Protection Effectiveness of Vapor Corrosion Inhibitor for Corrosion Under Insulation

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Corrosion under Insulation (CUI)

- CUI is a particularly severe form of localized corrosion that has been plaguing chemical process and Oil & Gas industries since the energy crisis of the **1960s** forced plant designers to include much more insulation in their designs.
- Intruding water is the key problem in CUI. Special care must be taken during design not to promote corrosion by permitting water to enter a system either directly or indirectly by capillary action. Moisture may be external or may be present in the insulation material itself. Corrosion may attack the jacketing, the insulation hardware, or the underlying equipment.

CUI: Corrosion under Insulation

CUI Concerns

- The corrosion under insulation war has been fought for many years in the oil & gas chemical/petrochemical industry.

- The corrosion processes are well understood but yet CUI often goes undetected until the damage is significant

- May lead to catastrophic failures, e.g. on equipment operating under high pressure (oil and gas leaks), chemical contamination.

- Carbon steel (general/localized corrosion)
- Stainless steel (localized corrosion/stress corrosion cracking).

CUI Cost

- CUI cost studies have shown that:
- 40 to 60 % of pipe maintenance costs are caused by CUI

- NDE/inspection costs with a high confidence level for detecting CUI are equal to or exceed field painting costs

- Approximately 10 % of the total maintenance budget is spent repairing damage from CUI

CUI Risk

- General temperature ranges in which risk of CUI is present:
- Carbon steel pipe: -4°C to + 175°C: Risk of CUI (highest risk area: +60°C to +120°C)

- Stainless steel pipe: +50°C to +175°C

- Insulation of process equipment is normally implemented when the outer steel temperature exceeds 50°C (due to the risk of work- related injuries as well as heat loss)

Insulated steel pipes corrode due to:

- Infiltration of water under insulation (rain, process liquids, fire water, etc.)
- Condensation water
- (Ingress of external contaminants)

The insulation material may also contribute to:

- CUI: Creates a crevice for water retention
- May absorb water
- May leach contaminants that increase corrosion rate

What is the Mechanism of Corrosion Under Insulation?

- The mechanism of corrosion under insulation involves three requirements:
- **Availability of oxygen/moisture.**
- **High temperature.**
- **Concentration of dissolved species.**

How to Avoid CUI:

- Avoid moisture entry to the insulation material or steel pipe surface:

    -Correct selection and design of the insulation material

    -Proper design of the item to be insulated, flanges, taps, flowmeters, supports are very hard to be insulted

    - Cover above the insulted items against rainfall,…

- Application of corrosion protection

On Average, 60% of all insulation in service for more than >10 years, will have corrosion-induced moisture. Be prepared.

Corrosion Protection Methods

Carbon steel:

- Organic coatings, VCI impregnated coatings
- Thermal sprayed aluminum (TSA)

Stainless steel (austenitic or duplex):

- Organic coatings, VCI impregnated coatings
- Thermal sprayed aluminum (TSA)

CUI Prevention Strategy

Data from operating facilities shows that water-free insulation is not practical in aging facilities.

Therefore, a CUI prevention strategy is necessary to provide long-term and reliable prevention

Choice of different strategies:

1. Organic coating on carbon steel pipe
   - Ongoing maintenance and re-painting
   - NDE (does prevent CUI but can help predicts remaining life)
2. TSA on Carbon steel pipe
3. Stainless steel pipe (+TSA or Al foil wrapping)

Initial maintenance and inspection costs should be assessed for each choice to give lowest total lifetime cost.

How to Inspect/solve CUI

The most common and straightforward way to inspect for corrosion under insulation is to cut plugs in the insulation that can be removed to allow for ultrasonic testing. However, many times such plugs can be the source of moisture leakage.

The main problem with this technique is that corrosion under insulation tends to be localized and unless the inspection plug is positions in the right spot the sites of corrosion can be missed.

Techniques that are available include special eddy current techniques, x-ray, remote TV monitoring and electro-magnetic devices.

Project Objectives

To evaluate VCI application in controlling CUI for steel pipes.

- Using CCT per GM protocol (salt spray-8hrs, ambient humidity-8hrs, and heated drying-8hrs)

- Cold/Hot cyclic corrosion tests:

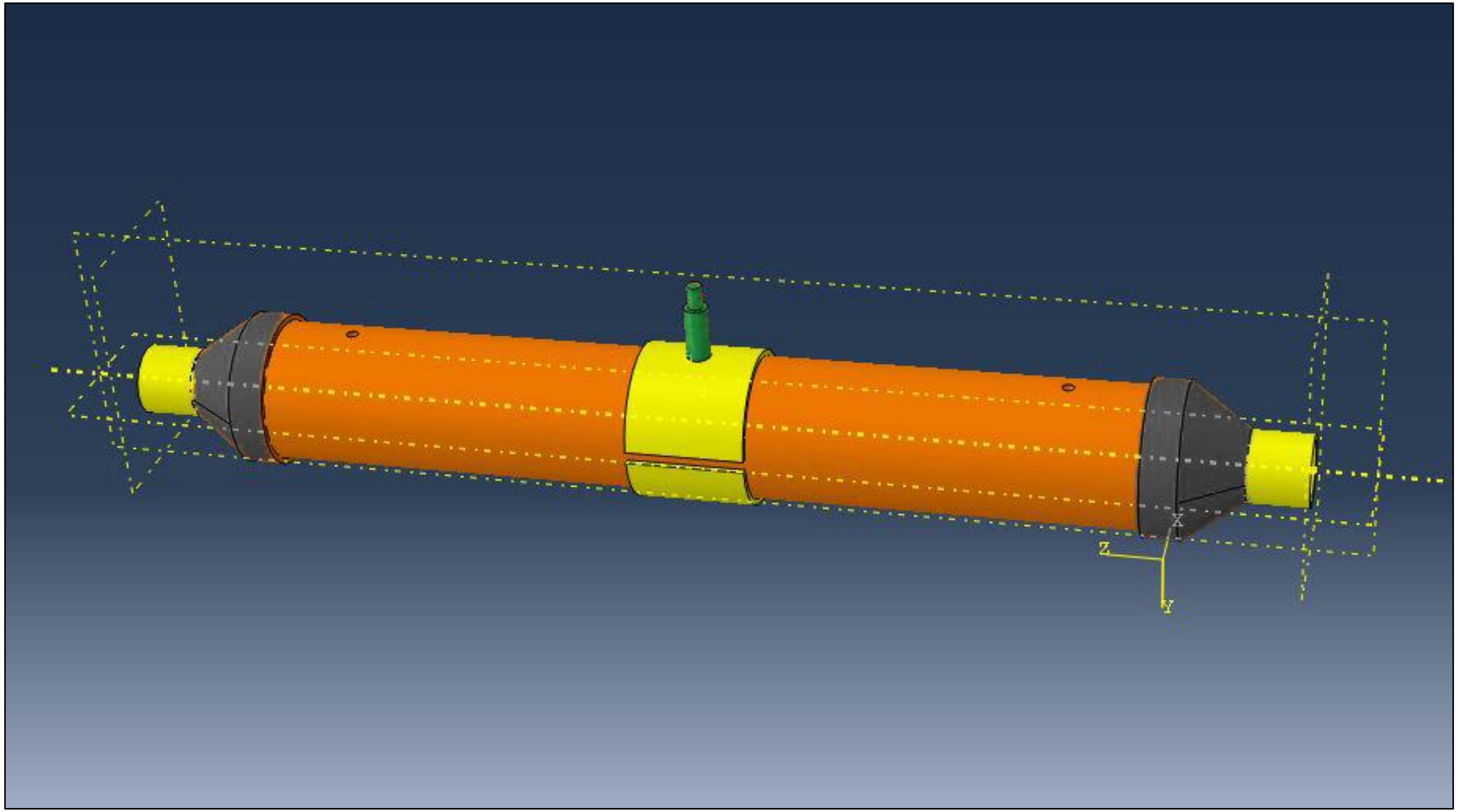
200 ppm sodium chloride solution was injected by tube into the pipe/insulation interfaces every 48 hours.

Hot dry air (120-140^{o}C) was blown through the pipes (inner diameter) for two hours per day and held at ambient temperature for twenty-two hours.

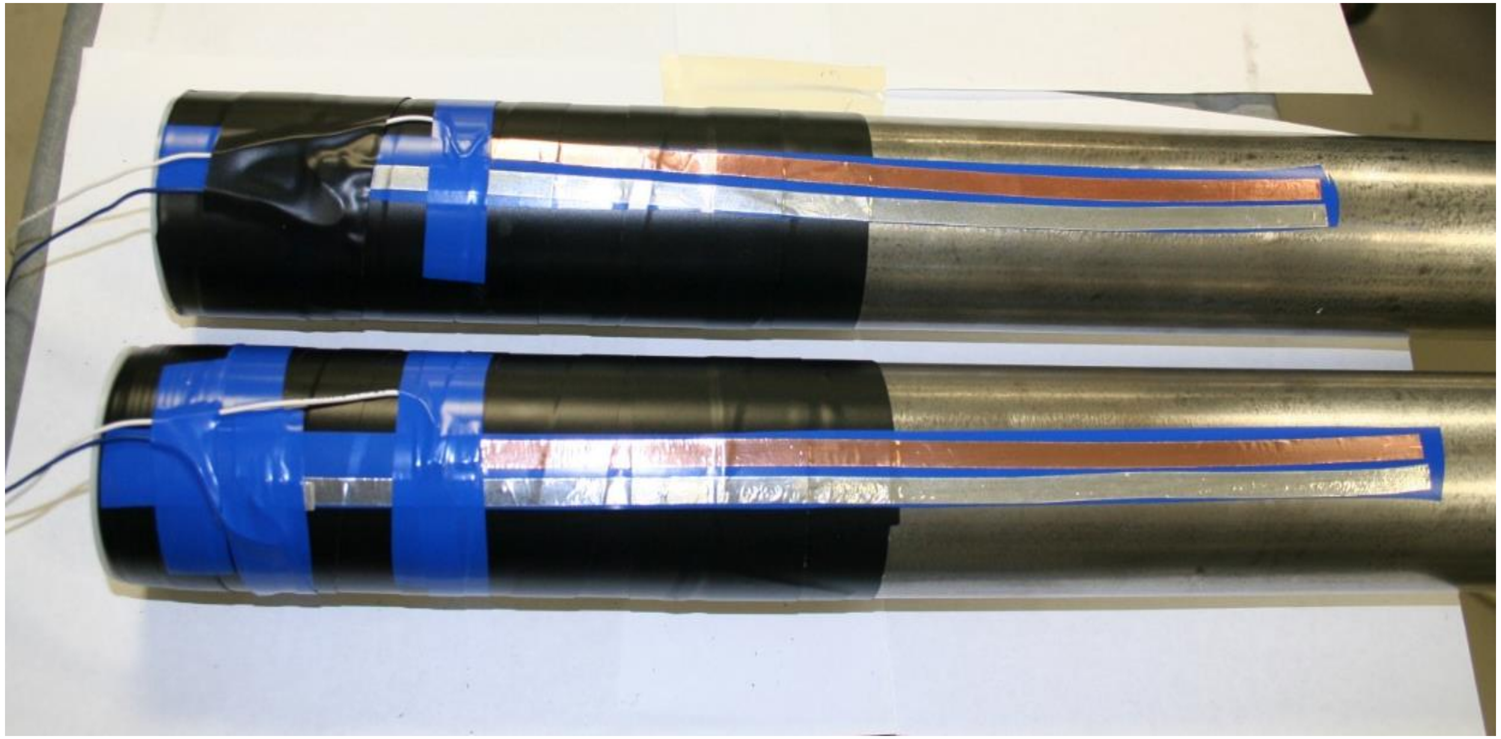
- Four samples were assembled, two samples were used as controls (no inhibitor applied), and two samples were wrapped with thermal insulation that was impregnated with a commercially available inhibitor, referred to as Inhibitor A.
- Inhibitor effectiveness to minimizing CUI damages was evaluated by different corrosion testing. Two samples (one with inhibitor, 1 without) were placed in in a cyclic corrosion test chamber for 4800 hours. A 24 hour cycle consisted of 8 hours salt spray, 8 hours humidity at ambient temperature, and 8 hours dry cycle at 45°C.
- The samples (one with inhibitor, 1 without) were disassembled every 720 hours (30 days) to evaluate their surface condition and document the extent of corrosion damage at pipe/insulation interfaces.

CUI Components

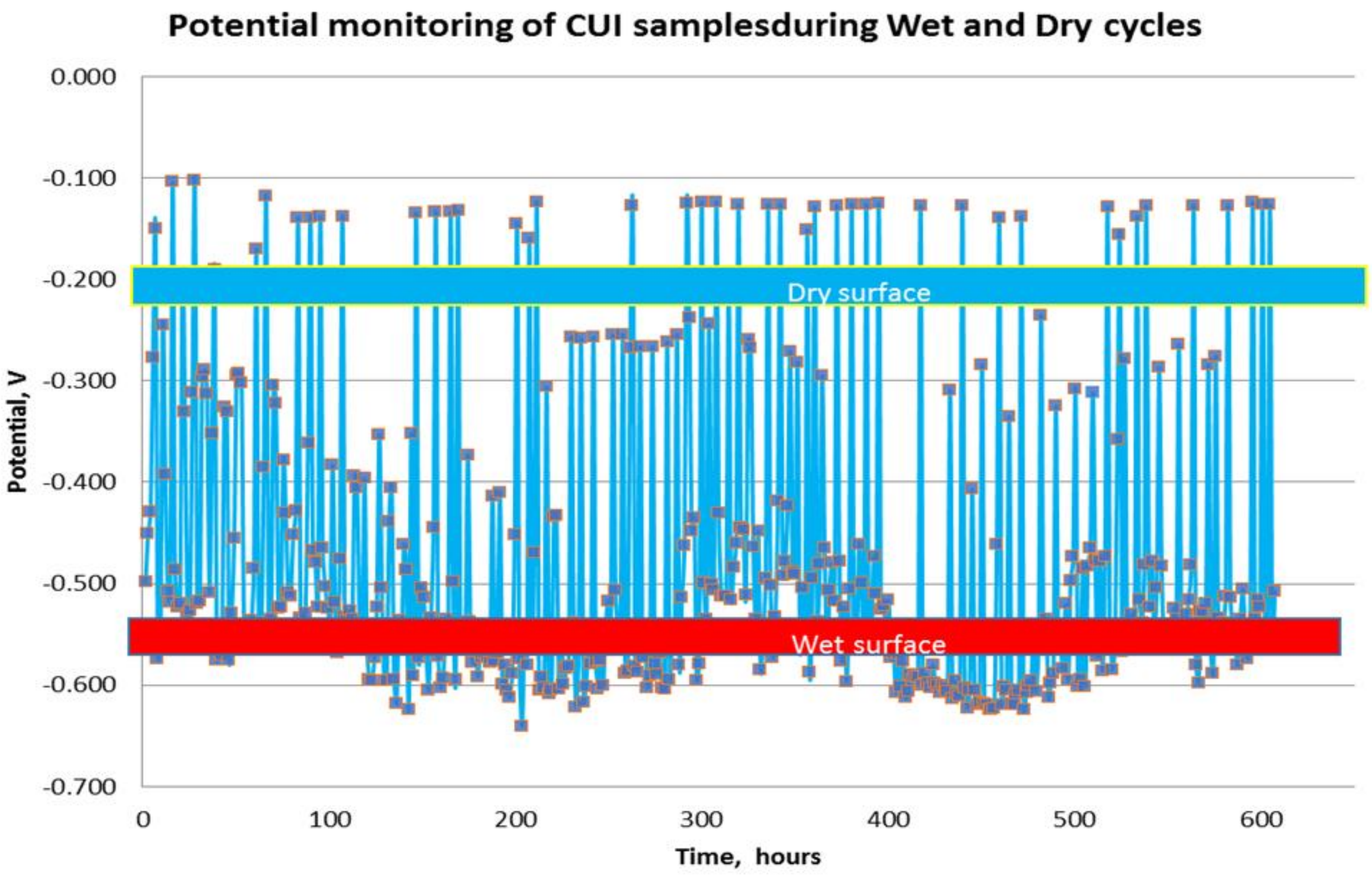
CUI Assembly

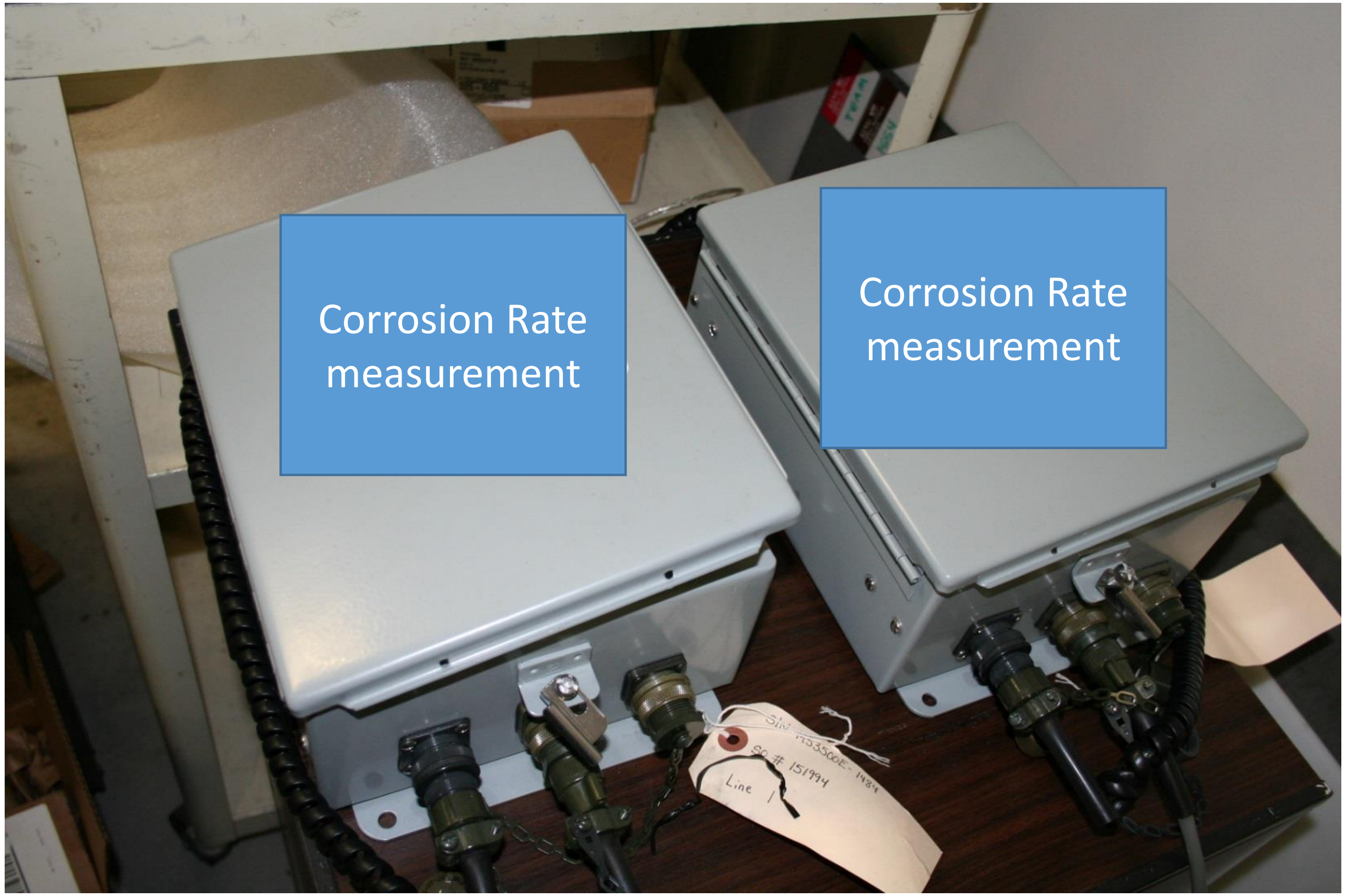


Wetness sensors under Insulation

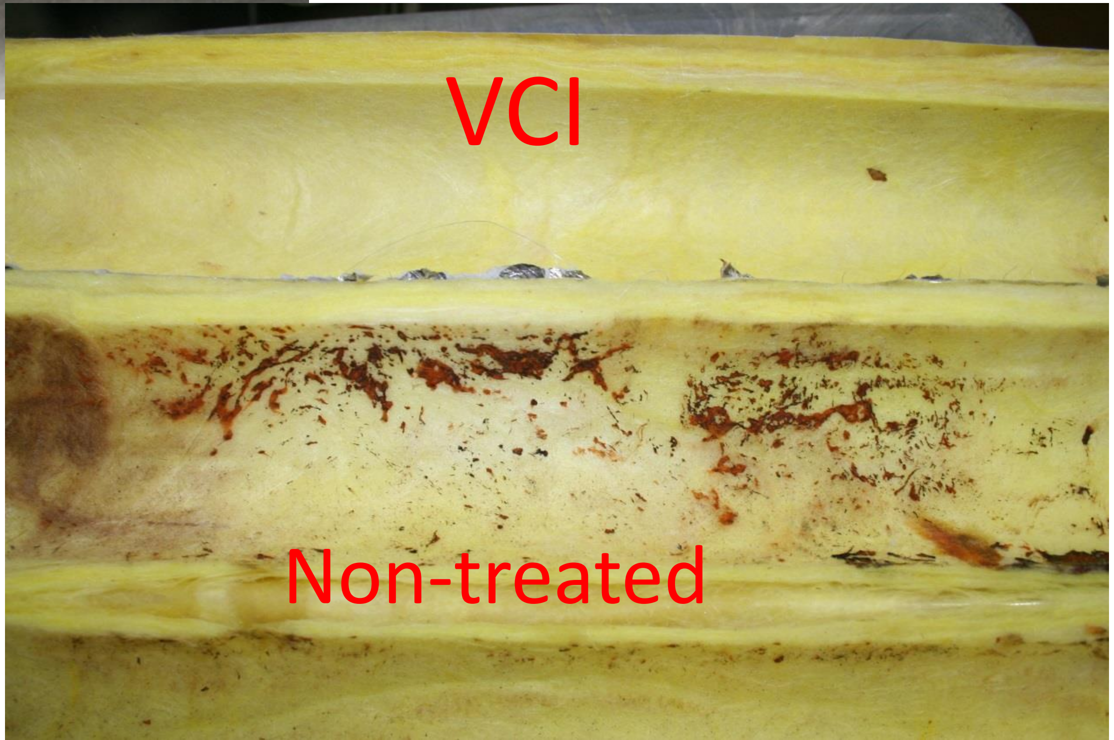


Monitored potential from wetness sensor during wet/dry cycling. The surface is wet when measured potential is -500 to -600 mV, and tend to be dry when potential shifted to higher than -200 mV.



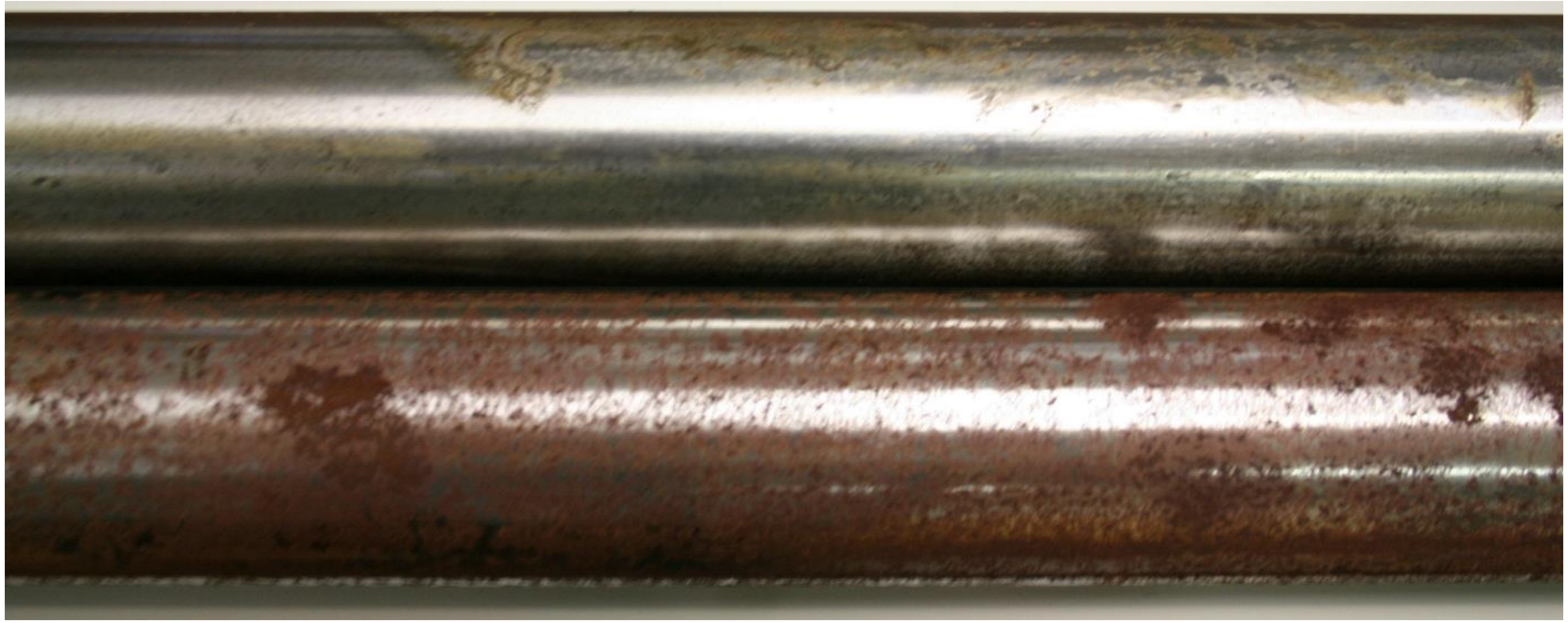

Corrosion Rate measurement
Corrosion Rate measurement

Comparison of Corrosion behavior of steel Pipes, CCT Day 14



Comparison of Corrosion behavior of steel Pipes, Day 30

CCT (GM test), 60 days

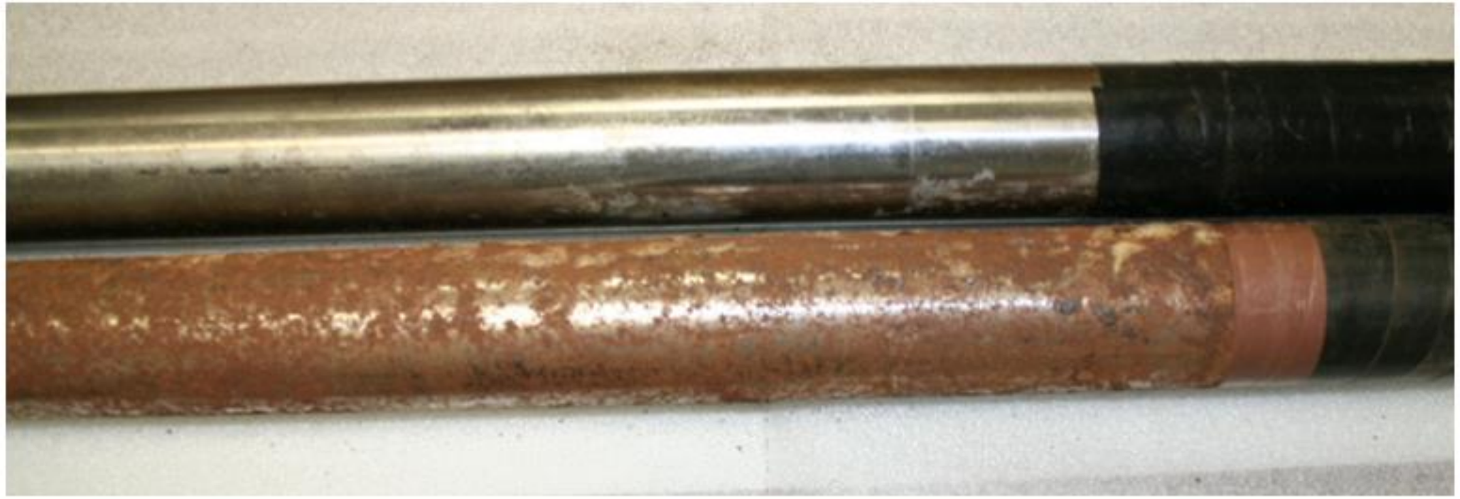


Hot/cold Cycles
(Day 90)

CCT (GM test),
90 days

Hot/cold Cycles

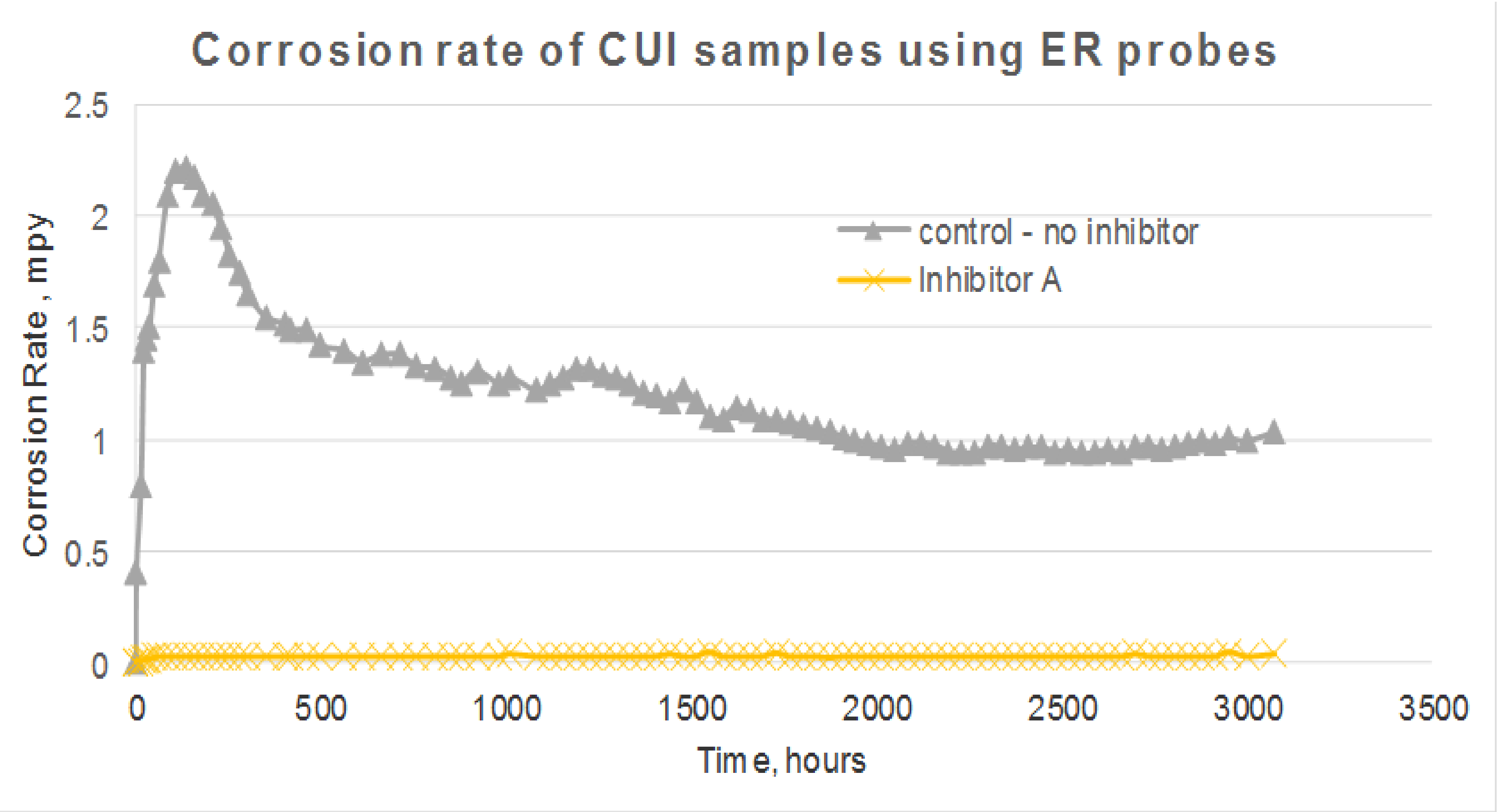
Day 120



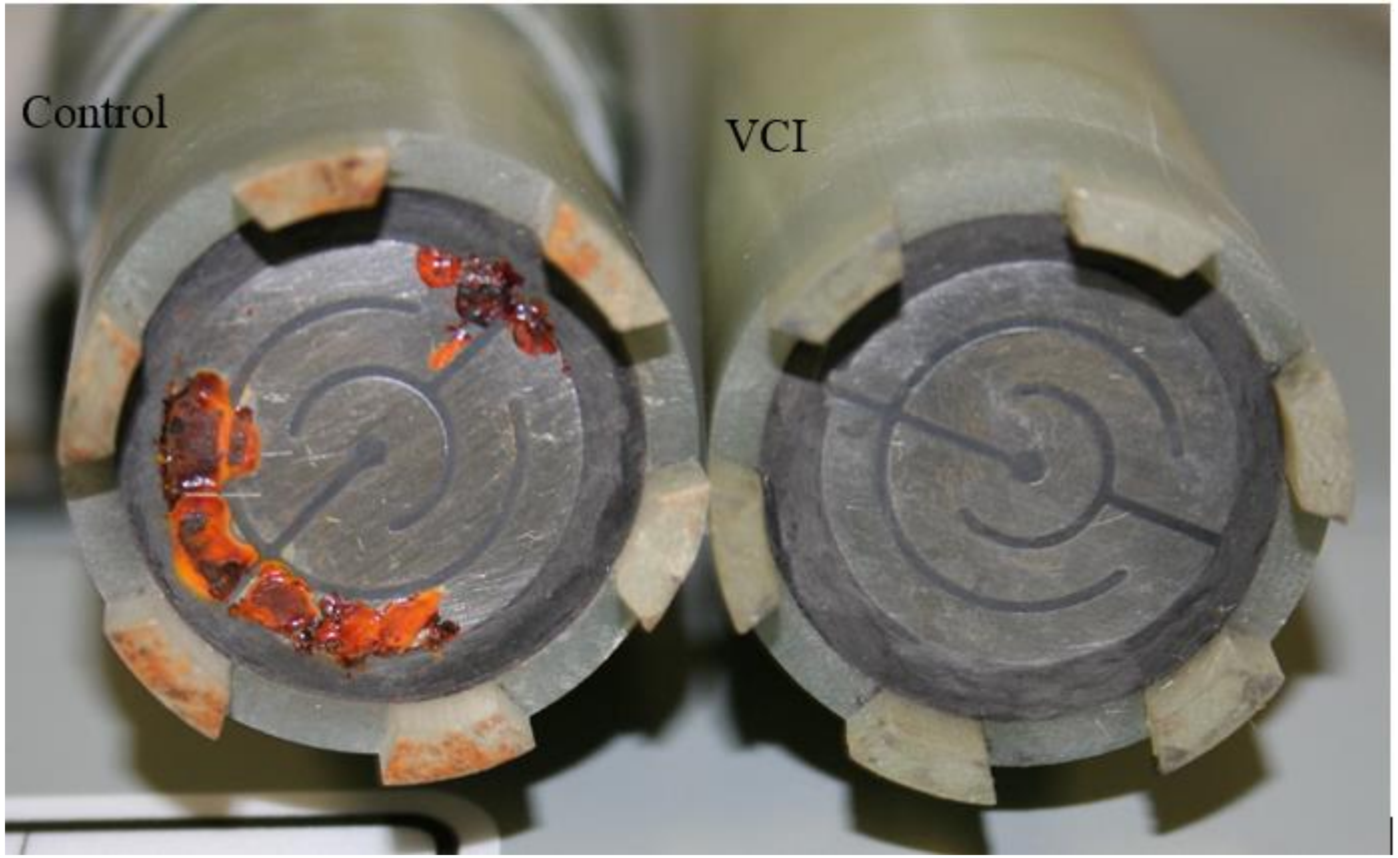
Salt spray
(CCT cyclic Day 176)

Hot/cold
Cycles
Day 176

Comparison of corrosion rate from the ER probes. The control sample (no inhibitor) measured ~ 0.96 mpy and as high as 2.2 mpy at 110 hours of testing, the inhibitor treated sample with a corrosion rate in the range of 0.03 to 0.04 mpy.



Comparison of electrical resistance probes used to measure the corrosion rate of the CUI samples. The control sample shows red rust formation; while protected samples with Inhibitor A, is clean, and shows no corrosion residue (Day 176)



Concluding Remarks:

- The effectiveness of commercially available vapor phase corrosion inhibitors against CUI was investigated using corrosion tests and corrosion rate measurements in isothermal and cyclic wet/dry test conditions. API 5L X65 steel pipes were insulated with thermal insulation, foam and placed in laboratory simulated CUI environment to monitor the degree of pipe surface wetness and corrosion behaviors. Results have demonstrated that VCI can successfully reduce corrosion attack under insulation despite the pipe surfaces being maintained in continuously wet/dry cyclic conditions.
- The corrosion rate was reduced from ~2.2 mpy for the control samples to less than 0.03 mpy for the VCI treated pipes, a change of corrosion rate by a factor of 30 for the pipes protected with VCI.
- Wetness probe system using galvanic CUI sensor is a practical remote monitoring method (non-visual and non-destructive) when pipe sections are being exposed to wetness by the insulation system. Inspection priorities can be determined as a function of duration of wetness. This can significantly reduce the visual inspection cost, so that CUI reduction becomes manageable.
- These investigation showed that an effective protective coating system under the insulation is critical and requires the inclusion of VCI to prolong the pipe integrity and lower inspection and maintenance cost.

Current Observation

- VCI injection into insulation system appears to minimize corrosion attacks of steel pipes.
- Concern: how often need to inject VCI
- And how practical injection method will work on-site.
- Explore VCI impregnated organic coatings