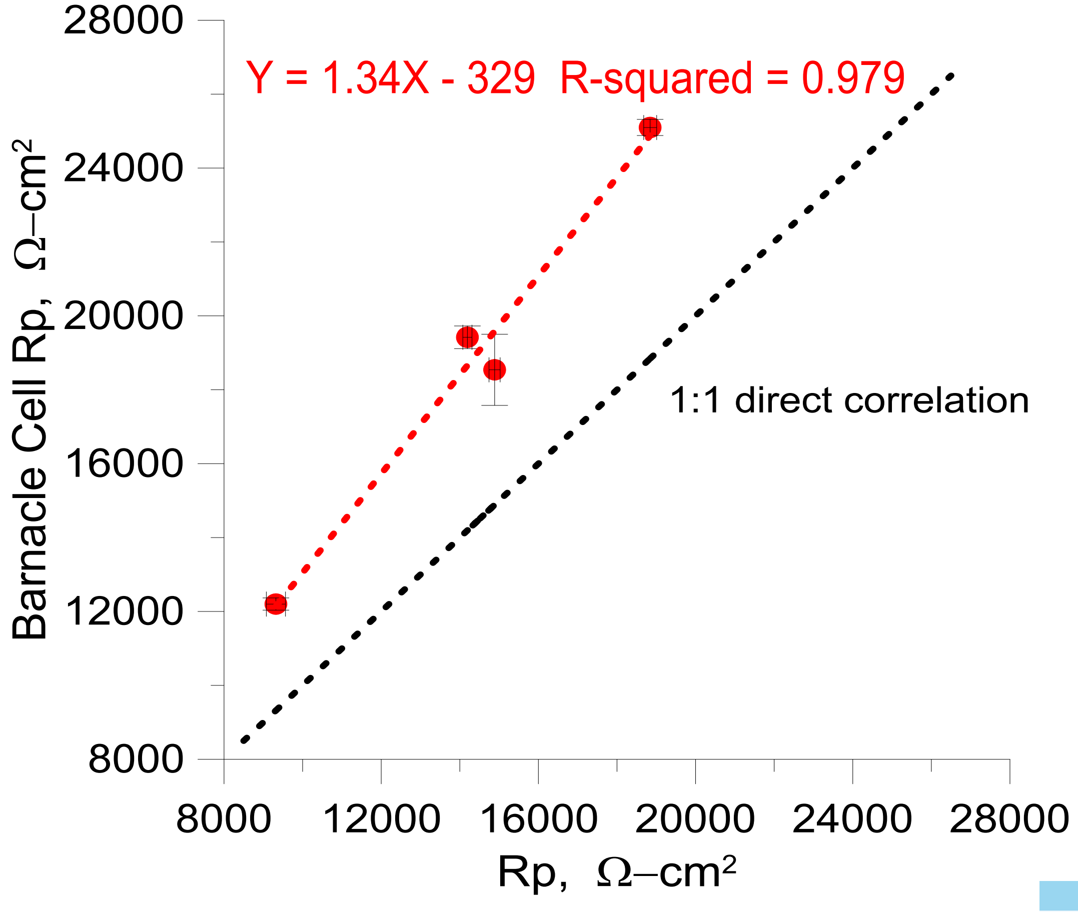
Results

- Differences in potentials between weldment and base metal
  - Too small to detect
- Suggests that corrosion kinetics may be more important than galvanic potential differences
  - Consistent with destructive laboratory tests

Results

- Compared R_p values of base metal
  - Barnacle cell
  - Traditional electrochemical cell
    - 1000 ppm $NaSO_4$ solution
    - Five replicate tests
- Linear relationship
  - Not 1:1
  - 1.34 slope – likely related to higher solution resistance with wetted sponge

LPR Comparison



LPR Comparison

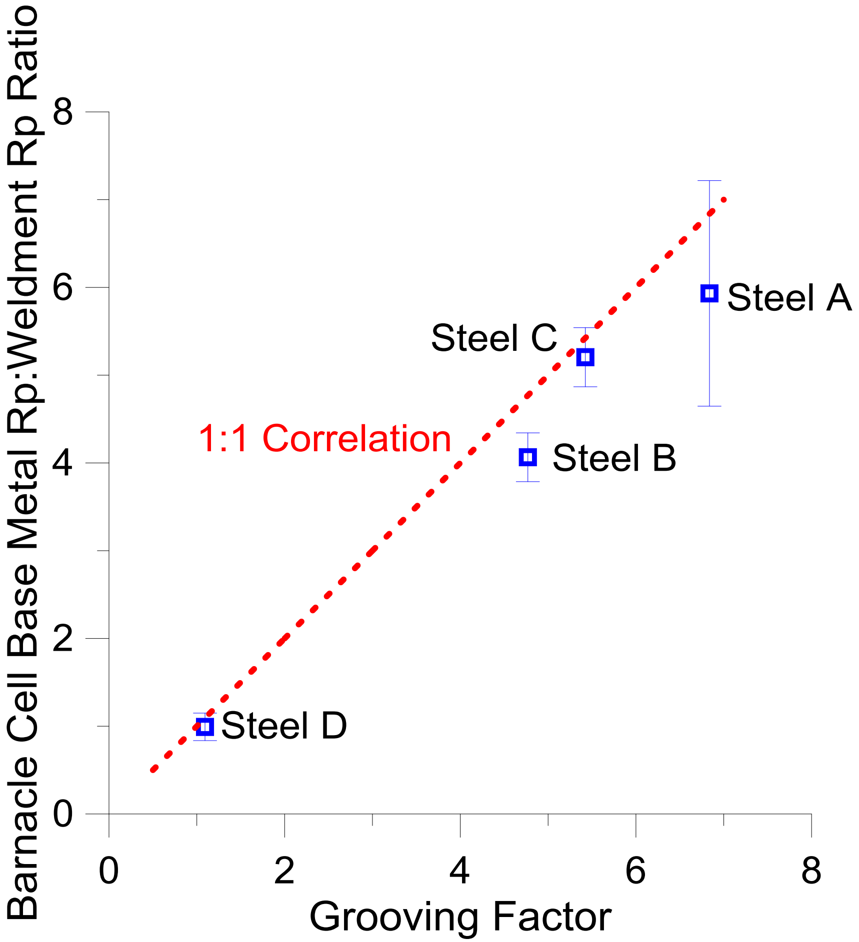
- Consequence of higher Rp values
  - Non conservative estimates of corrosion rate
    - Report Ratio of Rp for base metal to weld metal
    - Ratio α (i_{cor} WM)/(i_{cor} BM)
- Ratio >2 (Duran)
  - Indication of SSWC susceptibility

Potentiostatic Tests

- Compared barnacle cell results with potentiostatic tests
  - Four pipe steels
- Three steels were susceptible to SSWC
  - Grooving Factors > 5
- Rp ratios correlated with grooving factors

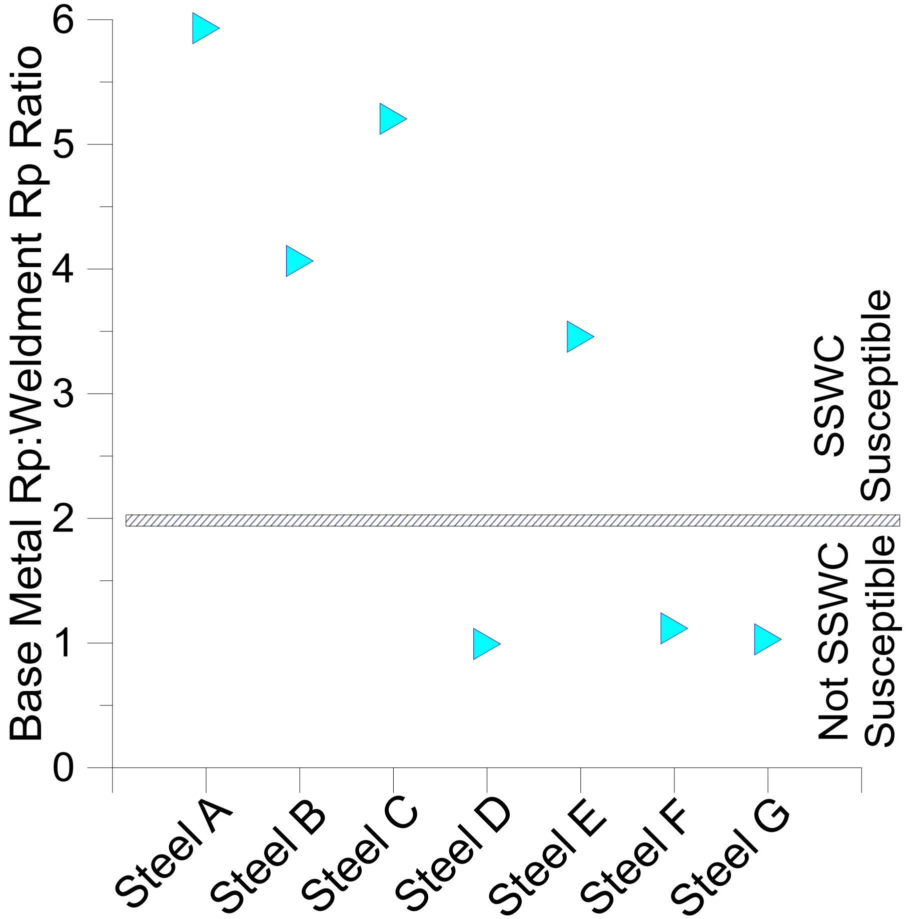
Grooving Factor vs Rp Ratio

3.5% NaCl



Analysis of Seven Steels

Tap Water



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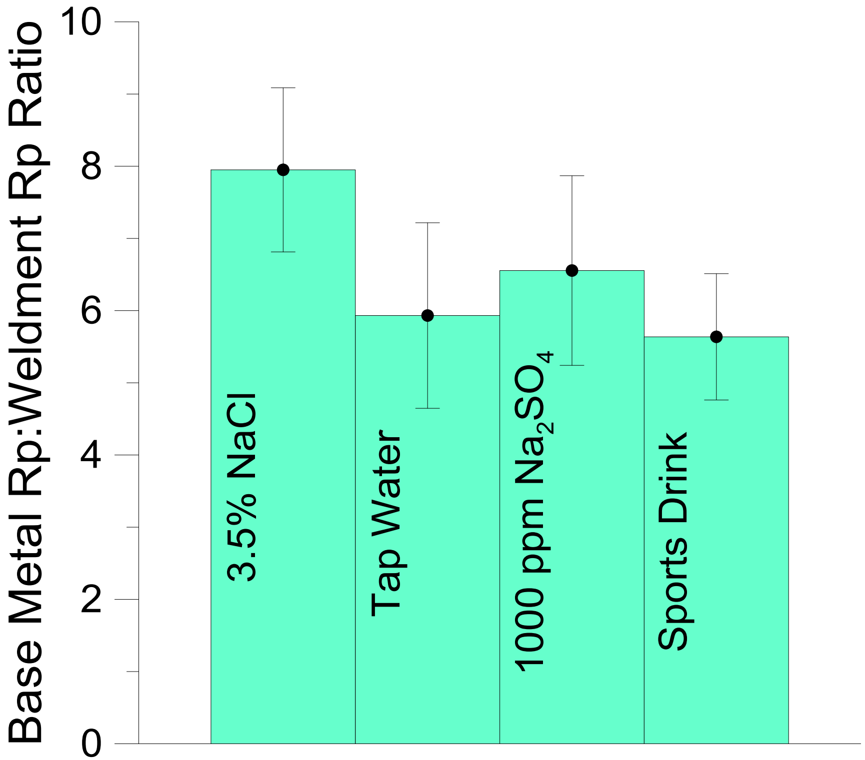
Analysis of Seven Steels

- Four of the steels susceptible to SSWC
  - Rp ratios: 3.5 to 6
  - One steel (E) - SSWC in service
  - Two non susceptible steels (F and G)
    - Newer HF ERW line pipe

Analysis of Electrolytes

Steel A



Conclusions

- Potential measurements not effective in identifying SSWC susceptible steel
- LPR using barnacle cell shows promise
  - Relatively simple technique
  - Results correlate with destructive tests
  - Not very sensitive to electrolyte used

Conclusions

- Testing limited to small number of line pipe steels
- Requires further validation
- Possible NACE standard

Acknowledgements

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