Evaluation of Silica-Based Green Inhibitor in Brine Using Coupled Multielectrode Sensors

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Presented to

Workshop on Coupled Multielectrode Array Systems for Corrosion Monitoring and Electrochemical Studies

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Presentation Outline

- Objectives of Study
- Cooling Water Treatment Limitations and Needs
- Silica Corrosion Inhibition Chemistry
- CMAS Laboratory Studies at High Temperatures
- Field Results with Silica Chemistry
- Conclusions

Objectives of Study

- Establish CMAS method for pilot evaluation of multiple metals at high temperature with high TDS (Zero Liquid Discharge) water chemistry
- Establish confidence in transferring laboratory / pilot data to field application
- Verify that silica inhibitor chemistry can control corrosion in high temperature cooling water
- Establish field monitoring potential of method

Limitations of Current Alkaline Cooling Water Treatment

Limit	**Impact**	***Control Mechanisms***
1. Ca/Mg	Scale	Blowdown / Inhibitor / Acid
2. Silica	Scale	Blowdown / Inhibitor
3. TDS	Corrosion	Blowdown / Inhibitor
4. pH	Corrosion / Scale	Blowdown / Acid

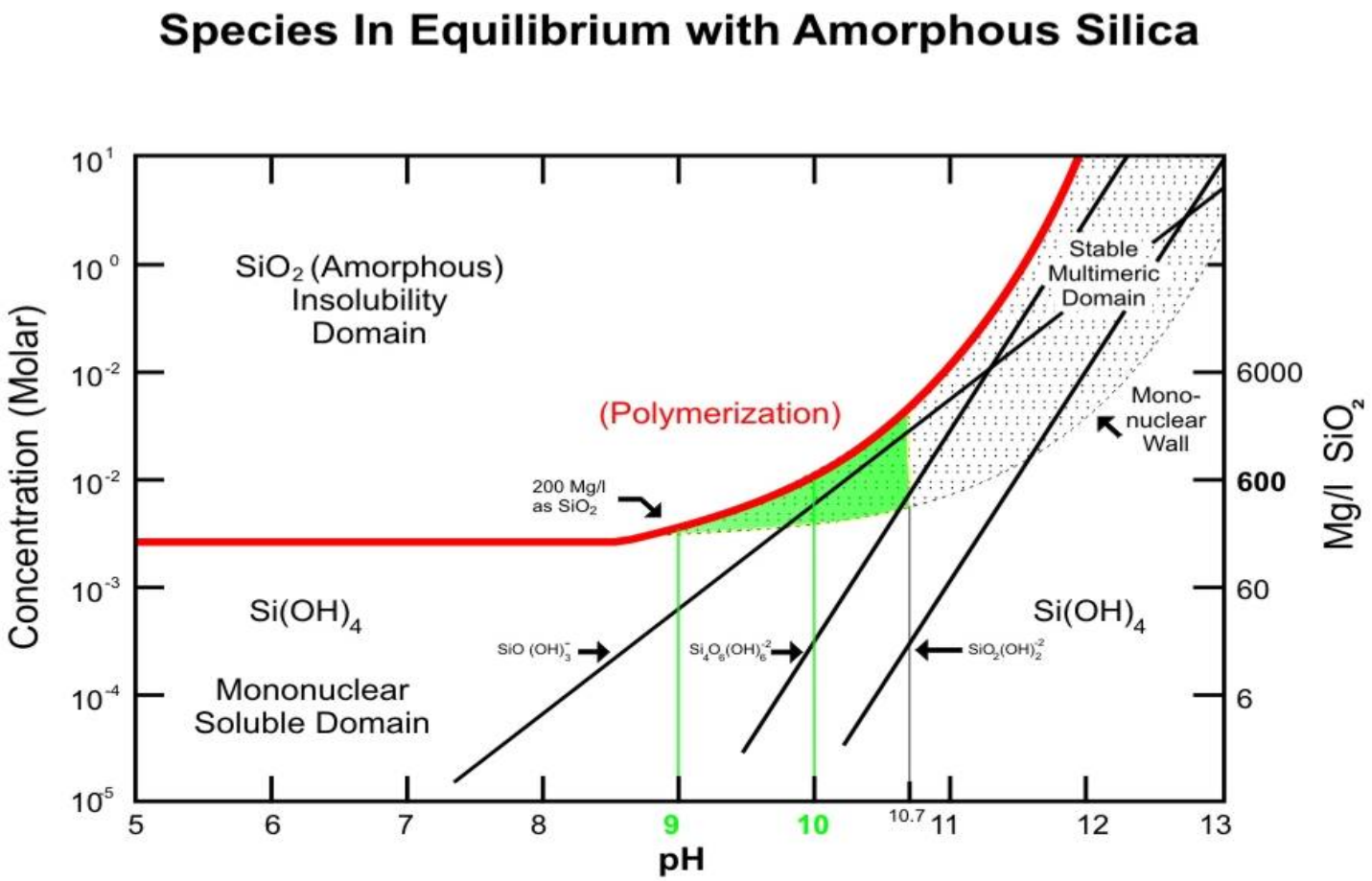
Cooling Water Treatment Needs and Goals

- Permit Zero Liquid Discharge operation
- Permit reuse of waste water
- Reduce high TDS corrosion
- Reduce corrosion at high temperatures
- Eliminate scale and silica limitations
- Reduce use of organic or toxic chemicals
- Sustain our environment through reduction in water use and chemical discharge

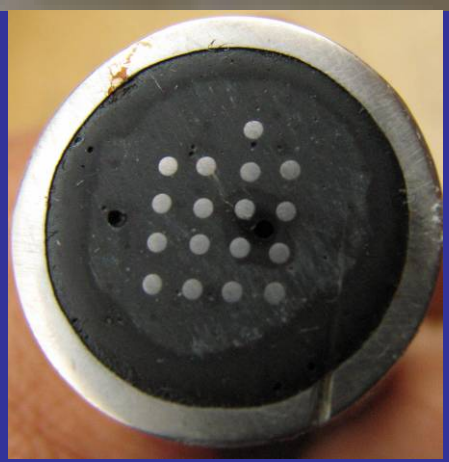
Silica Chemistry Approach

- Soften makeup water, no scale ions
- Concentrate TDS, eliminate blow down
- Control pH to 9 to 10 range
- Concentrate silica to 200-600 mg/L
- No excess silica concentration limit
- “Green” – eliminate chemical use

Relationship between Soluble, Insoluble (amorphous) and Stable Multimeric (polymeric) Silica Species at Varying pH and Concentration in Absence of Polyvalent Metal Ions

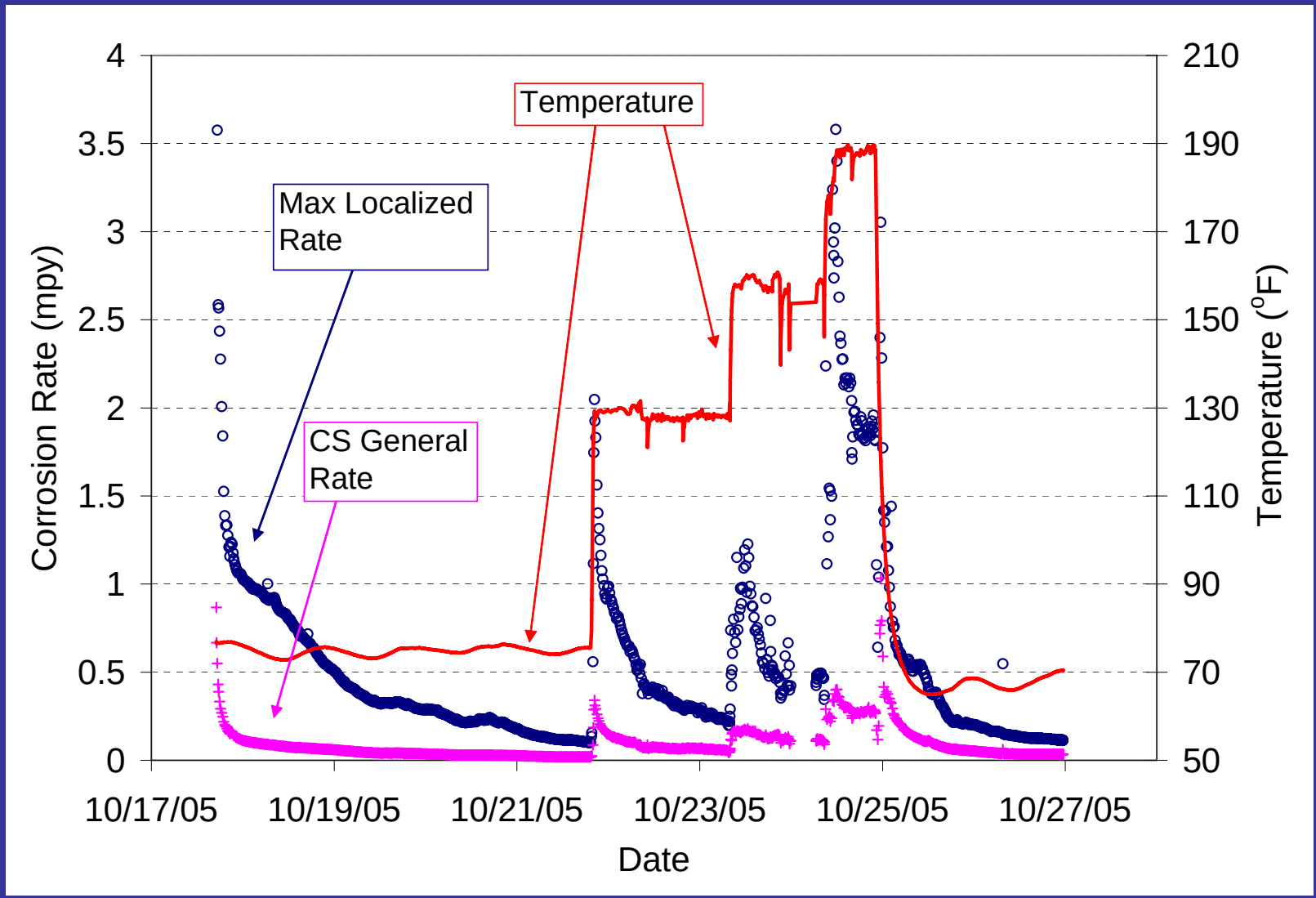


Coupled Multielectrode Array Sensors Used in the study

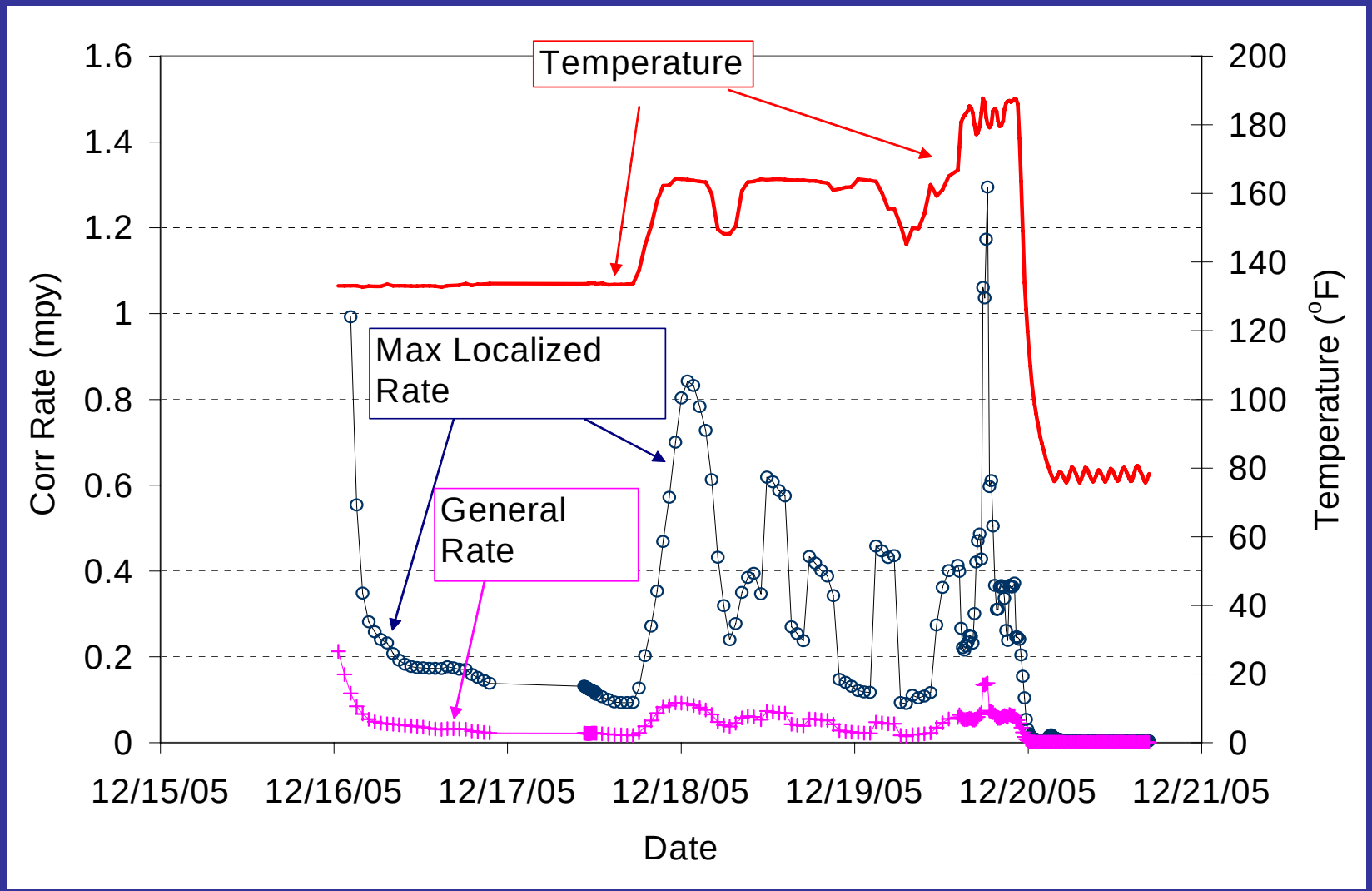


- Real time coupled multi-electrode array corrosion probes were used
- Probes measures peak localized and general corrosion rates
- Test water chemistry:
  - 50,000 conductivity
  - 450 ppm silica
  - 9000 ppm chloride
  - pH 10.0
- Temperatures:
  - 77^{o} F; 130^{o} F; 160^{o} F; 190^{o} F
  - **(25^{o} C; 54^{o} C; 71^{o} C; 88^{o} C)**
- Metals:
  - Carbon Steel 1008,
  - 316L SS
  - AL1100
  - Copper 1100
  - Zn

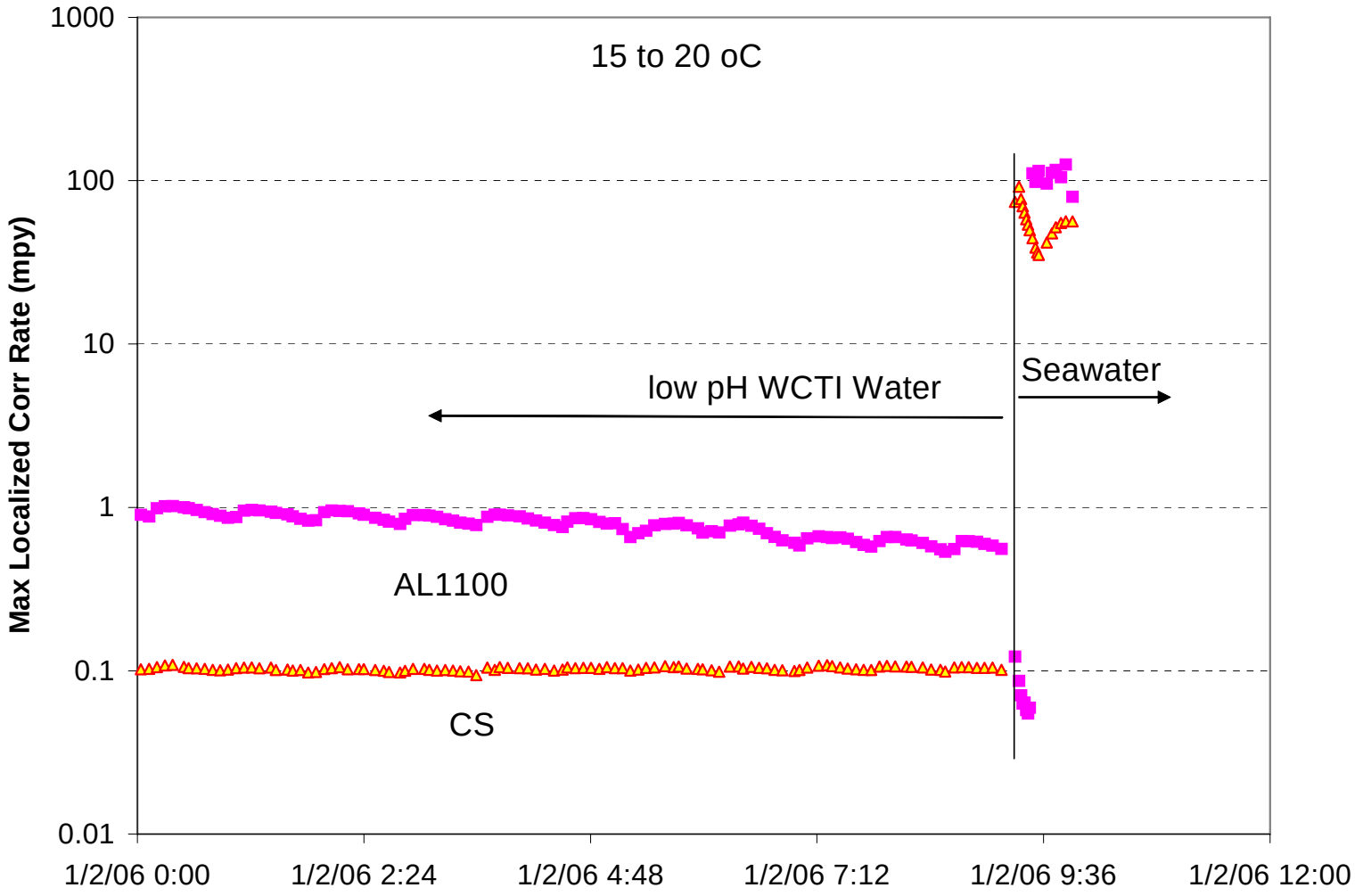
Localized and General Corrosion Rates of Carbon Steel in High Silica / High TDS Water



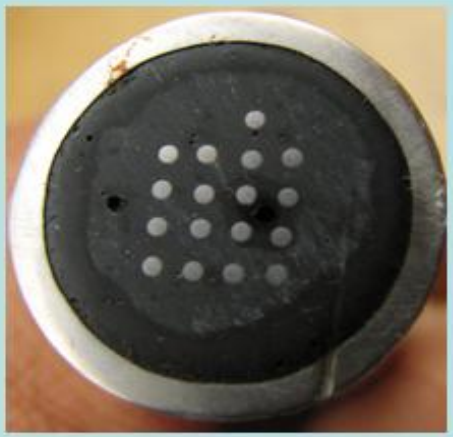
Localized and General Corrosion Rates of Aluminum 1100 in High Silica / High TDS Water

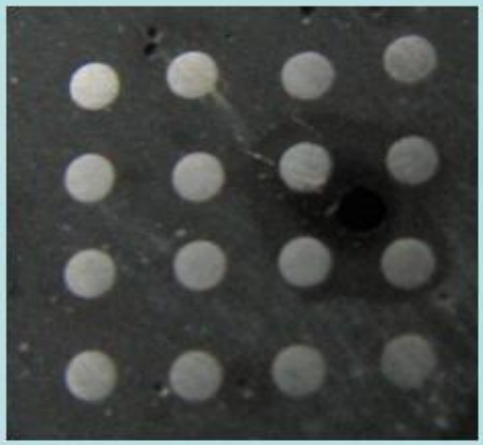


Localized Rates of Aluminum and Carbon Steel in High TDS / High Silica water and in Seawater

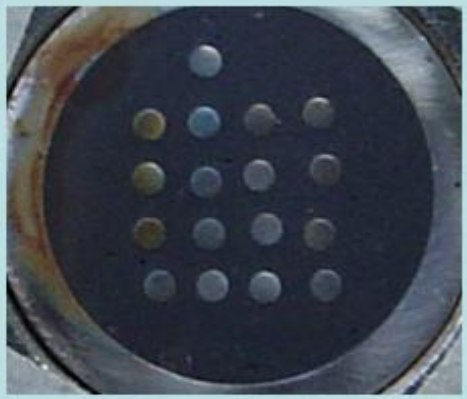


Post-Test Probe Appearance – Carbon Steel: Localized Corrosion at 40 mpy in Unprotected Brine, and < 0.2 mpy in Silica Inhibited Brine





Carbon steel, one week in high-silica brine solution (pH=10) at up to 190 °F

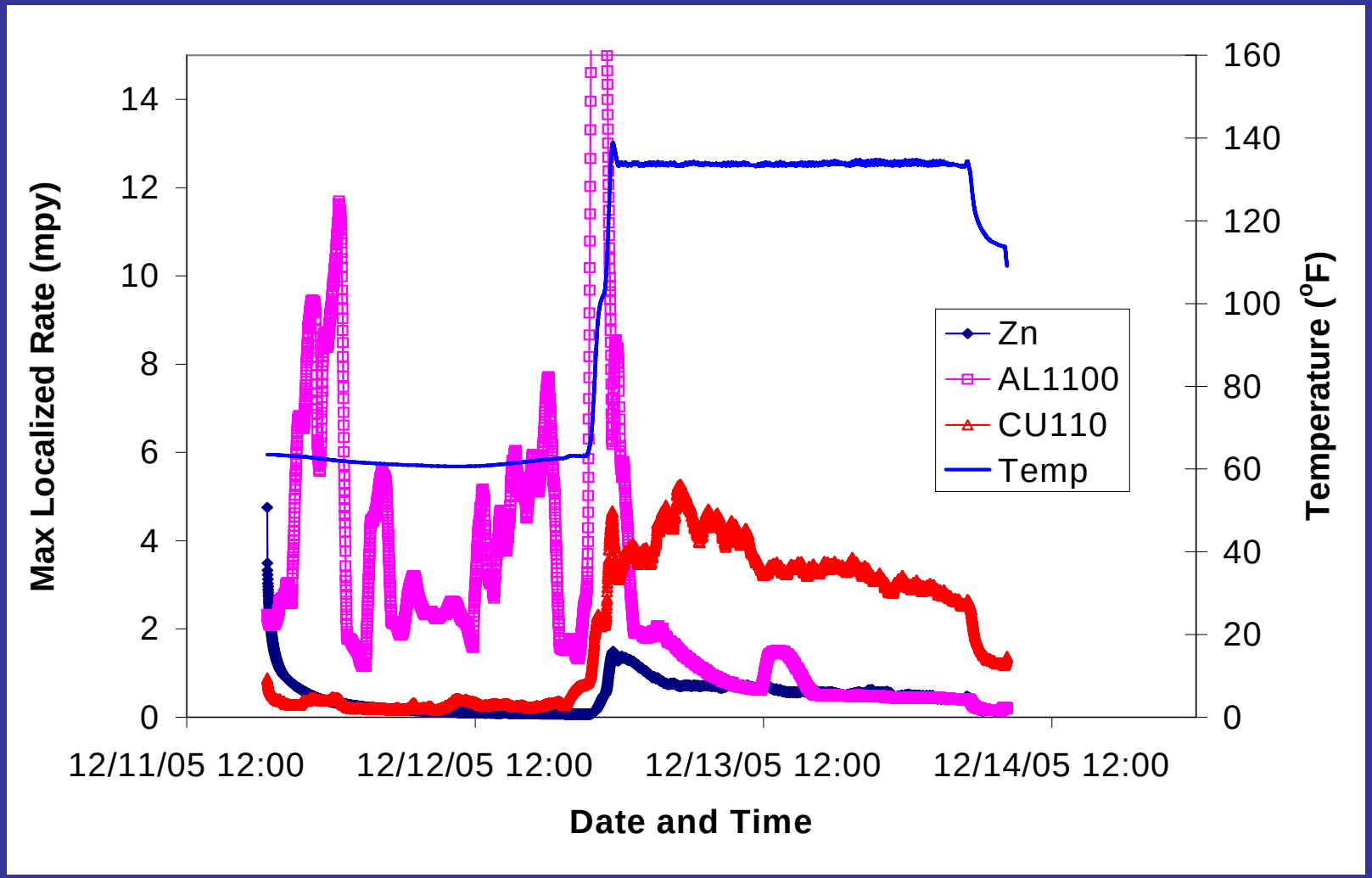


Three weeks in seawater at room temperature

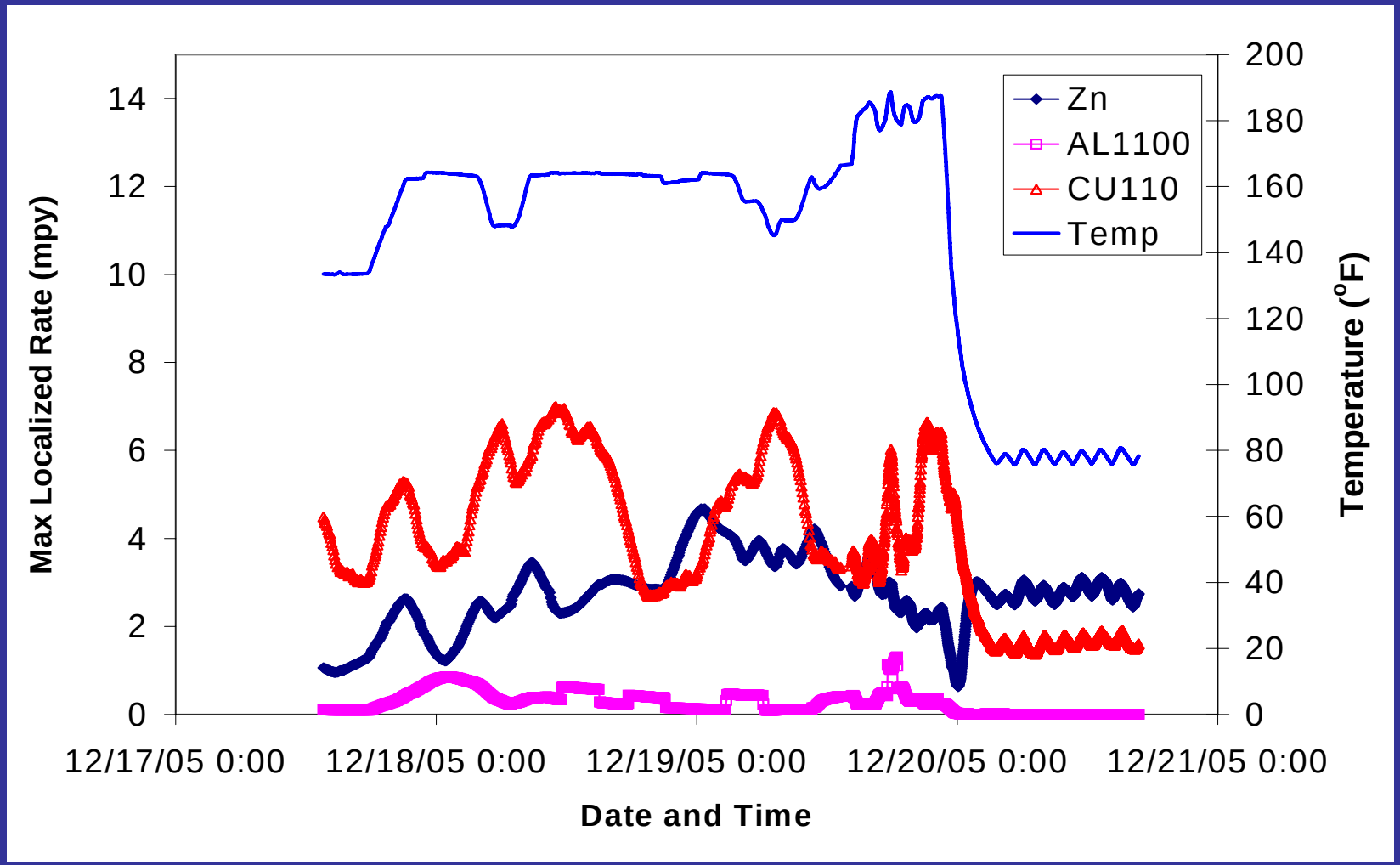
Carbon steel

316L Probe

Localized Rates of Zinc, Aluminum and Copper in High TDS / High Silica Water at 65° F and 136° F

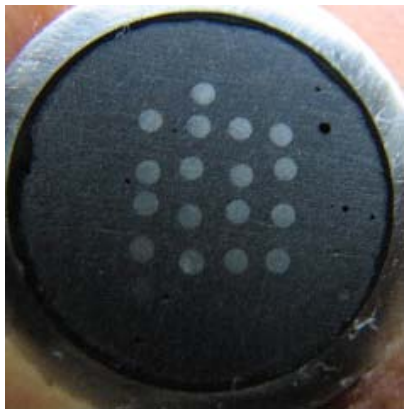


Localized Rates of Zinc, Aluminum and Copper in High TDS / High Silica Water at 160° F, 180° F and Room Temperature

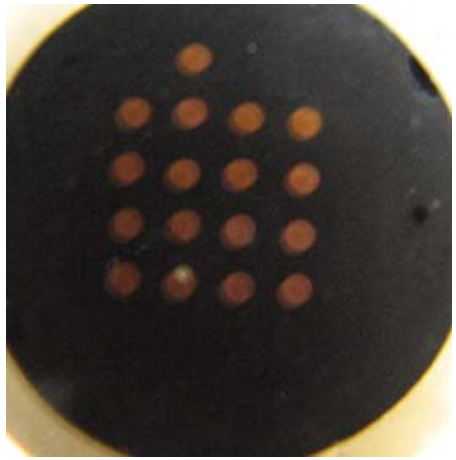


Post-Test Appearance for Zinc, Copper and Aluminum Probes after 11- day Immersion in High Silica Water at up to 190° F (prior to cleaning)

Zn

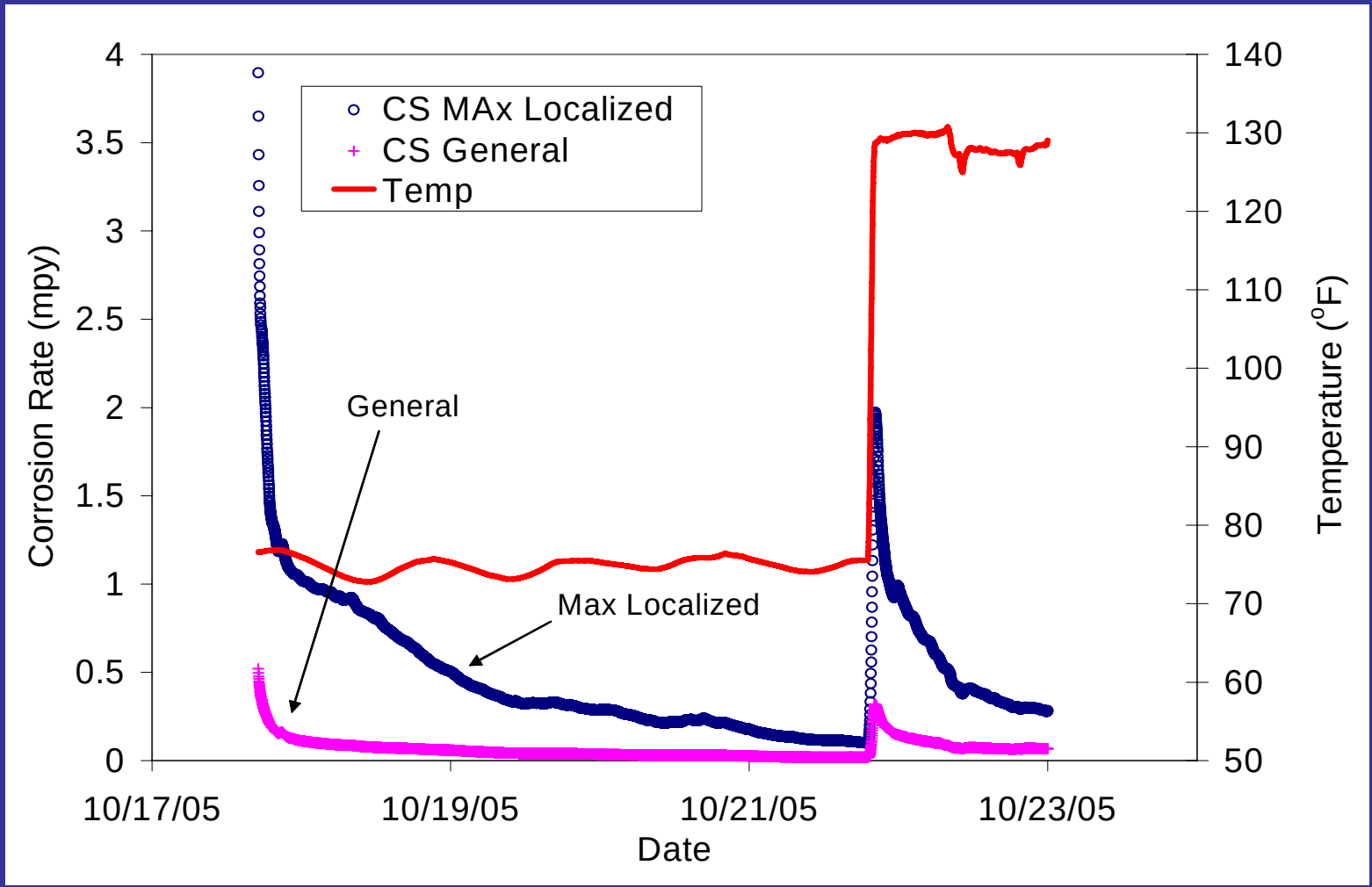


CDA110

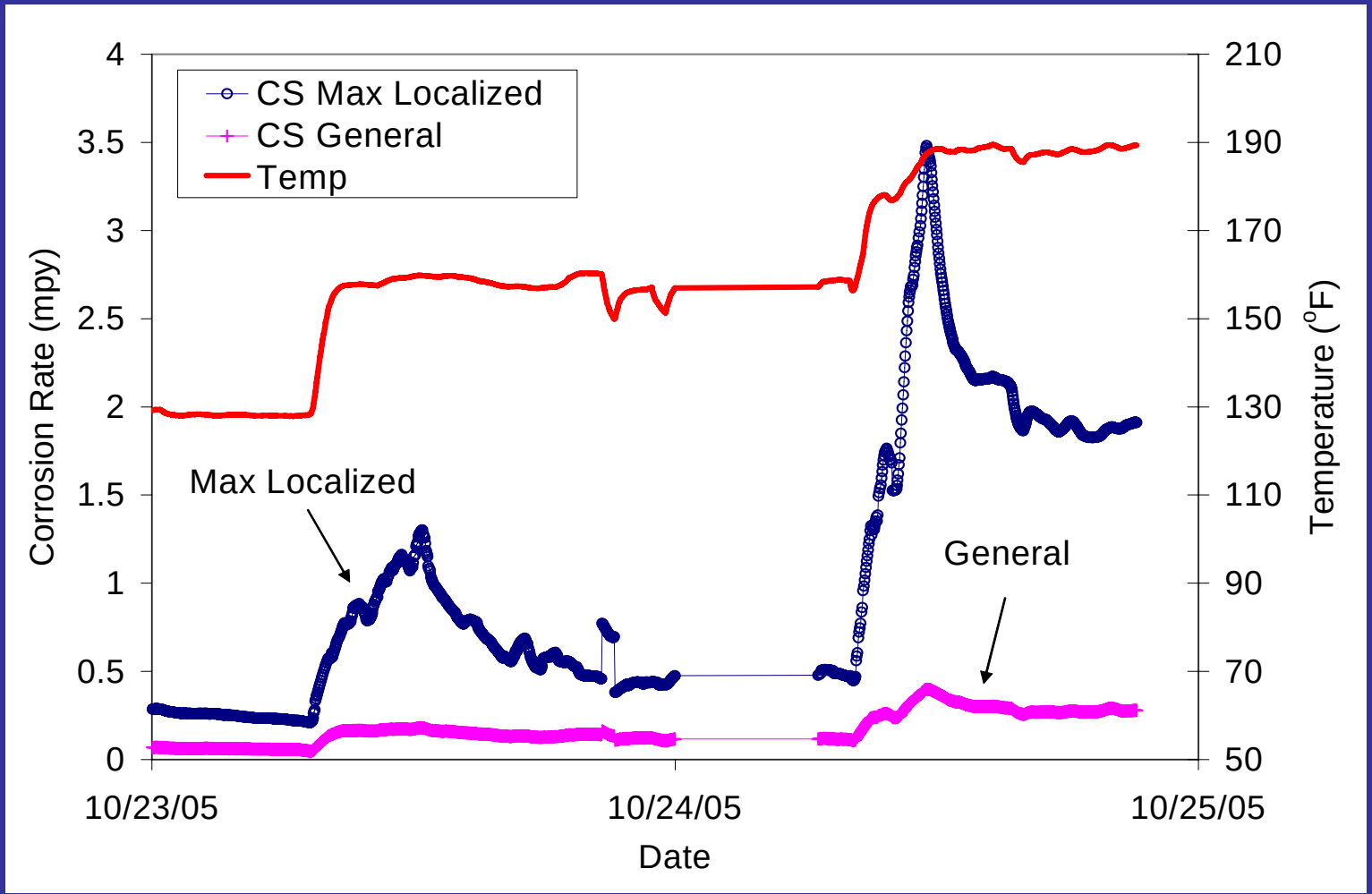


AL1100

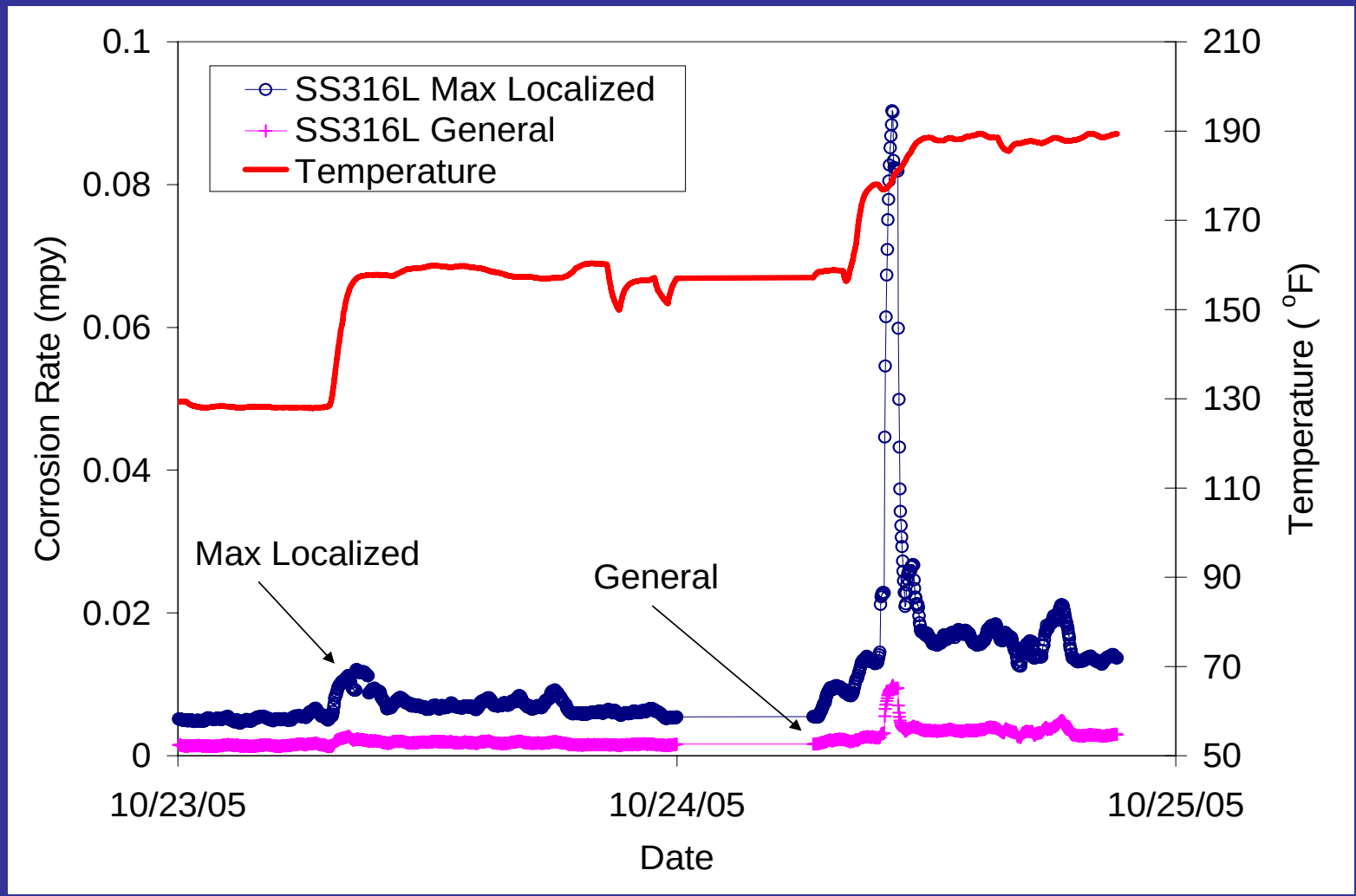
Transient Response of Localized and General Corrosion Rates for CS in High TDS / High Silica Water, Following Temperature Change



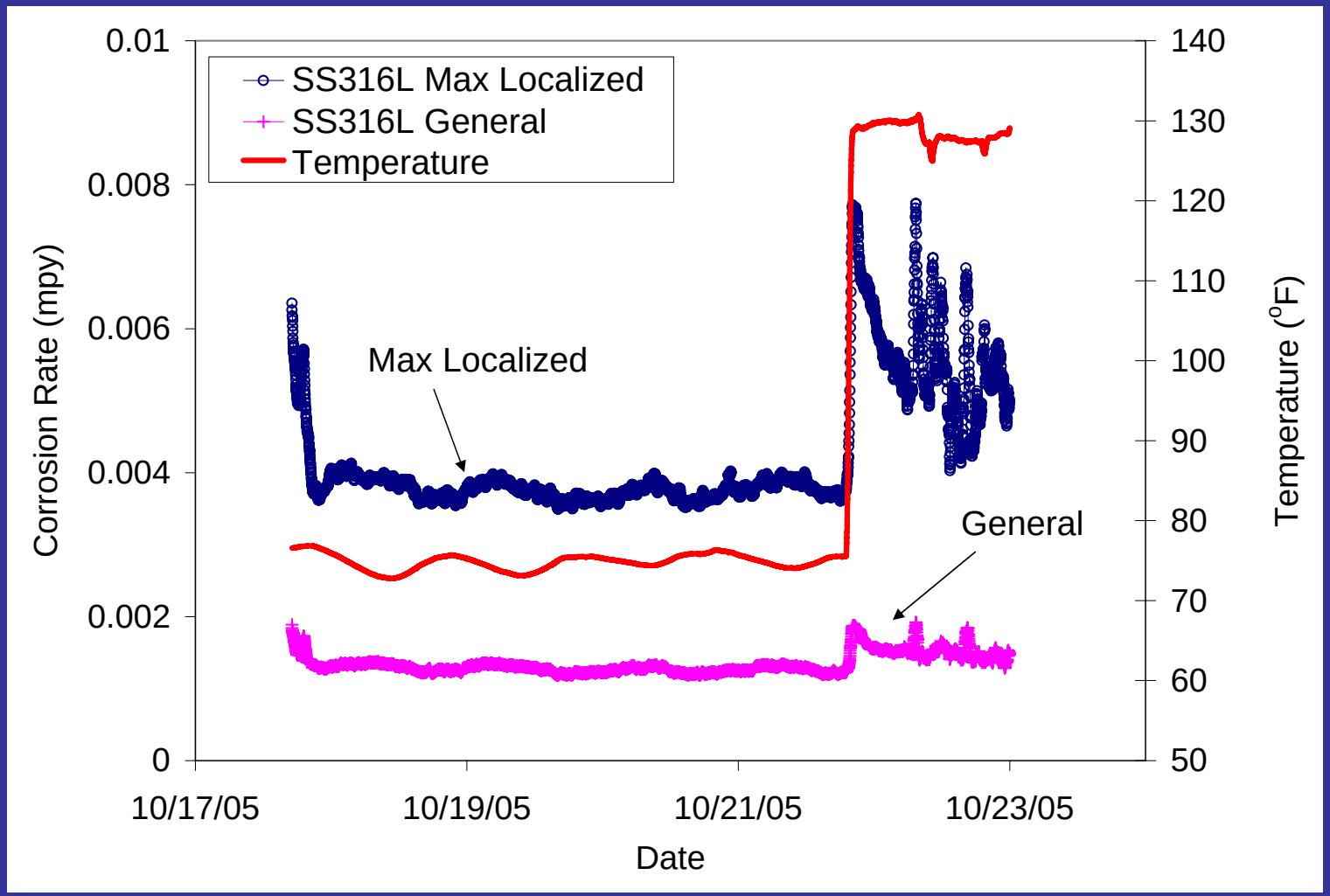
Transient Response of Localized and General Corrosion Rates for CS in High TDS / High Silica Water, Following Temperature Change



Transient Response of Localized and General Corrosion Rates for SS316L in High TDS / High Silica Water, Following Temperature Change



Transient Response of Localized and General Corrosion Rates for SS316L in High TDS / High Silica Water Following Temperature Change



Field Results with Silica Corrosion Inhibition Chemistry

- Carbon steel weight loss and Corrator general rates < 0.2 mpy
- Correction of carbon steel coupon mount bias shows rates below 0.02 mpy
- Copper weight loss rates < 0.1 mpy
- Localized rates low, but variable (bridging)
- Galvanized “white rust” mitigated

Silica Inhibitor Conclusions

- Rapid inhibitor film formation confirmed
- Excellent corrosion inhibitor at high TDS
- Excellent inhibitor at high temperatures
- Permits Al, Cu, Zn use at high pH (10)
- No scale at “ZLD” operation
- Permits reclaim / waste water use
- Provides “green” water chemistry and water use reduction to sustain the environment

Conclusions on Pilot Study Method

- Four years of field results corroborated
- Permits efficient (time/cost) evaluation of multiple metals, temperatures, and chemistry
- Immediate transient response to inhibition variables (temperature change)
- Reliable localized (pitting) rates, which is crucial to metal and inhibitor selection
- Field use will permit tracking of control responses to pH, Temp, TDS, Inhibitor, ect.