Improved Effectiveness of Corrosion Prevention and Control Systems for Hydraulic Steel Structures

Thomas Carlson

Materials Engineer

USACE – Champaign, IL

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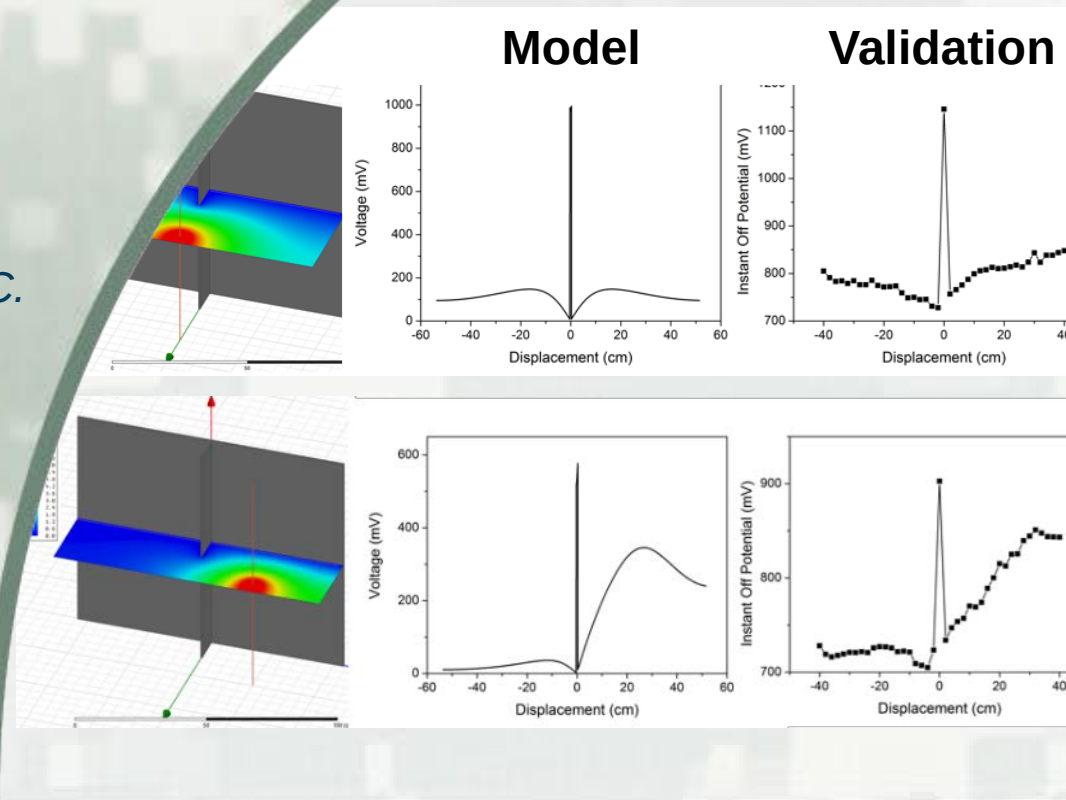

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Project Team

- ERDC-CERL
  - Michael McInerney – Project Manager and Electronics Research Engineer
  - Charles Marsh – Materials Engineer
  - Vincent Hock (USACE RAO) – Metallurgist and NACE Fellow
  - Jonathan Trovillion – Materials Engineer
  - Matthew Brenner – Physicist
  - Matthew Ziemann – Research Assistant
  - Jason Selling – Research Assistant
- USACE Mobile District
  - Anthony Perkins
  - Greg N. Hall
  - James Curry
- USBR
  - Jessica Torrey

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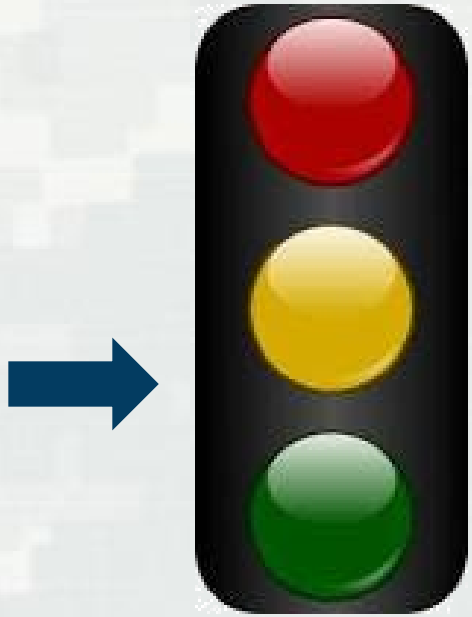
Project Objectives

Condition Assessment



Structural Health Monitoring (SHM) System

1. A better understanding of cathodic protection and coatings, and their interaction.
2. Development of integrated CPC monitoring system with predictive capability.
3. Holistic approach will provide an input to overall SHM system.

Big Payoffs!

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What is CPC?

Corrosion Prevention and Control

Material Selection

1. Steel
2. Stainless Steel
3. Polymer
4. Etc.

Cathodic Protection

1. Impressed Current
2. Sacrificial Anode

Coatings

1. Coal Tar Epoxy
2. Epoxy
3. Vinyl
4. Urethane

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"Why Do We Care?"

Economic

-565 million tons of freight valued at $214 billion (2012)

Water Resources Infrastructure

-Corps Navigation Mission:

Provide safe, reliable, efficient, effective and environmentally sustainable waterborne transportation systems for movement of commerce, national security needs, and recreation.

Cost

-$93,765,000 spent on corrosion M&R in FY15 (USACE)

-Reduced O&M costs

-Coastal Navigation

-Inland Navigation (12,000 miles of navigable waterways that touch 38 states)

Maintain National Assets

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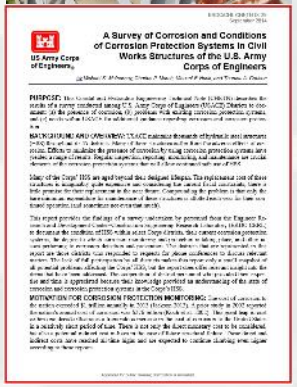
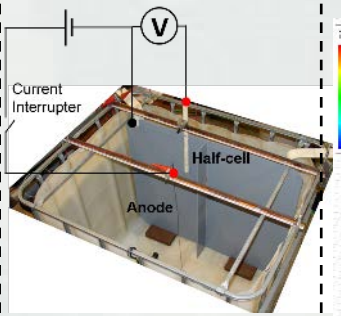
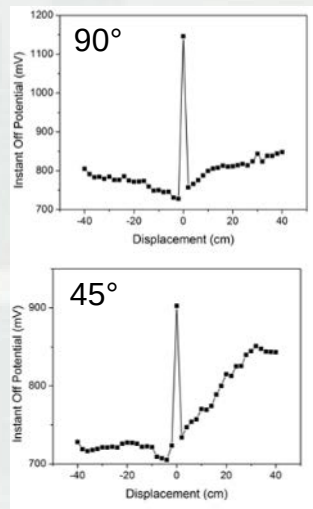
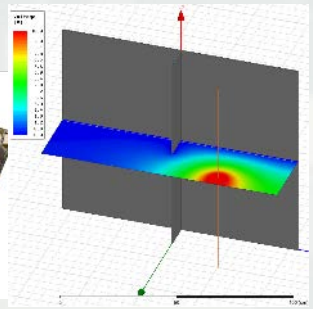
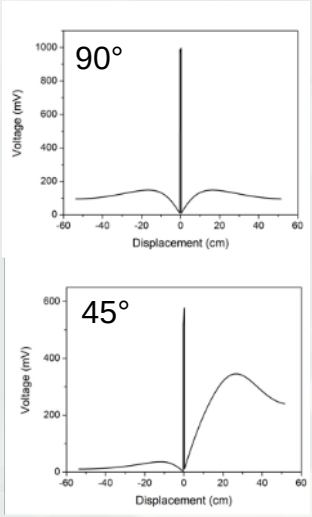
Project Overview

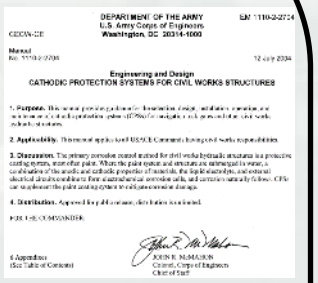


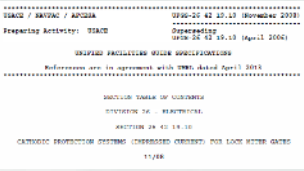




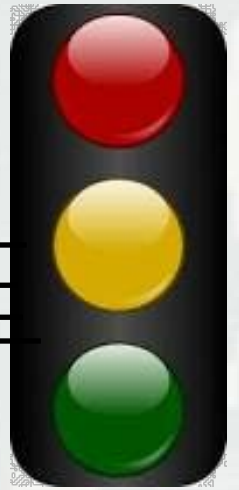








Structural Health Monitoring System



Other Inputs

Field Survey → Laboratory Research → Modeling → Data Acquisition & Analysis → Products & Guidance

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Field survey shows every square inch of the structure is not protected from corrosion.

Pintle socket during dewatering

Corrosion at Claiborne Lock due to inadequate CPC systems

Weld corrosion

Coating failure

Corrosion around socket bolts

Flame cut drain holes

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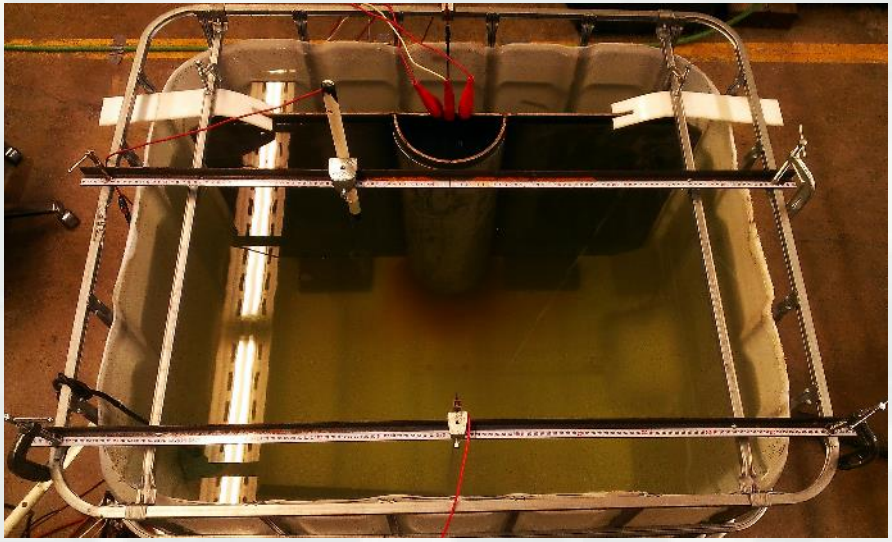
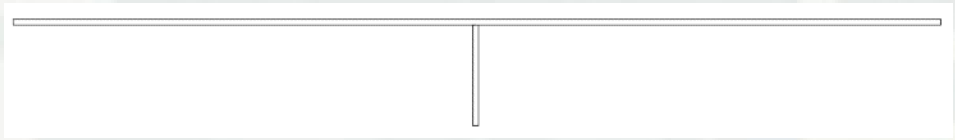
Laboratory Tests on Bare Steel Plates

Purpose: Use simple geometry in the lab to validate the modelling results.



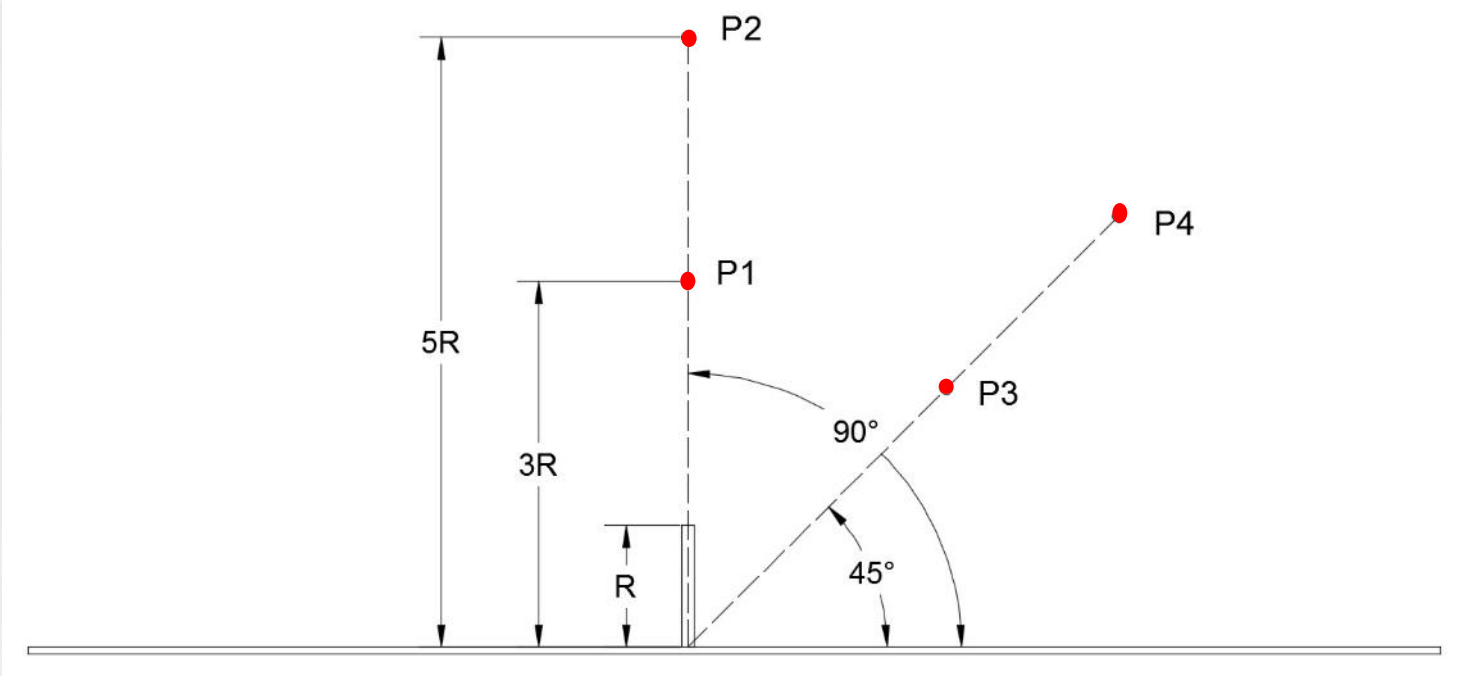


"T" Plate

Half Pipe

Measurements taken using half-cell probe:
-Native Potential
-Instant On
-Instant Off Potential (IOP)

Bare Steel “T” Plate Schematic



4 separate impressed current anode locations: P1, P2, P3, P4.

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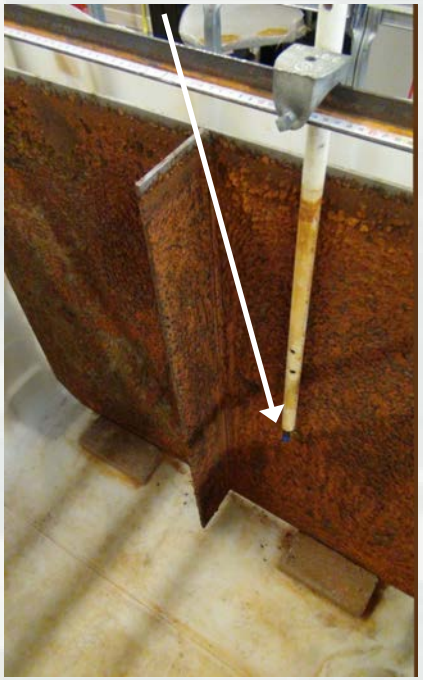
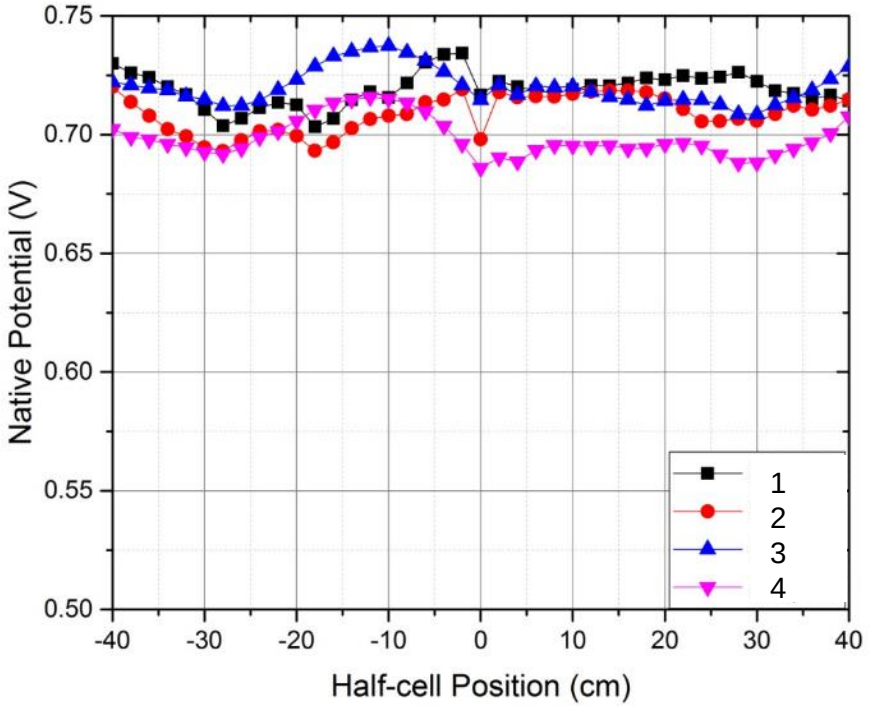
Native Potential of Bare Steel "T" Plate

Tip of Half-Cell

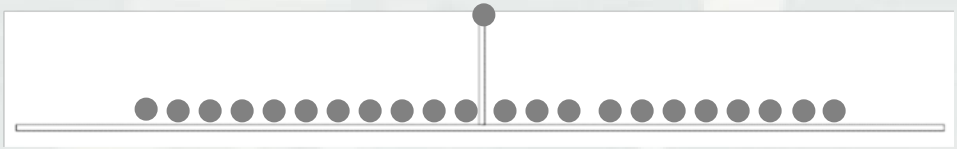


-Steel plate showing general corrosion and location of half-cell probe inside 280 gallon tank.



Average native potential of 720mV.

-Measurements taken after native potential stabilized.
-Cathodic protection is not active.



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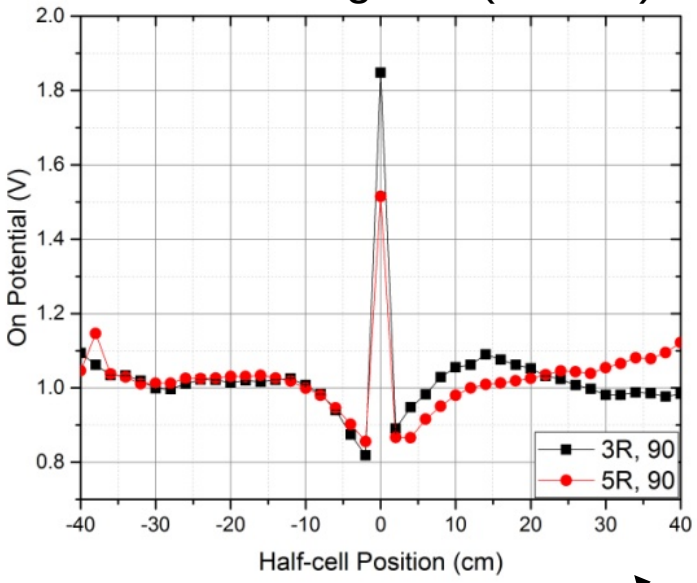
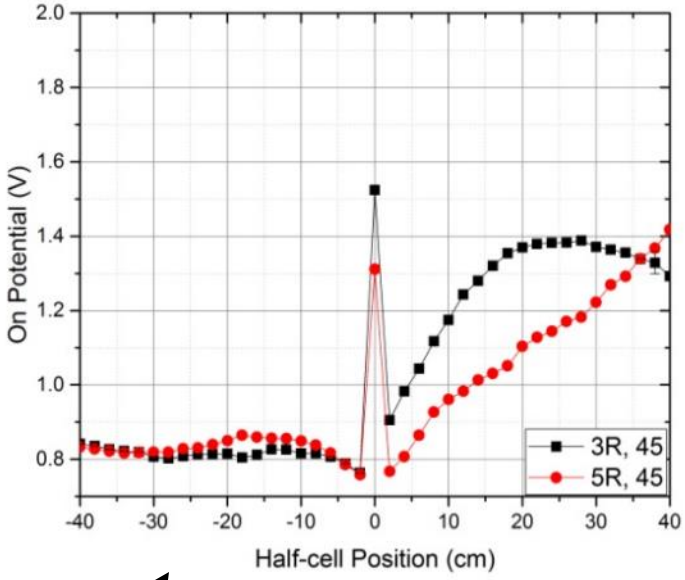
“On” Potential of Bare Steel “T” Plate

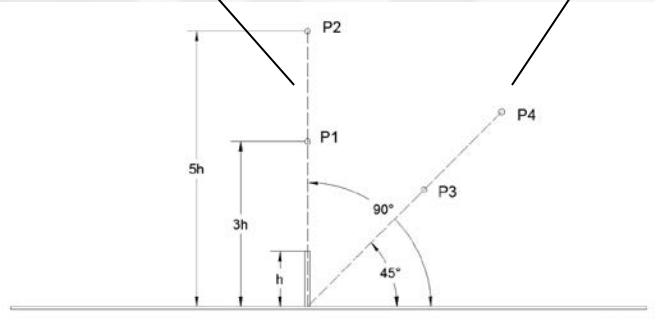
Anode at 90 degrees (P1, P2).



Anode at 45 degrees (P3, P4).



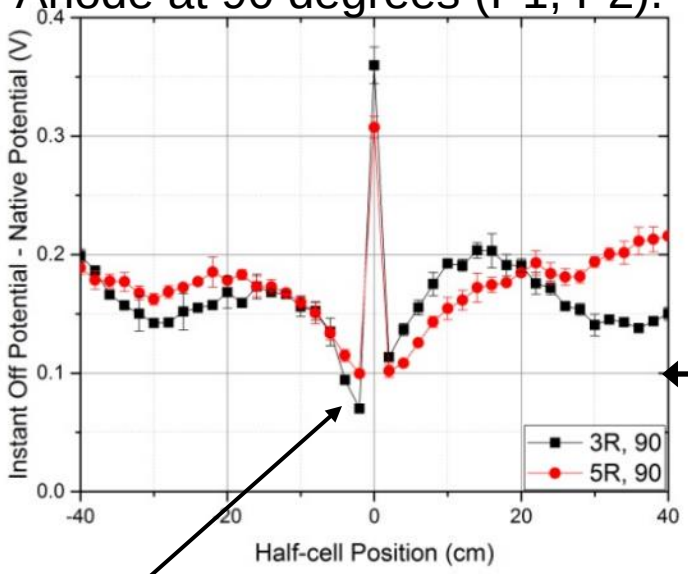
-DC potential was applied by mixed metal oxide anode with constant driving voltage of 20 VDC.



-Same half-cell measurement locations
-4 different anode locations (P1, P2, P3, P4)

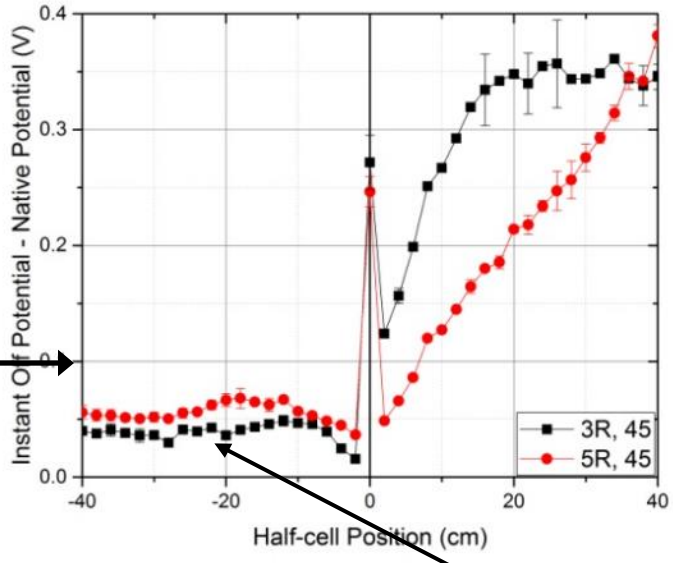
Polarization of Bare Steel “T” Plate

Anode at 90 degrees (P1, P2).



NACE 100mV Criteria

Anode at 45 degrees (P3, P4).



Reduced polarization region

Polarization = Instant Off Potential – Native Potential

Reduced polarization region

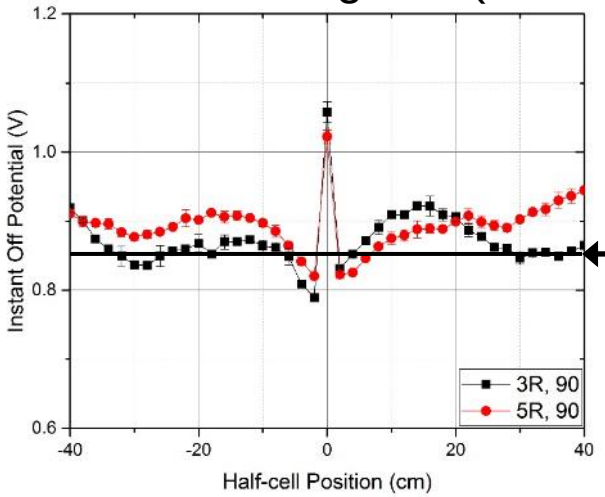
Results:

-Anode placement quantitatively shows an influence on the resulting surface polarization distribution.

-According to the 100 mV DC polarization criteria, it is shown that some locations are not protected.

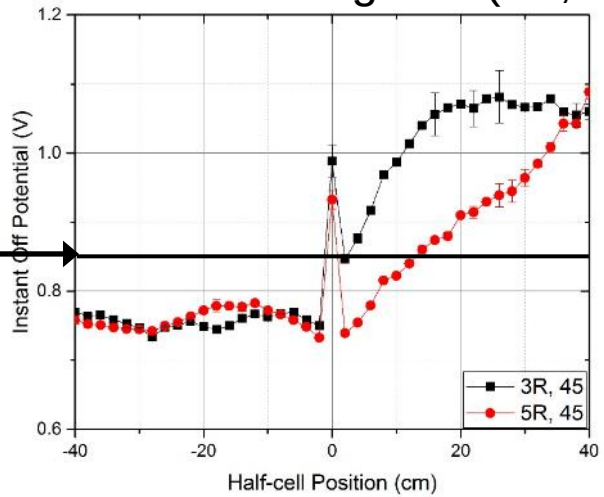
Comparison between experimental measurements and model for “T” plate

Anode at 90 degrees (P1, P2).



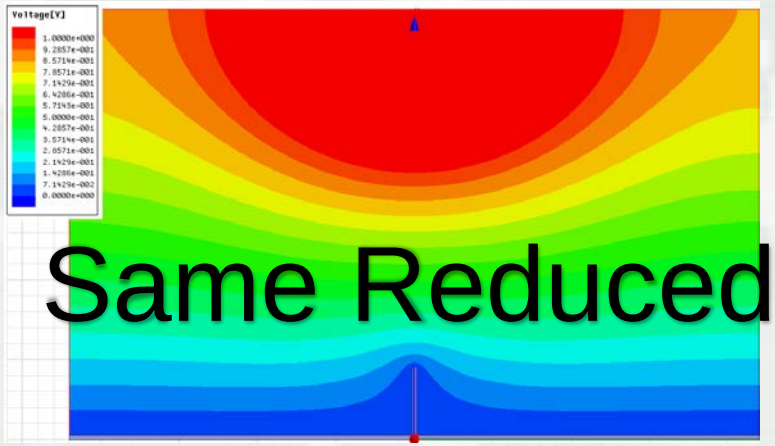
NACE 850mV Criteria

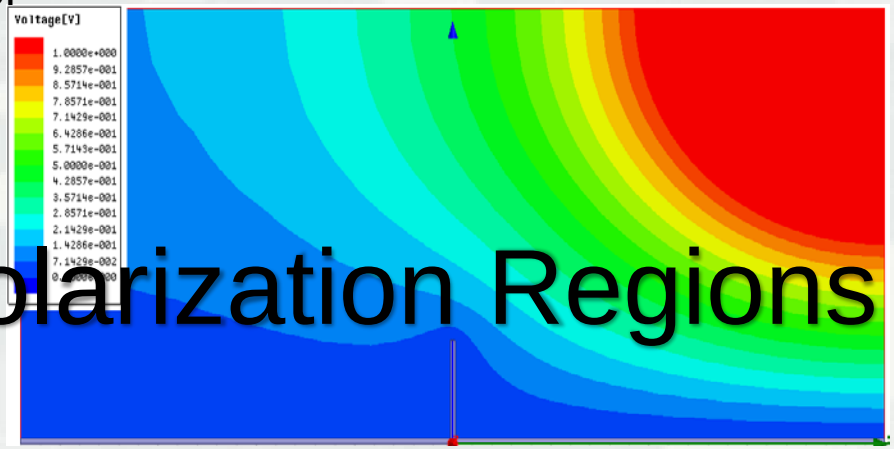
Anode at 45 degrees (P3, P4).



Measurements

Model

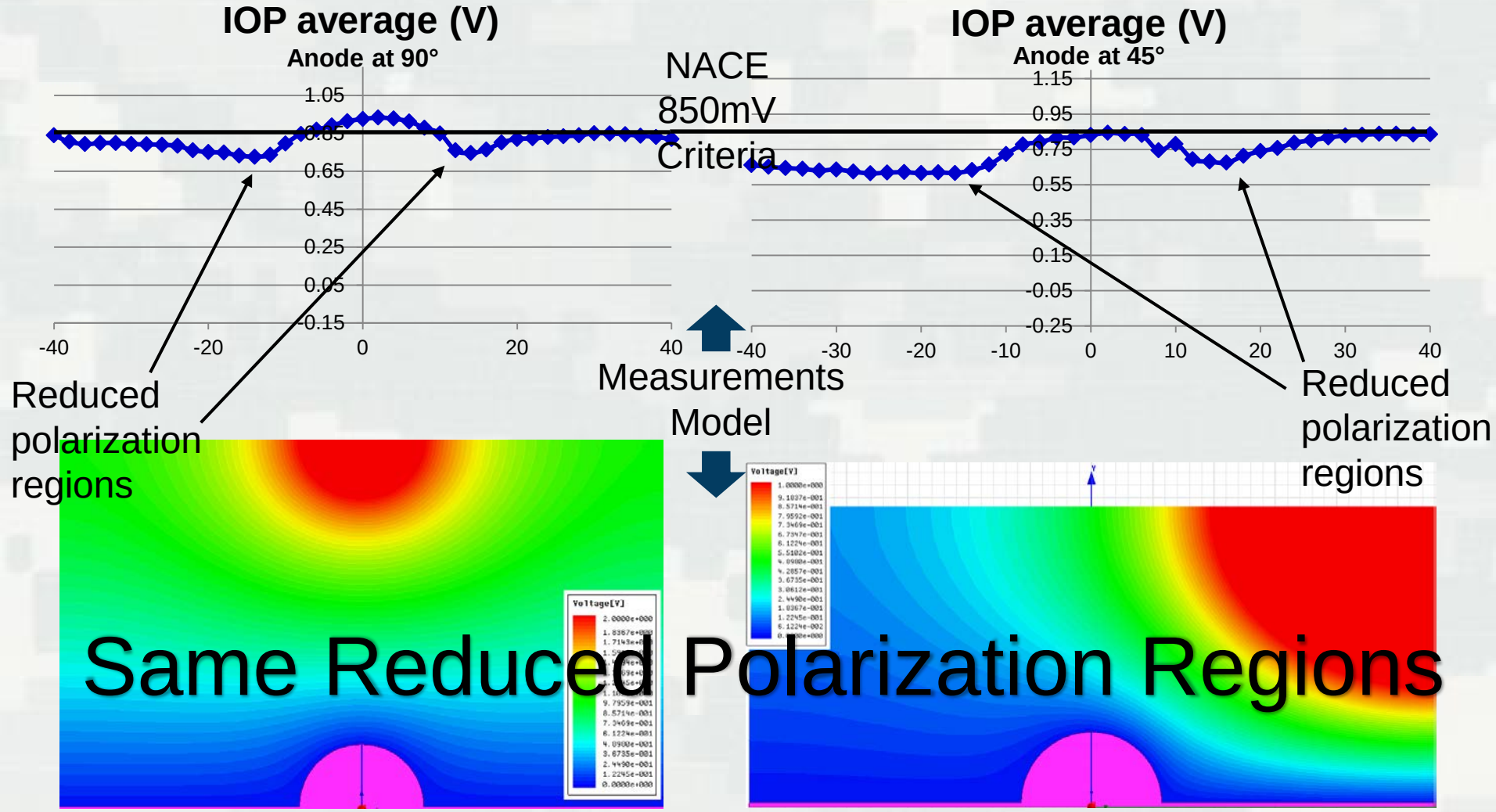




Same Reduced Polarization Regions

Models generated using ANSYS Maxwell electromagnetic field simulation software.

Comparison between experimental measurements and model for "half-pipe" plate



Models generated using ANSYS Maxwell electromagnetic field simulation software.

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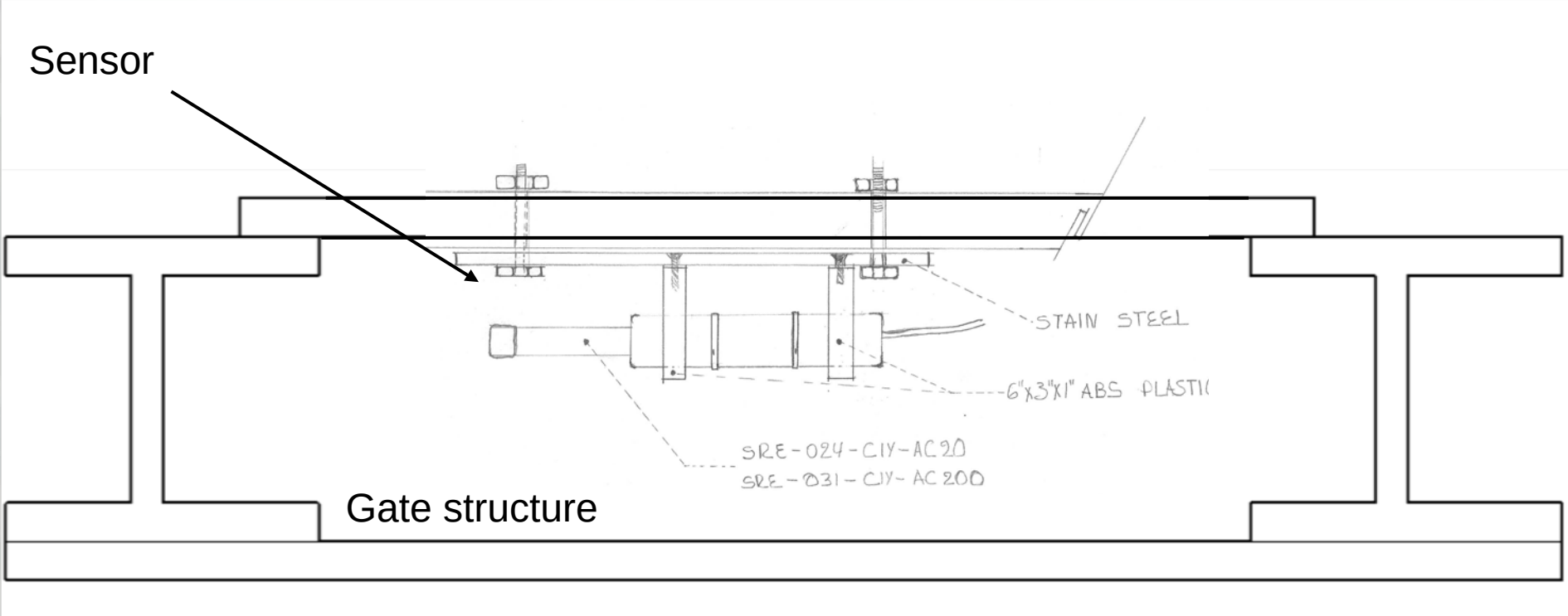
Research Takeaway

- Effective application of cathodic protection is dependent on
  - Anode placement
  - Geometric complexity
- May also require changes to structure geometry

Data Acquisition & Analysis



- A state of the art sensor with built-in coupons will measure native potential and CP current density on a gate structure.
- Working with a commercial firm to develop a sensor which will measure the CP effectiveness and coating degradation simultaneously
  - A new application for lock gates.

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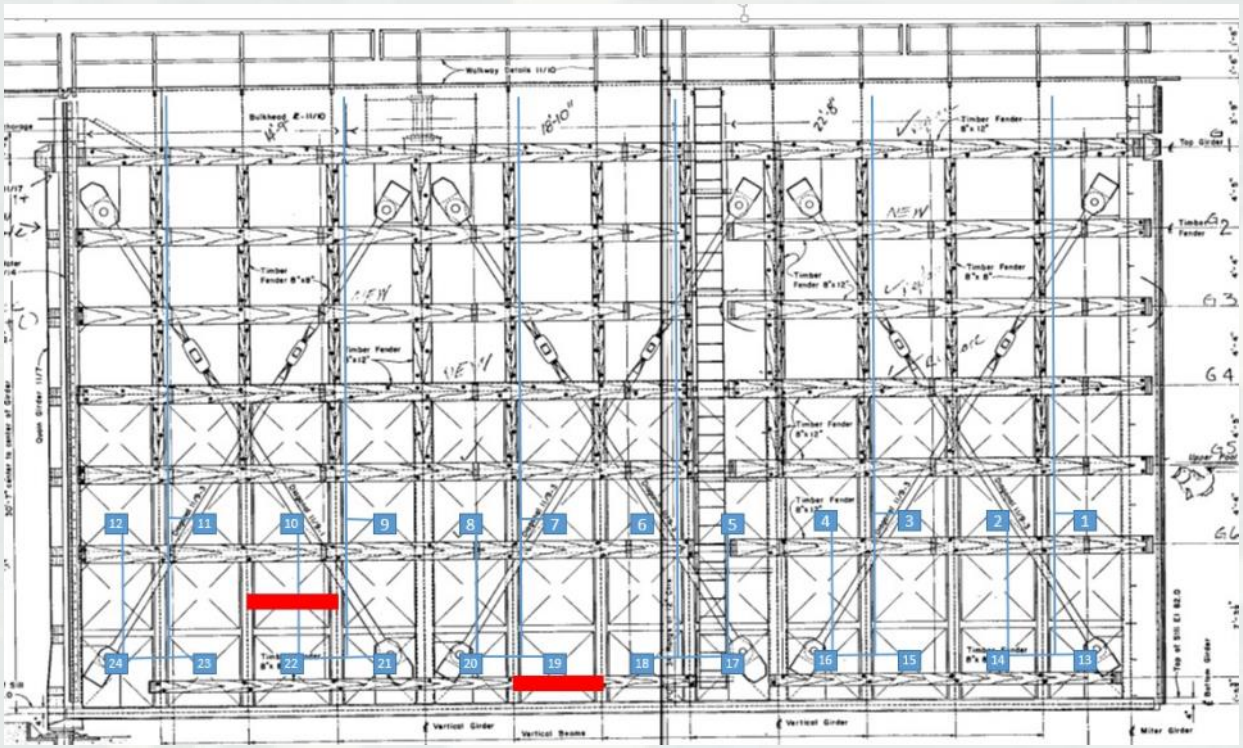
Field Demonstration at Selden Lock and Dam

Mobile District: Selden Lock and Dam on the Black Warrior River

Installation on upper gates while lower gates are replaced.



Sensor located between anodes and below water level.

-Using rugged test probes, the field site will provide opportunity for long term data acquisition and analysis of CP system performance.
-Will be the first time in many years a sensor will be installed on a lock gate to monitor rectifier voltages/currents, and anode currents.

Field Demonstration System Schematic

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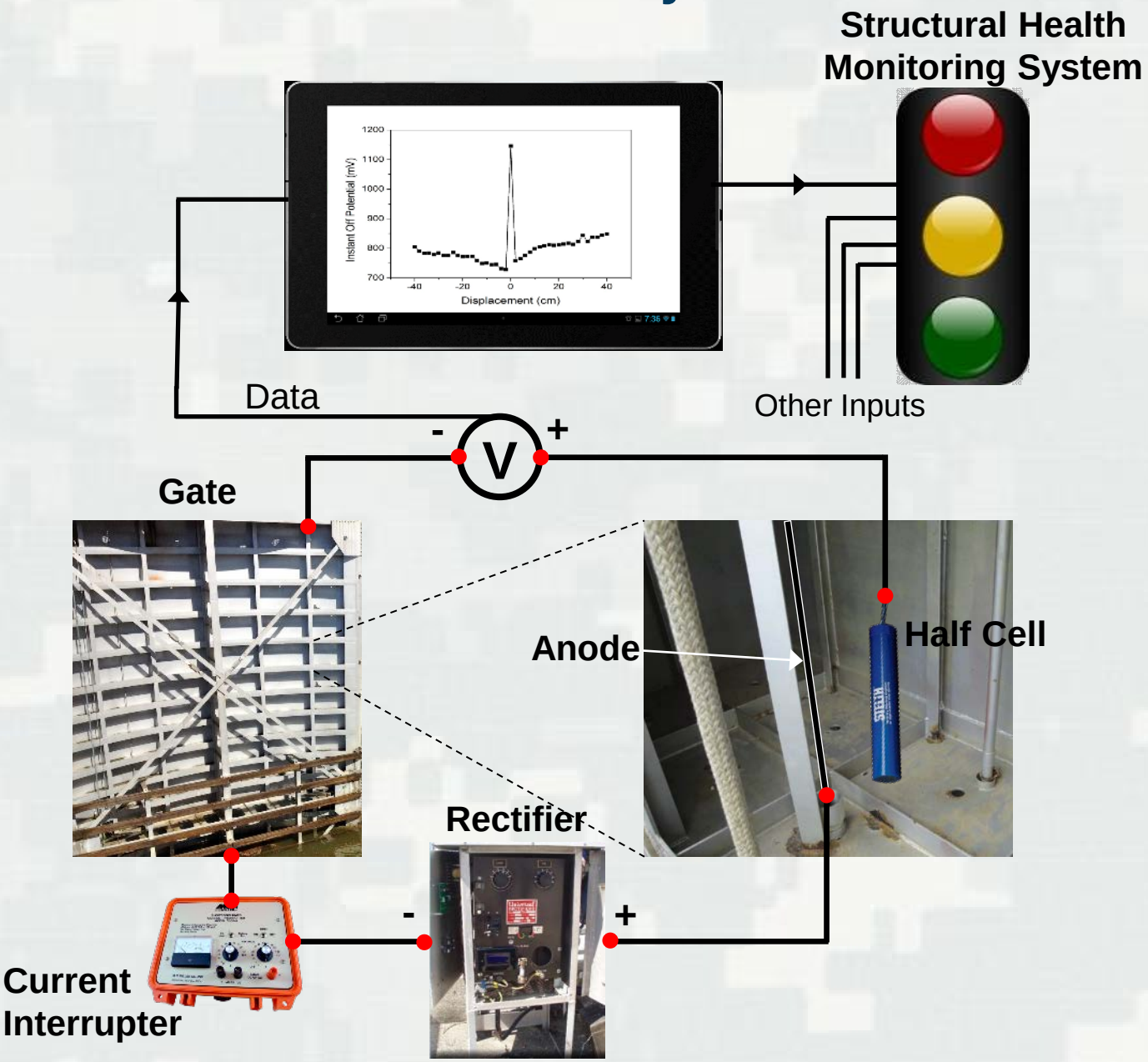

One part of the holistic approach to Structural Health Monitoring of HSS.

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Products & Guidance

Journal article: "Combined Structure Geometry and Anode Placement Effects on Cathodic Protection Effectiveness"

- Inspection procedures for both CP protected components and non-CP protected components
- System specifications
- Recommended updates to Corps of Engineers guidance documents such as EM 1110-2-2704
- Guidance for training

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EM 1110-2-2704

CECW-CE

Manual
No. 1110-2-2704

12 July 2004

Engineering and Design
CATHODIC PROTECTION SYSTEMS FOR CIVIL WORKS STRUCTURES

1. Purpose. This manual provides guidance for the selection, design, installation, operation, and maintenance of cathodic protection systems (CPSs) for navigation lock gates and other civil works hydraulic structures.

2. Applicability. This manual applies to all USACE Commands having civil works responsibilities.

3. Discussion. The primary corrosion control method for civil works hydraulic structures is a protective coating system, most often paint. Where the paint system and structure are submerged in water, a combination of the anodic and cathodic properties of materials, the liquid electrolyte, and external electrical circuits combine to form electrochemical corrosion cells, and corrosion naturally follows. CPSs can supplement the paint coating system to mitigate corrosion damage.

4. Distribution. Approved for public release; distribution is unlimited.

FOR THE COMMANDER:

JOHN R. McMAHON
Colonel, Corps of Engineers
Chief of Staff

6 Appendixes
(See Table of Contents)

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USACE / NAVFAC / AFCESA — UFGS-26 42 19.10 (November 2008)

Preparing Activity: USACE — Superseding UFGS-26 42 19.10 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2013
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SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 42 19.10

CATHODIC PROTECTION SYSTEMS (IMPRESSED CURRENT) FOR LOCK MITER GATES

11/08

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Conclusions

- Experiment and model provide insight into reduced polarization regions which influence the effectiveness of CP systems on complex structures.
- Field site data acquisition will confirm the presence of adequate or inadequate CP on a real gate with impress current CP.
- Updates to current guidance documents as well as other research results will be published.
- Improved effectiveness of CPC systems on hydraulic steel structures will help ensure that every square inch of the structure is cathodically protected.