BUREAU OF RECLAMATION

Demonstration of USACE Corrosion Protection System Inspection and Monitoring Advancements

Science and Technology Program
Research and Development Office
Final Report No. ST-2021-19283-01

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Reclamation has been collaborating with the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) since Fiscal Year (FY) 2013 on projects to improve corrosion inspections and corrosion protection and control systems on hydraulic steel structures. This project, funded from FY19-FY21, has facilitated continued collaboration, site demonstrations, and information exchange, and has allowed Reclamation input and access to the exciting tools and techniques that are being developed at USACE.</td></tr>
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Mission Statements

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Demonstration of USACE Corrosion Protection System Inspection and Monitoring Advancements

Final Report No. ST-2021-19283-01

prepared by

Technical Service Center
Materials and Corrosion Laboratory Group
Grace Weber, M.S., Materials Engineer

Cover Photo: United States Army Corps of Engineers and Bureau of Reclamation researchers inspecting a rectifier that is part of a remote cathodic protection monitoring system at Selden Lock and Dam (Photo credit: Reclamation).

Peer Review

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Research and Development Office
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Final Report ST-2021-19283-01

Demonstration of USACE Corrosion Protection System Inspection and Monitoring Advancements

GRACE WEBER Digitally signed by GRACE WEBER Date: 2021.09.24 08:33:17 -06'00'

Prepared by: Grace Weber
Materials Engineer, Materials and Corrosion Laboratory, 86-68540

CHRISTINE HENDERSON Digitally signed by CHRISTINE HENDERSON Date: 2021.09.24 09:50:08 -06'00'

Checked by: Chrissy Henderson, Ph.D.
Materials Engineer, Materials and Corrosion Laboratory, 86-68540

BOBBI JO MERTEN Digitally signed by BOBBI JO MERTEN Date: 2021.09.24 11:07:13 -06'00'

Technical Approval by: Bobbi Jo Merten, Ph.D.
Civil Engineer, Materials and Corrosion Laboratory, 86-68540

JESSICA TORREY Digitally signed by JESSICA TORREY Date: 2021.09.24 12:03:48 -06'00'

Peer Review by: Jessica Torrey, Ph.D., P.E.
Group Manager, Materials and Corrosion Laboratory, 86-68540

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Acronyms and Abbreviations

CP	Cathodic protection
CPC	Corrosion protection and control
ERDC	Engineer Research and Development Center
FY	Fiscal year
GACP	Galvanic anode cathodic protection
HSS	Hydraulic Steel Structures
ICCP	Impressed current cathodic protection
MIPR	Military Interdepartmental Purchase Request
R&D	Research and Development Office
Reclamation	Bureau of Reclamation
S&T	Science and technology
SMEs	Subject matter experts
TSC	Technical Service Center
USACE	United States Army Corps of Engineers

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Executive Summary

The Bureau of Reclamation (Reclamation) has been collaborating with the United States Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) since 2013 on projects to improve corrosion inspections and corrosion protection and control (CPC) systems on hydraulic steel structures (HSS).

From Fiscal Year (FY) 19 to FY21, this project has furthered the CPC collaboration between Reclamation and USACE by funding a variety of activities which were discussed at regular monthly collaboration team meetings. This has facilitated continued collaboration, site demonstrations, and information exchange, and has allowed Reclamation input and access to the exciting tools and techniques that are being developed at USACE. The following collaboration activity topics were included during this project period:

- Annual Reclamation-USACE Meetings Presentations
- Corrosion Control Remote Monitoring Systems
- Robotic Cathodic Protection (CP) Inspections
- Future Research Identification and Development
- Dual CP Proof of Concept
- Tank Ring Anode CP Optimization
- CP Remote Coupon Testing
- Corrosion Training and Outreach

The CPC collaboration was mutually beneficial in a variety of ways. Reclamation staff were able to travel to USACE sites to participate in installation and testing of novel CPC systems, which provided invaluable hands-on experience. Information shared at monthly collaboration meetings has been used to inform future investigations and improve best practices. And lastly, the collaboration has resulted in some new research projects, and the technologies and techniques that demonstrate advantageous outcomes may be considered for further adoption.

1. Introduction

1.1 Project Background and Motivation

Collaboration between the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) and Bureau of Reclamation (Reclamation) Technical Service Center (TSC) on corrosion protection and control (CPC) projects first began in late fiscal year (FY)13. Both Reclamation and USACE are charged with maintenance of hydraulic steel structures (HSS). Corrosion of HSS costs each agency millions of dollars each year in maintenance, repair, and replacement. Lack of available funding has caused critical infrastructure to fail to the point of being inoperable, a considerable risk to water availability and commerce transport. Thus, the main objective of the collaboration is to improve CPC methods on HSS using cathodic protection (CP).

The collaboration benefits each agency in a number of ways:

- Broader justification of need from researchers, field personnel, and managers from both agencies.
- Greater refinement of project goals and target solutions.
- More versatile CPC monitoring products because of each agency's different structures, CPC systems, service environments, and maintenance/inspection procedures.
- Shared expertise between each agency's team members in field equipment and techniques (e.g., Borin sensors and exothermic welding) through in-kind research partnerships.
- Greater access to each agency's published and shared respective needs reports, resulting in a broader distribution of solutions.

1.2 Previous Work

Reclamation researchers recently completed two conducting studies in collaboration with researchers at USACE titled "Corrosion Mitigation System Monitoring" (S&T 4108) and "Safe Underwater Corrosion Condition Assessment" (S&T 4279), in 2017 and 2018 respectively. More information and the final reports from these studies are available online through the Reclamation Research and Development Office (R&D) at the following links:

- https://www.usbr.gov/research/projects/detail.cfm?id=4108
- https://www.usbr.gov/research/projects/detail.cfm?id=4279

Another related Reclamation research project is titled "Impact of Specimen Geometry and Polarized Potential on Cathodic Disbondment Testing for Protective Coatings" (S&T 8100) which included testing of the same USACE coating system used in S&T 4279. More information and the final report are available online through Reclamation R&D at the following link:

- https://www.usbr.gov/research/projects/detail.cfm?id=8100

2. Summary of Collaboration Activities

This report documents the collaboration approach and activities from FY19 through FY21. During this time frame, the collaboration team functioned through regularly scheduled monthly meetings, with additional meetings scheduled as needed. The primary collaboration activities during this period are listed in the table below. Descriptions of each activity follow in the sections below.

Table 1.—CPC collaboration team primary activities from FY19 to FY21.

Collaboration Activity	Period of Activity
Annual Reclamation-USACE Meeting Presentations	FY19–21
Corrosion Control Remote Monitoring Systems	FY19–21
Robotic CP Inspections	FY19–21
Future Research Identification and Development	FY20–21
Dual CP Proof of Concept	FY20–21
Tank Ribbon Anode CP Optimization & Polysiloxane Study	FY20–21
CP Remote Coupon Testing	FY21
Corrosion Training and Outreach	FY21

2.1 Annual Reclamation-USACE Meeting Presentations

Each year, Reclamation and USACE meet to discuss progress achieved under the Collaborative Research Team's charter and identify opportunities for continued improvement. At each annual meeting, CPC collaboration team members have the opportunity to co-present on the collaboration progress and any specific topics of interest from that year.

In December 2018, the annual meeting was held in Denver, CO. The CPC collaboration team co-presented on two topics: "CPC System Optimization & Next Generation" and "Underwater Corrosion Assessment."

In December 2019, the annual meeting was held in Vicksburg, MS. The CPC collaboration team co-presented on "Improved Effectiveness of Corrosion Prevention and Control Systems (Corrosion Mitigation System Monitoring)."

In December 2020, the annual meeting was held virtually and facilitated by Reclamation due to COVID-19 travel restrictions. The CPC collaboration team co-presented on "CPC System Optimization Overview."

Presentation slides are included in Appendix A. The CPC collaboration team will continue to attend annual meetings and co-present on the CPC collaboration progress, outcomes, and needs.

2.2 Corrosion Control Remote Monitoring Systems

Remote monitoring systems allow for automated collection of cathodic protection testing data at regular intervals, with data being available online. This can allow staff to review the data remotely and determine if the system is operating properly, which can reduce the number of inspection and testing trips required. Because of the potential benefits, this topic is a great area of interest for the collaboration team.

Selden Lock and Dam Site Visit

In June 2019, two Reclamation team members traveled to Selden Lock and Dam in Alabama to receive training from USACE staff on the remote corrosion control monitoring system present at that site. The team members were able to look at the CP system components and observe testing. Trip photographs can be accessed as described hereinafter in the "Supporting Data Sets" section.

Notably, USACE corrosion staff had an improved method for testing ON and Instant OFF potentials on the gate using the following equipment:

1. GPS-synchronized current interrupters
2. iBTVM Bluetooth voltmeter, Android (MC Miller)
3. Magnum enclosed test reel with submersible adapter (MC Miller)

The Bluetooth voltmeter works with an app on an Android phone or tablet. Using the "Single Read" feature, the app can log datapoints by tapping the screen for each ON and Instant OFF potential. These datapoints are automatically added to a list of data which can be saved as a .csv file and imported into Excel for graphing and analysis purposes. This method should be investigated for future use by Reclamation to test gate CP systems.

Cape Canaveral Site Visit

In February 2020, a Reclamation team member was present at a USACE cathodic protection installation at Canaveral Lock in Cape Canaveral, Florida. The system was being retroactively installed on the gates and frames of an existing lock structure using state-of-the-art anodes, rectifiers, and remote monitoring systems.

Further details are included in the travel report, TM-8540-2020-34 (Appendix B).

Borin Data Center

In June 2020, USACE corrosion staff provided a training to Reclamation staff on use of the Borin Data Center for corrosion control remote monitoring. After the training, Reclamation staff were provided with a login and administrative access to the USACE Borin Cloud data. Reclamation staff were able to review the remote CP data and to assist USACE corrosion staff with data processing from the remote Borin monitoring systems.

One of the standing goals of this collaboration activity is to improve data processing workflows so that data spreadsheets can be quickly converted into a graphic format that is easily interpretable by facility operators and maintenance staff. From FY20–21, Reclamation corrosion staff tested the use of PowerApps and Power BI as a data processing tool. These apps offered an advantage over using Microsoft Excel alone because of their ability to continually pull data from a chosen file location and run the same analysis. Future work in this area is needed to refine the PowerApps and Power BI tool so that it can more easily be used for a variety of corrosion control remote monitoring sites.

One takeaway by Reclamation team members based on USACE experience was that the Borin Data Center website and access was not user-friendly. If possible, it would be preferable to use different remote monitoring equipment and software to avoid dependence on Borin Cloud for access to the monitoring data.

2.3 Robotic CP Inspections

Robotic CP inspections are an area of interest for the collaboration team because of the potential benefit to improve safety of CP inspections on underwater or otherwise inaccessible features. The inspection robots would be either remotely operated or fully automated to allow corrosion inspections, CP testing, and other kinds of condition testing (such as ultrasonic thickness) to be performed without putting Reclamation employees into potentially dangerous work environments.

Due to lack of funding, robotic CP inspections were not further investigated during the period of operation for this project. However, the topic remains an area of interest for both USACE and Reclamation. Upcoming USACE funding may allow robotic CP inspection research and investigations to move forward. Reclamation corrosion staff should remain involved and continue to seek out updates on the status of any work performed by USACE in this area.

2.4 Future Research Identification and Development

As part of the CPC collaboration, Reclamation corrosion staff have included USACE corrosion staff as partners and team members in their Reclamation Science and Technology (S&T) Program proposals. Having USACE subject matter experts (SMEs) with interest and stake in the projects strengthens the proposals, especially when the SMEs can contribute in-kind work or direct assistance. The collaboration team members also help to define a proposed scope of work that will benefit both agencies.

In FY20, Reclamation corrosion staff submitted three FY21 research proposals with CPC topics to the S&T Program, none of which received funding:

- Advanced Cathodic Protection System Technology Demonstration (otherwise referred to as "Alternative Energy for Remote CP" in collaboration monthly meeting agendas)
- Engineering and Maintenance for CP Systems Coupled with Vinyl Coatings
- Improving Coating Evaluations for Vinyl Zinc-Rich Systems Based on Impedance Spectroscopy Data

In FY21, Reclamation corrosion staff submitted three FY22 research proposals with CPC topics to the S&T Program, with funding decisions still pending:

- Engineering and Maintenance for CP Systems Coupled with Vinyl Coatings (resubmitted)

- Determining compatibility of Zinc Anodes for CP in Various Waters Specific to Reclamation and USACE Facilities: Phase II
- Modular Anode Sled Development and Testing for CP of Immersed Steel Structures

2.5 Dual Cathodic Protection Proof of Concept

USACE is currently conducting a proof-of-concept study for dual CP, which utilizes both impressed current CP (ICCP) and galvanic CP (GACP) in a single system. Although USACE does not typically design for these systems, USACE corrosion staff have recently identified a number of existing structures with hybrid systems. This study will determine the effects of combining ICCP and GACP in a single system, as well as the use of remote monitoring for hybrid systems.

Reclamation provided feedback to USACE researchers on the research plan and initial results and implementation. And in late FY21, Reclamation and USACE began discussion for a Military Interdepartmental Purchase Request (MIPR) that would provide funds for additional Reclamation assistance on the USACE dual CP research.

2.6 Tank Ribbon Anode CP Optimization & Polysiloxane Study

Reclamation has an ongoing conducting study, "Advancement of Cathodic Protection Monitoring and Control for Water Storage Tanks," that investigates a new approach of using ribbon anodes in circular rings to provide CP for small scale water storage tanks. The use of ribbon anodes in the shape of a ring to protect tanks is novel to Reclamation and differs from the typical design of rod anodes hung in a circular configuration.

During FY21, researchers have constructed a full-scale model of a water storage tank and have begun to prepare the tank for testing, which will occur in FY22. The goal of the project is to investigate different ribbon anode positions to determine the optimal anode configuration to achieve appropriate polarization. Polarization will be determined by measuring the structure's polarized potential (instant OFF) using six coupons distributed within the interior of the tank. A secondary goal for this study is to examine the use of polysiloxane coatings under immersed conditions with bare ribbon anodes within an inch of the coating surface. Cathodic disbondment and coating performance in these conditions will be evaluated.

The topic of ribbon anodes for tank CP was discussed during the monthly collaboration meetings and USACE provided input on the project's experimental design, as well as passed on information about USACE CP designs for water tanks to the project's principal investigator.

More information on this ongoing study is available online through Reclamation R&D at the following link:

- https://www.usbr.gov/research/projects/detail.cfm?id=20023

2.7 CP Remote Coupon Testing

Remote coupon testing is a technique used on direct-connect CP systems to obtain instant-OFF potentials, which can otherwise not be obtained from this kind of CP system. Often, Reclamation uses solely visual inspection of direct-connect CP systems to determine if they are functioning appropriately and providing adequate protection to the structure. This method offers a quantitative rather than qualitative approach to direct-connect CP inspection. The test methodology is described in NACE standard SP0104-2014.[1]

During the collaboration project, Reclamation and USACE shared knowledge regarding each agency's use of the technique and its effectiveness. A USACE corrosion staff member utilized the technique with success at a facility in New Orleans District as part of a close interval remote coupon and reference cell survey to determine whether the structure in question was being adequately protected by a direct-connect CP system. In early FY21, a Reclamation corrosion staff member utilized the technique during a direct-connect CP inspection of a drain pipe at Reclamation's Marble Bluff Dam. USACE and Reclamation corrosion staff will continue to share information regarding use of the testing technique to remain updated on best practices for corrosion and CP inspections.

2.8 Corrosion Training and Outreach

In late FY21, Reclamation corrosion staff helped to develop virtual course materials for the USACE PROSPECT Corrosion Course. The course was held in August 2021, and several Reclamation members presented as guest instructors through funding provided by a USACE MIPR.

Reclamation's involvement in the USACE virtual training course was only possible through the maintenance of the CPC collaboration leading up to the training. Reclamation was given the opportunity to participate due to relationships with key USACE corrosion staff members. USACE staff were aware of Reclamation's newly developed virtual corrosion course, and this virtual content (presentation slides and training videos) was used while in the USACE virtual corrosion course.

Reclamation's participation in the training course also had an added benefit of broadening the course content. The Corrosion Control and Cathodic Protection Systems Technical Center of Expertise[2] in USACE Mobile District primarily focuses on CP systems for inland waterways and related structures. Reclamation TSC has expertise on CP for other structures such as pipelines, water tanks, and other associated metalwork, which are relevant to some of the clients and regional contacts who attended the training. By co-teaching the course, the CPC collaboration team was able to broaden the scope of what was provided to the attendees. Sharing the course resources between each agency was also mutually beneficial to share information and expertise, allowing the best outcomes for each agency.

3. Conclusions and Next Steps

The CPC collaboration between Reclamation and USACE has benefitted both agencies in a variety of ways, including greater refinement of project goals, sharing of expertise, and broader distribution of solutions. Through regular monthly meetings, the collaboration team discussed and shared information on each agency's CPC activities. This information sharing furthered Reclamation's CPC knowledge, particularly in corrosion control remote monitoring systems, which are not typically used at Reclamation facilities. This and the other collaboration topics will continue to be investigated as a means of improving Reclamation's best practices in corrosion mitigation and condition monitoring.

Additionally, through the relationships formed in the collaboration, Reclamation corrosion staff were given the opportunity to travel to USACE sites to observe and participate in CPC installations and testing. This hands-on experience was invaluable and gave Reclamation staff insight into novel CPC techniques that may be useful at Reclamation facilities. Reclamation corrosion staff were also able to assist with development of a USACE virtual training course, and the success of the course has encouraged further collaboration between the two agencies in future corrosion trainings.

Some research activities discussed as part of the collaboration are ongoing, including a USACE investigation of robotic CP inspections and dual CP proof of concept study, and a Reclamation tank CP optimization study. Reclamation corrosion staff will continue to request updates on the ongoing USACE research topics. Non-advantageous research outcomes by USACE will still provide benefit to Reclamation by providing awareness of areas that do not need further investigation without money spent to reach that conclusion. And if the ongoing USACE CPC research projects demonstrate advantageous outcomes, these technologies and techniques may be considered for further adoption by Reclamation.

Supporting Data Sets

Additional files associated with this project can be accessed as described below:

- File path: T:\Jobs\DO_NonFeature\Science and Technology\2019-PRG-Demo of USACE Cathodic Protection Advancements
- Point of Contact: Grace Weber, gweber@usbr.gov, 303-445-2327
- Short description of the data: Files primarily include email correspondences, remote monitoring datasheets, site visit photographs, and collaboration meeting agendas.
- Keywords: corrosion protection and control, U.S. Army Corps of Engineers (USACE), cathodic protection, corrosion inspection
- Approximate total size of all files: 216 Files, 15 Folders, 935 MB

References

1. NACE SP0104 (2014), "The Use of Coupons for Cathodic Protection Monitoring Applications" (Houston, TX: NACE International).

2. "Corrosion Control and Cathodic Protection Systems." *Mobile District Website*, US Army Corps of Engineers, www.sam.usace.army.mil/Missions/Military-Missions/Engineering/Corrosion-Control-and-Cathodic-Protection-Systems/. Accessed 09/13/2021.

Appendix A—Annual Meeting Presentations

Improved Effectiveness of Corrosion Prevention and Control Systems

(Corrosion Mitigation System Monitoring)

Progress Review / Project Status Brief

11/28/2018

1

Improved Effectiveness of CPC Systems

Overview

- Jessica Torrey (Reclamation) and Michael McInerney (USACE)
- Effort Initiation date: late FY13
- Problem: Corrosion of hydraulic steel structures (HSS) costs each agency $Millions$ every year in maintenance, repair, and replacement
- Collaboration: formed after Tech Exchange meeting and from introductions by mutual collaborators; funded by S&T Program and MIPR (Reclamation) and XXXX (USACE)
- Tech Transfer: Reclamation will specifically follow USACE work at Selden for potential implementation on Reclamation gates
- Other collaborators:
  - ERDC-CERL
  - Corps Districts (Mobile, Rock Island, Louisville, Huntington, Nashville)
  - Reclamation Hydraulics Lab (test gate)

2

2

Improved Effectiveness of CPC Systems
Collaboration Approach and Activities

- FY18 Collaboration Activities:
  - USBR team members will travel to Selden Dam for training on CP monitoring system
  - Continue to share designs, specs, drawings, product info, etc. in support of pilot testing programs
  - Continue to work together on data analysis and interpretation, and model development
  - Bi-weekly conference calls
- FY19 Collaboration Activities:
  - Final report collaboration
  - Bi-weekly conference calls (as funding allows)

Sensors installed on gate at Selden Lock



Fiscal Year	USACE	USBR	Other Sources
Pre-2018 (sum)		$174k	
2018		carry-over	
2019		carry-over*	

* Reclamation proposal to continue collaboration was not funded for FY19; carryover funding supports final report preparation and closeout

3

3

Improved Effectiveness of CPC Systems
Benefits and Added Value

- Broader justification of need from researchers, field personnel, and managers from both agencies
  - Helps to refine goals of projects and target solutions
  - Agencies each published and shared respective needs reports
- Input from both agencies should make the CPC monitoring product more versatile- each agency has slightly different structures, CPC systems, service environments, and maintenance/inspection procedures
  - Results in broader distribution of solutions
- Team members are able to share expertise between agencies in field equipment and techniques (ex. Borin sensors and exothermic welding)

USBR test gate fabrication, installation, and testing

4

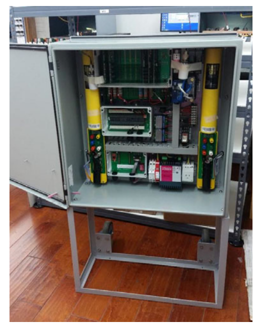
4

Improved Effectiveness of CPC Systems

Issues or Help Required

- Continue to make PIs aware of other funded projects that could assist with the outcome of this work

Remote monitoring unit at Selden Lock



5

5

Corrosion and Coatings Thickness Assessment for Above and Below-Water Metal Structures (USBR: Underwater Corrosion Condition Assessment)

Progress Review / Project Status Brief

Jessica Torrey and Richard Brown

11/28/2018

1

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment
Overview

- Jessica Torrey (USBR) and Jim Evans (USACE)
- Effort Initiation date: FY16
- Problem: Hydraulic Steel Structures (HSS) are susceptible to protective coating loss and corrosion, and many lack sufficient access for periodic condition assessment. There is significant need for a HSS inspection tool that can improve inspection area coverage, reduce inspection subjectivity and minimize risk to human life.
- Collaboration: formed after Tech Exchange meeting and from introductions by mutual collaborators
- Tech Transfer: Reclamation will specifically follow USACE work on crawler for potential implementation
- Other collaborators:
  - CERL
  - Navy
  - Phil Sauser

2

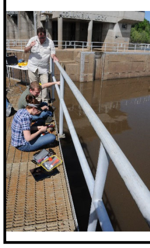
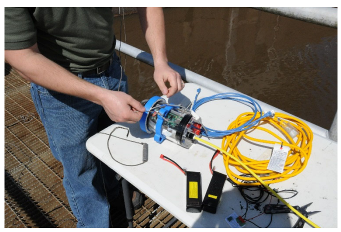
Underwater Corrosion and Anti-Corrosion Coating Condition Assessment

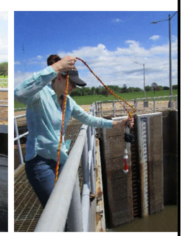
Approach and Activities

- FY18 Activities:
  - Webex from Diakont and potential demonstration of their underwater tank inspection system
- FY19 Collaboration Activities:
  - Final report collaboration

Fiscal Year	USACE	USBR	Other Sources
Pre-2018 (sum)	$800k	$110k	
2018	$400k	$51.5k	
2019	$0	carry-over*	

* Reclamation proposal to continue collaboration was not funded for FY19; carryover funding supports final report preparation and closeout



3

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment

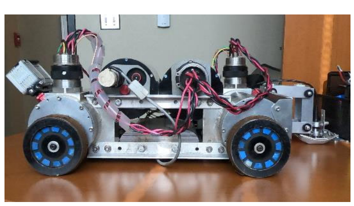
Benefits and Added Value

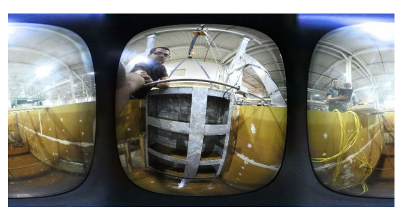
- Each agency brings unique expertise-
  - Reclamation has experts in corrosion and corrosion inspection using conventional tools
  - USACE has experts in instrumentation and prototype development

Robotic Crawler Camera

Underwater Camera Imaging and Corrosion Analysis

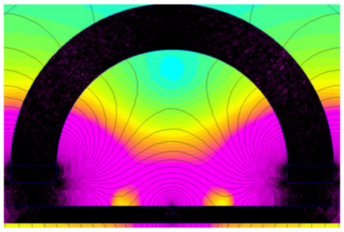
Full Size Robotic Crawler





4

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment
Benefits and Added Value


Magnetic Flux Bridge Simulation

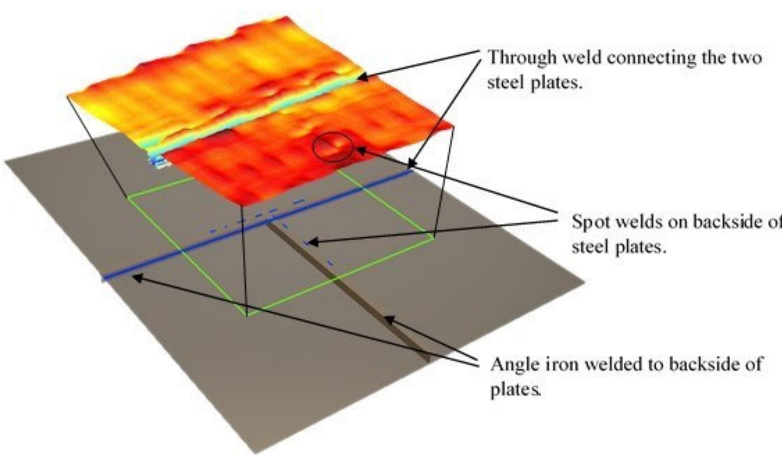

Protective Coating Thickness Measurement Probe


Magnetic Flux Bridge


Magnetic Flux Sensor Array

5

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment
Benefits and Added Value



Magnetic Flux Leakage Scan of Test Specimen

6

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment

Benefits and Added Value

- https://www.youtube.com/watch?v=O65Xb7LHM7E

Magnetic Flux Leakage Scan of Test Specimen

7

Underwater Corrosion and Anti-Corrosion Coating Condition Assessment

Issues or Help Required

- Reclamation: None identified. Reclamation PI hopes to close out project by December 2018 and no further collaboration has been funded.

8

CPC System Optimization
Overview

Grace Weber (USBR) and Dr. Rebekah Wilson (USACE)

FY 13 Collaboration Initiation

The USBR and USACE are charged with maintenance of hydraulic steel structures. Lack of available funding has caused critical infrastructure to fail to the point of being inoperable, a considerable risk to water availability and commerce transport.

Objective: To improve Corrosion Prevention and Control (CPC) methods on HSS through CP

US Army Corps of Engineers
Mobile District

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

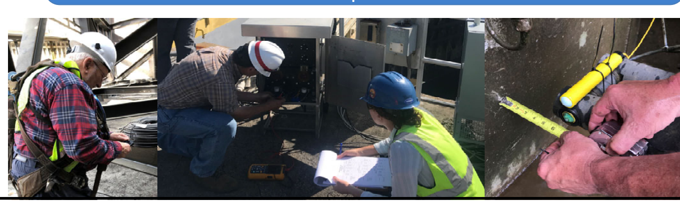
1

CPC System Optimization
Collaboration Approach and Activities FY20

USBR
- Field Support to Develop & Install CP System
- R&D Proposals

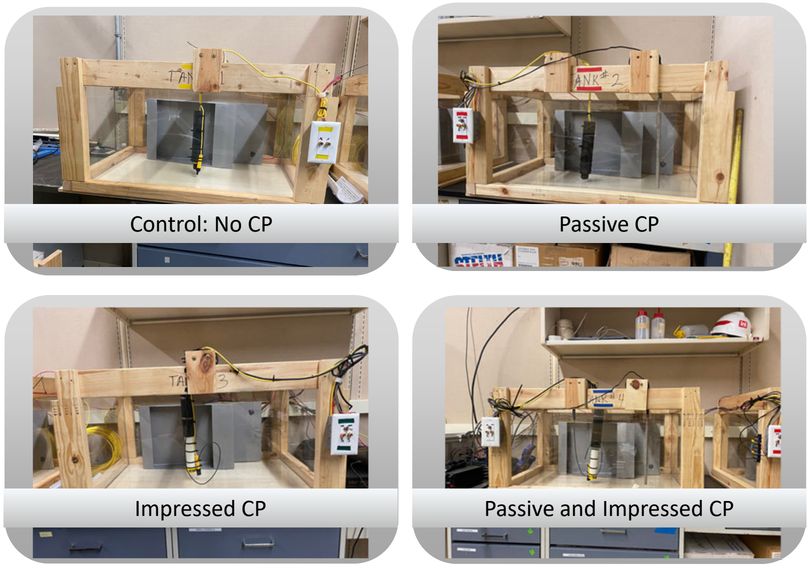
USACE
- R&D Dual CP Proof of Concept & Remote Monitoring
- Field Support to Develop & Install CP System

Presence at CP installations (Selden and Cape Canaveral), Regular Collaboration Meetings, Collaboration Team in Proposals



2

Experimental Set Up



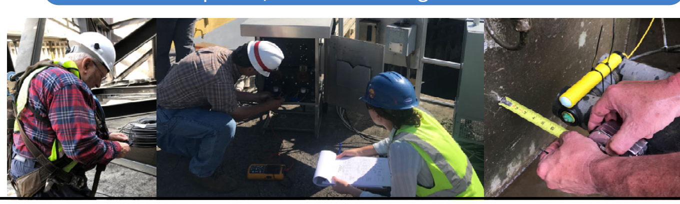
3

CPC System Optimization

Collaboration Approach and Activities FY21

USBR	USACE
Field Support to Develop & Install CP System	R&D Dual CP Proof of Concept & Remote Monitoring
R&D Proposals	CP R&D Dual CP Proof & System Monitoring

Continued Presence at CP installations (Selden and Cape Canaveral), Regular Collaboration Meetings, Collaboration Team in Proposals, Data Processing of Field and Lab Data

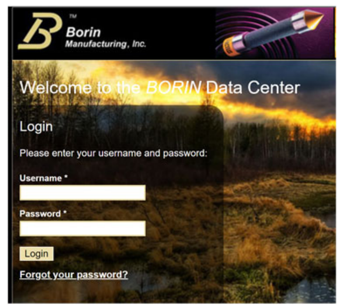


4

CPC System Optimization

Successes and Challenges

- Benefits and Added Value:
  - USBR visit facilities, hands-on experience with remote monitoring systems
  - USACE gain insight and assistance with data processing
  - Research partnerships – in-kind
- Issues:
  - Setting up new work agreements – resolved by using original collaboration charter
  - COVID delays and travel restrictions
  - Research proposal rejections – less funding than anticipated
  - Identifying other funding avenues



5

Appendix B—Cape Canaveral Travel Report

United States Department of the Interior

BUREAU OF RECLAMATION
PO Box 25007
Denver, CO 80225-0007

IN REPLY REFER TO:

86-68540
2.2.4.21

May 19, 2020

VIA ELECTRONIC MAIL ONLY

MEMORANDUM

To: Reclamation Technical Service Center, Engineering & Laboratory Services Division, Materials & Corrosion Laboratory, Denver, CO
Attention: Jessica Torrey (86-68540)

From: Grace Weber, Materials and Corrosion Laboratory Group (MCL), 86-68540

Subject: Travel Report – USACE Cape Canaveral CP Installation
Referral Number: 8540-2020-34

TRAVEL REPORT

TSC Personnel Onsite: Grace Weber (86-68540)

1. **Travel dates:** February 23, 2020 – February 26, 2020
2. **Site visited:** Cape Canaveral Lock, Cape Canaveral, FL
3. **Purpose of trip:** Observe United States Army Corps of Engineers (USACE) installation of cathodic protection (CP) system at Cape Canaveral Lock (Cape Canaveral).
4. **Persons contacted:**
    a. Vincent Hock (USACE ERDC-CERL)
    b. Heather Johnson (USACE ERDC-CERL)
    c. Jeff Ross (USACE Nashville District, project manager)
5. **Background:** Rehabilitation at Cape Canaveral includes blasting and recoating the four lock gates and installing new CP systems, including new rectifiers, conduit, and anodes. Design for the CP system on the structural (frame) side of the gates was done by USACE Mobile District. Design for the CP system on the skin side of the gates was done by USACE Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL). This design includes the use of enhanced MMO ribbon anodes, previously only used on turbines, and a CP monitoring and control system.

The previous CP system on the frame side of the lock gate consisted of ten mixed metal oxide (MMO) wire anodes suspended in the center of the structural members, each with a concrete anchor attached on the end (Figure 1). There were some issues with installation, such as use of schedule 40 conduit in place of schedule 80 conduit, and the conduit being run over open water. However, this system lasted for 30 years and performed properly. Out of the ten anodes observed at Gate 1 (east gates), only one had failed after 30 years. Disconnection of the concrete anchor on that anode may have been a contributor.

6. **Daily work onsite:**

Monday, February 24: Weber, Hock, and Johnson inspected the ongoing rehabilitation work on Gate 4 (west gates). Hock explained the new frame CP system which uses tubular cast iron anode strings mounted in steel channels (for protection). Fiberglass is bonded to the interior of the channels for proper current distribution. There are two cast iron anodes per string. Each anode should have a 250-ft lead on the end (double feed anode string), and the two anodes should be joined to each other by a 1-ft length of cable. However, the anode string only had a single, 500-ft lead instead of the 250-ft-double feed leads. Also, the joining cable between the two anodes was 4 ft long instead of 1 ft long (Figures 2, 3, and 4).

To confirm the observations made from the walkway, Weber, Hock, and Johnson went “in the pit” of Gate 4. Here, they confirmed that the anodes were not as ordered. Due to schedule constraint, there was not enough time to return the order and get the correct anodes. After rechecking electrical calculations, Mobile District verified that a single lead would work for the design. Anode strings were flipped so that the 500-ft lead would be at the top instead of the bottom, removing the need for cable clips going up the channel and allowing the cable to go directly into conduit.

While in the pit, Weber, Hock, and Johnson labeled the anode lead wires at the anode end and the stripped end based on the drawings (Figure 5). This would help with identifying anodes at the rectifier side, which is especially important for the monitoring and control system to function properly. While in the pit, the three also inspected the bond between the fiberglass and the steel channels. The epoxy used was fast setting at the ambient temperature of the work site (exact specs unknown) which made application difficult. Where proper bonding did not occur, brass bolts will be added to properly secure the fiberglass. It is unknown if isolation will be used between the brass bolts and surrounding metal.

Tuesday, February 25: Hock described the rectifiers that will be used for the CP system. The new rectifiers are 230V/30A single phase, and each case measures 18” deep, 24” wide, and 6’ tall. The large voltage and current are necessary to drive all anodes in the CP system. The large case size allows for the rectifier and all CP monitoring and control components to be housed within. The rectifiers have a maximum operating temperature of roughly 90 degrees Fahrenheit, so the south lock house (where the rectifiers will be located) will require air conditioning.

There is a March 5 deadline to finish work on the west gates. On this date, the gates will be opened, and the lock will be watered to allow manatees and other wildlife through.

A conference call was held with the ribbon anode manufacturer contact, Greg Smith (APS Materials). Each ribbon anode installation will take roughly 15 minutes and that the torque requirement for the fiberglass bolts is 20 ft-lb. The reference cells require special, custom-order wire which has a longer lead time than the typical anode cables. Mobile District had previously informed Smith that the length requirement for the ribbon anode leads was greater than previously specified. This would pose a problem since the manufacturer had already begun to fill the order based on the original specified length.

To re-check the necessary anode lead lengths, Weber, Johnson, and Jim Harrington (electrical engineer) measured distances for the conduit run at Gate 1 (Figure 6). The three confirmed that 250-ft leads would not reach the south lock house, and that 305-ft leads would be necessary. Adding a safety factor, 350 ft would be an appropriate lead length.

After further communication with Smith, the team learned that the manufacturer had already cut the leads to 250-ft length as originally specified. Obtaining additional cable and bonding to the anodes would require too much time and would not fit within the March 5 schedule restriction. However, it would be possible for Smith to bond the 250-ft leads to the anodes, obtain additional cable from the supplier, and bring these by Monday. Due to the schedule restriction, although not ideal, splicing the cable would be necessary. The splices would be placed in a cable distribution box already located under the walkway. Plans were solidified for Smith to come to Cape Canaveral the following Monday, March 2, with the ribbon anodes (250-ft leads), additional cable, and splice kits. On that day, Smith would also demonstrate installation of the ribbon anodes. Hock and/or Johnson would return the following Monday to be onsite with Smith.

Weber, Hock, and Johnson met with the electricians on the project. Hock discussed plans for getting all conduit runs in place for the west gates in time for the anode installation on Monday. One complication was a missing strut that was supposed to support some of the conduit. The strut was never installed as specified in the construction drawings. This strut would either need to be bolted or welded in place, or the conduit run would need to be altered. Because this conduit ran in line with another conduit, the idea was brought up to combine the cables from both into one conduit. Since the cast iron anodes had changed from double feed to single feed, the conduit might have room. However, some cables were for the reference cells and others were for anodes, so this was not ideal due to difference in currents. Anode cables are #6 AWG. Structure and reference cell cable sizes are unknown.

Wednesday, February 26: Weber returned to the pit of Gate 4 and met Alfred Beitelman, the USACE coatings expert who was performing dry film thickness testing on the coating on the west gates. Beitelman was using a PosiTector probe that transmitted data to his cell phone. Beitelman described issues he was noticing with the coating. Thickness ranged from 1-2 mils all the way to 70 mils. Desired thickness is around 15-20 mils. In areas that are too thin, additional coating can be applied. But in areas that are too thick, there is danger of solvent entrapment.

7. **Lessons Learned**:

- Double check anode lead length calculations prior to placing order with manufacturer.
    - Ensure that there is sufficient cable to account for contingencies, such as changes in anode locations or unexpected bends/junctions in the conduit run.
    - In the long run, it is cheaper to order leads too long than to fix an error resulting from leads being too short.
- Effective communication between all involved parties is necessary at every step.
    - Miscommunication can result in problems down the road.
    - Communication that leaves out an involved party can create additional problems or delay solutions.
- Tight schedule restrictions limit available responses to problems once the project is near the deadline.
    - Extra budget to deal with contingencies is helpful when there will be strict schedule constraints.
- Ensure that there are appropriate quality control/quality assurance techniques in place during each step of the process.
    - Checking quality along the way and making changes to method/procedure is better than determining that quality does not meet standards at the end.

8. **Recommendations for Reclamation**:

- Double-check anode lead calculations before placing the order with the manufacturer. Have at least one separate set of eyes perform the calculations independently. If the two answers are off by a significant amount, they may need to recheck again, or have a third party review each calculation.
- Work on the east gates will begin in March 2020. This would be a good opportunity for Reclamation to return and see more of the process, including the ribbon anodes (skin side CP system), reference cells, and monitoring and control system.

9. **Follow-up Questions for USACE:**

- Was the ribbon anode installation successful? The reference cell installation? The monitoring and control system installation?
    - Were there any problems encountered? How could they be avoided?
    - Do all systems function properly after installation?
- What changes, if any, will be made to the CP design or installation process for the east lock gates?

10. **Incidents:** None.

SIGNATURES AND SURNAMES FOR:

Travel to: Cape Canaveral Lock, Cape Canaveral, FL

Dates of Travel: February 23, 2020 – February 26, 2020

Names and Codes of Travelers: Grace Weber (86-68540)

Author Date

Grace Weber, M.S.
Materials Engineer, Materials and Corrosion Laboratory

Peer Review Date

Daryl Little, Ph.D.
Materials Engineer, Materials and Corrosion Laboratory

Technical Review Date

Chrissy Henderson, Ph.D.
Materials Engineer, Materials and Corrosion Laboratory

Photos:

Figure 1. Conduit on the frame side of Gate 1 (east gates). Some conduit is running over open water rather than following structural members. MMO anode wires remaining from the previous CP system are seen hanging into the water. Concrete anchors keep the wire anodes in position.

Figure 2. A screenshot from a video that shows the cast iron tubular anode string mounted in a channel on the frame side of Gate 4. The cable lead at the top of the string is not present. The bond between the two cast iron anodes is 4 ft instead of 1 ft, so the cable does not fit between the anodes as it should. The proposed solution is to coil the cable and fit the coil within the channel. Also shown is the fiberglass bonded to the interior of the channel. This prevents over-polarization of the metal where the anodes are mounted. Instead, the cathodic current will polarize the frame pieces and channel across from each anode pair.

Figure 3. Screenshot from a video that shows the bottom of the cast iron tubular anode string mounted in one of the channels on the frame side of Gate 4. The screenshot shows that the cable lead is present at the bottom of the anode string. The anodes are mounted using coated U-bolts and a fiberglass isolation panel (red). The fiberglass bonded to the interior of the channel is present, and cured epoxy (white) can be seen where the fiberglass joins to the steel channel.

Figure 4. Identifying tag on anode cable lead bundle showing a 500-ft length. The cable bundle was measured, and it was confirmed that each anode lead was 500 ft long instead of the 250-ft length specified

Figure 5. Vincent Hock (USACE ERDC-CERL) labelling the anode lead based on the design drawing for identification purposes after pulling the cable through the conduit.

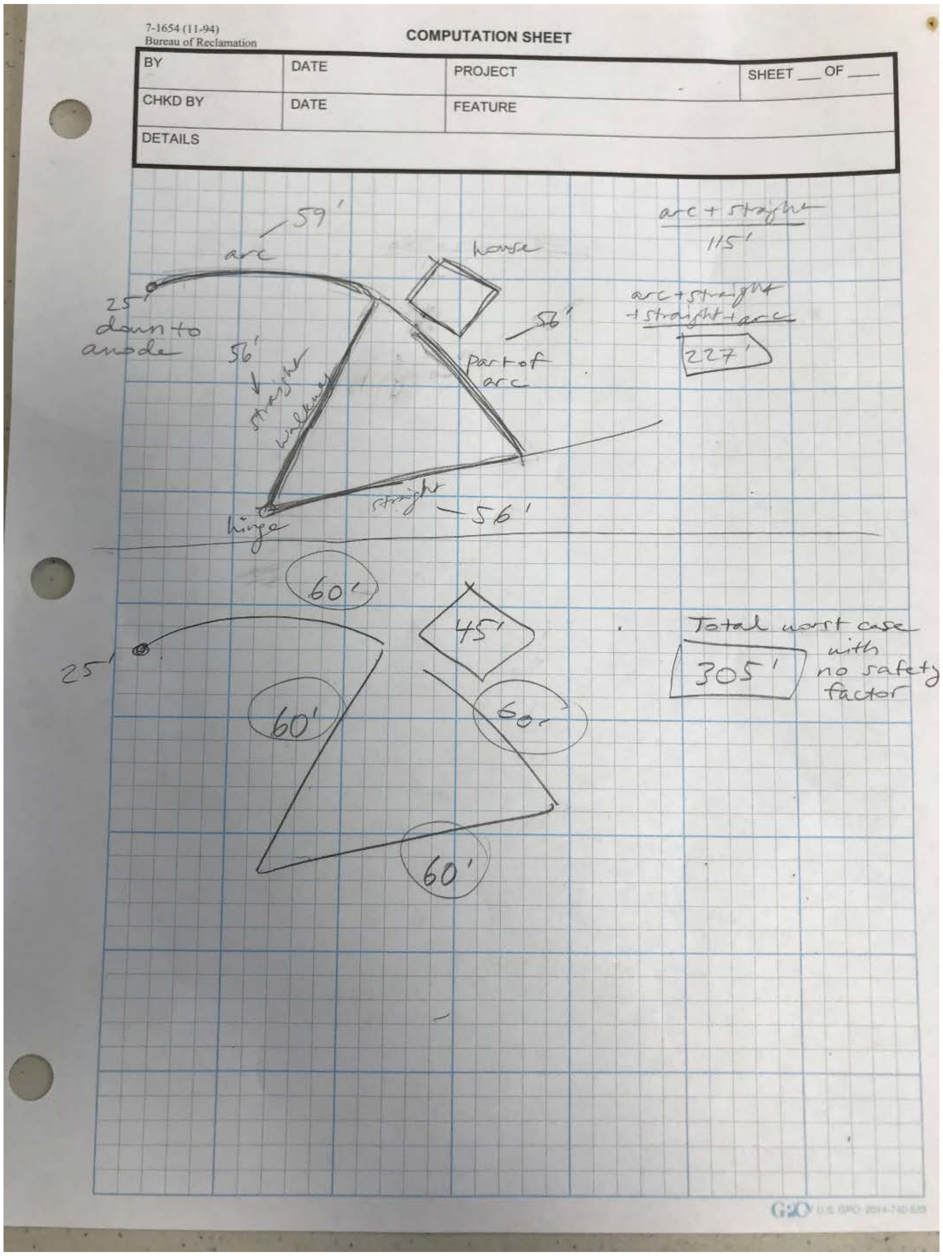


Figure 6. Schematic and rough calculations based on measurements made at Gate 1 used to determine necessary anode lead length for the west gates.

Figure 7. View from the pit of Gate 4. A manlift and structural frame members can be seen in the foreground. In the background, Vince Hock (USACE ERDC-CERL) can be seen standing at ground level by the edge of the pit.