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Cathodic Protection Program Improvement Plan

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Abstract: This program plan has been prepared for operations and engineering personnel familiar with the concepts and principles of corrosion prevention and the operation of cathodic protection (CP) systems at Hanford. This program plan includes activities necessary to develop a comprehensive CP operation and maintenance program. This plan is broken down into two stages, activities to be introduced in years one through three of its execution, and activities to be introduced in years four through six of its execution. At the end of year six, the activities described in this plan, plus their implementing procedures, will form the core of a detailed CP operation and maintenance program based on American National Standards Institute (ANSI) and NACE International (NACE) standards plus "industry best practices."

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CATHODIC PROTECTION PROGRAM IMPROVEMENT PLAN

November 2013

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LIST OF TERMS

Abbreviations and Acronyms

ACVG	Alternating Current Voltage Gradient
ANSI	American National Standards Institute
ASTM	ASTM International
CIP	Close Interval Potential
CP	Cathodic Protection
CSE	Copper Sulfate Electrode
DCVG	Direct Current Voltage Gradient
DST	Double-Shell Tank
ECDA	External Corrosion Direct Assessment
ER	Electrical Resistance
GIS	Geographic Information System
GPS	Global Positioning System
IQRPE	Independent Qualified Registered Professional Engineer
NACE	NACE International
O&M	Operations and Maintenance
PSP	Pipe-to-Soil Potential
TFO	Tank Farm Operations

Units

mV	millivolt
pH	dimensionless unit, cologarithm of the activity of dissolved hydrogen ions
V	volts

1.0 INTRODUCTION

Cathodic protection (CP) systems have been operated at the Hanford Site since the 1940s to protect buried pipelines, vessels, and other metallic components of the waste transfer system from external (i.e., "soil-side") corrosion. As early systems reached their useful life expectancy, they were abandoned and replaced with more modern CP systems. The current CP system in operation in tank farms is approximately 30 years old. Despite its age, the CP system still appears to be in serviceable condition.

In 2008, efforts were initiated to characterize the condition of the existing CP system and recommend upgrades and repairs necessary to maintain proper operation of the system. Early work is documented in RPP-RPT-33664, *Independent Assessment of Cathodic Protection-Related Findings in the 2006 Double-Shell Tank Integrity Assessment Report*, and RPP-25243, *Assessment of Hanford Site Cathodic Protection Systems for Post-2005 Buried Piping Installations*. Additional efforts to characterize the CP system and associated piping have continued throughout the years since 2008. These efforts have significantly improved the understanding of the condition of the CP system, the associated transfer lines, the unique coating systems on the lines, and the management of system data.

Although the condition of the Tank Farm Operations (TFO) CP system is now better understood, the majority of CP-related maintenance and operation activities still focus primarily on meeting state and federal regulatory obligations.

2.0 PURPOSE

This document describes a plan for developing a comprehensive Operations and Maintenance (O&M) program for the TFO CP system.

NOTE: This plan supersedes previously issued CP program-related documents (RPP-PLAN-35917, *Program Plan for the Management of the Hanford Site Cathodic Protection System*, RPP-PLAN-45268, *Hanford Site Cathodic Protection Monitoring Program Plan*, and RPP-PLAN-35915, *Work Plan for Hanford CP Compliance Improvement*).

The plan described herein is broken down into two stages: "near-term" activities to be addressed in years one through three of this plan, and "long-term" activities to be introduced in years four through six. At the end of year six, the activities described in this plan, plus their implementing procedures, will form the core of a detailed CP O&M program based on American National Standards Institute (ANSI) and NACE International (NACE) standards plus "industry best practices" (i.e., necessary standard of care).

3.0 BACKGROUND

The original design of the direct-buried waste transfer system for Hanford's tank farms and waste processing facilities did not foresee the use of CP systems to prevent exterior corrosion of these systems due to their contact with soil. The original waste transfer line systems consisted of

groups of one to seven bare lines placed on top of wood-leveling blocks and backfilled with native soil. Most of the original lines were fabricated from austenitic (e.g., 304 and 316) stainless steel to resist chemical corrosion on the interior surfaces. Corrosion damage on the exterior of the lines due to contact with the soil was not considered to be a significant risk.

By 1948, corrosion-related failures had occurred in the stainless steel lines around B-plant and T-plant. Failures were attributed to pitting corrosion on the exterior of the lines in contact with soil. It was demonstrated that pits initiated on stainless steel lines at bits of paint, organic materials, wood chips, and other foreign materials capable of setting up oxygen-concentration or galvanic cells on the exterior surface of the pipes. By 1948, the first impressed current CP systems were installed to prevent further damage to these lines (HW-33504, *Cathodic Protection of Stainless Steel Waste Lines, Interim Report No. 1, Underground Pipeline and Structure Corrosion Study Program*).

In 1955, in response to an Atomic Energy Commission inquiry regarding the need for CP systems on buried waste lines at Hanford, Hanford Site engineering personnel made the first investigations into soil corrosivity at the site. Data on corrosion in soils similar to Hanford soils were reviewed and correlated to the record of buried pipeline failures at Hanford. Based on this review, it was determined that bare, carbon steel lines with no applied CP are attacked once buried, with first failures expected within 16 to 20 years after installation. For coated lines without CP, localized pitting corrosion at coating defects is expected to produce failures in significantly shorter periods of time.

The application of CP to the lines mitigated failures, but a low rate of failures persisted and was deemed unacceptable. During the 1950s, buried piping designs at the Site steadily moved toward the pipe-in-pipe configuration with the inner and outer pipes constructed of either carbon or stainless steel (WHC-SA-2690-FP, *Corrosion Control at the Hanford Site*). Cathodic protection was applied to the outer encasement to minimize leakage of radioactive materials to the environment (HW-35009, *An Evaluation of Buried Waste Line Design Practice, Interim Report No. 2, Underground Pipeline and Structure Corrosion Study Program*). Worker safety and environmental protection also became increasingly important drivers for piping system design over this time period. By the 1970s, all nuclear waste lines were pipe-in-pipe with CP (SD-WM-ES-033, *Justification for Applying Cathodic Protection to Underground Waste Lines in the 200 Areas*).

The Site's initial CP systems were maintained, expanded, and upgraded periodically through 1977 when an evaluation of the 200 East and 200 West CP systems was performed by Harco Corporation (WHC-SA-0648-FP, *Cathodic Protection System Operating Experience for Underground Piping at the Hanford Site*). Recommendations of the assessment included major system rework, installation of additional test stations, and electrical isolation of rectifiers. In 1980, Battelle Columbus Laboratories evaluated the CP system and recommended that it be abandoned in place (WHC-SA-0648-FP). The CP systems were de-energized later the same year. In 1981, Battelle Columbus and Pacific Northwest Laboratory assessed corrosion conditions in the 200 Areas and recommended that new CP systems be designed and installed (Thompson, N. G., et. al, *Analysis of Complex Corrosion Conditions Project B-234*).

Design work on a new CP system was performed by Ebasco Services, Inc., from 1982 to 1984 (Ebasco, *Upgrade of Hanford 200 Areas Cathodic Protection System Project B-234 Corrosion Field Survey,* and Ebasco, *B-234 Upgrade of 200 Areas Cathodic Protection-Hanford Site*). The system was installed between 1986 and 1995 in the 200 East and 200 West tank farms by Hanford contractors under several separate projects. In the mid-1990s, the Site changed its CP policy, eliminating the use of impressed-current CP on new "pipelines with waterproof construction" (i.e., piping with insulation and fiberglass reinforced plastic jacketing, with or without coating) installed under projects W-058, W-211, W-314, and E-525 (RPP-25299, *Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*). From 1997 to 1999, additions were made to the CP system in 241-AY and 241-AZ Tank Farms. In 2005, additions were made to the CP system in 241-AN Farm. Additional details on the design and installation of tank farm CP systems are available in RPP-25299.

There are presently approximately 36 rectifiers, 1,418 anodes, and 529 test stations installed at the Hanford Site. Of these, 16 rectifiers, 367 test stations, and approximately 955 anodes remain in active service today. Due to changes in the mission of the facility, the remainder of these components have been turned off and abandoned in place.

The Hanford Site double-shell tanks (DSTs) and ancillary equipment are regulated as treatment, storage, and disposal units under the Resource Conservation and Recovery Act of 1976. Management of these facilities is regulated under Title 40, *Code of Federal Regulations,* Part 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (40 CFR 265), and *Washington Administrative Code* (WAC) 173-303-640, "Tank Systems." These regulations require periodic review of the waste transfer and storage systems by an Independent Qualified Registered Professional Engineer (IQRPE) to determine if these systems are structurally sound and fit for use over the life of the mission.

The most recent IQRPE review of the TFO CP system is documented as part of the DST System Integrity Assessment. The DST System Integrity Assessment is comprised of seven volumes that individually address the DSTs, waste compatibility, the waste transfer system, and the CP system:

- RPP-28538, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14* (main assessment document containing summary of all observations, findings, and recommendations from the other six volumes);
- RPP-27591, *Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity;*
- RPP-25153, *Volume 3: IQRPE DST System Integrity Assessment – Waste Compatibility;*
- RPP-25299; *Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*;
- RPP-27097, *Volume 5: IQRPE DST System Integrity Assessment – Waste Transfer Line Encasement Integrity Technology Study;*

- RPP-22604, *Volume 6: IQRPE DST System Integrity Assessment – Evaluation and Documentation of DST Secondary Liner Issues;* and
- RPP-20556, *Volume 7: IQRPE DST System Integrity Assessment – Evaluation of the Dome Load Program for Double-Shell Tanks.*

The CP-related observations, findings, and recommendations summarized in RPP-28538 are extensive, requiring significant field work, excavations, visual inspections of buried lines, engineering assessments, upgrades, repairs, as well as operational and program management changes. Many of the CP-related recommendations documented in RPP-28538 have already been addressed or incorporated into the existing TFO CP O&M program. Remaining IQRPE recommendations plus ANSI/NACE and industry recommended O&M practices are incorporated in the program improvement plan described herein.[1]

4.0 CP PROGRAM IMPROVEMENT PLAN

The activities in this program plan have been broken into "near-term" activities (years one through three) and "long-term" activities (years four through six). Ongoing activities are included in the list of "near-term" activities in this plan.

All activities described in this plan are related to a subset of 125 waste transfer, process, drain, and flush lines deemed essential to the cleanup mission at Hanford. These lines were identified by Site engineering personnel in 2006 and are now commonly known as "Select List Lines" (RPP-RPT-33664). A complete list of the Select List Lines is available in RPP-RPT-54152, *System Design Description of Double-Shell Tank Cathodic Protection System.* It is anticipated that the list of Select List lines will be reevaluated during the IQRPE assessment due to changes in the Site mission since 2006.

Please note that all data collected as a result of the implementation of this plan (including any changes to the CP system) will be reflected in the Hanford Site CP Geographic Information System (GIS).[2]

4.1 NEAR-TERM ACTIVITIES

Certain baseline system repairs, analyses, and data collection activities (some of them ongoing) must be completed to address remaining IQRPE CP-related findings (as documented in RPP-28538) and assess the need for system repairs, upgrades, and improvements. The following activities will be completed in years one through three of this program plan.

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[1] Please note that the program improvement plan described herein supersedes all previous program plan activities described in RPP-PLAN-35917, RPP-PLAN-45268, and RPP-PLAN-35915.

[2] The GIS is a system of analytical tools and applications, which allows capturing, analyzing, managing, and displaying all forms of geographically-referenced information. The GIS is used at Hanford for spatially correlating CP system data with components and test stations as positioned on the ground. The geographic features are based on the most current tank farm CP drawings and as-built information. Data for the system are collected during various CP O&M activities.

4.1.1 GPS-Based Current Interrupters

The pulse generators currently installed or in use at the Hanford Site are at or beyond design life. There are barely enough existing units available to complete the annual pipe-to-soil potential (PSP) survey and new units are no longer available from the manufacturer. Some pulse generators are no longer in synchronization with the others. As such, CP current is not being simultaneously interrupted during the annual PSP surveys and data quality is being affected. The pulse generators currently in use during the annual PSP surveys will be replaced with modern global positioning system (GPS)-synchronized remote monitoring and interruption units.

4.1.2 GPS-Based Data Loggers

Modern handheld data logging instruments are now available to help reduce the time to collect CP data and reduce transcription errors. Handheld GPS-based data loggers that are fully compatible with the Hanford Site CP GIS database are available. Automated data loggers will be purchased and implemented for most if not all CP system data collection activities.

4.1.3 Depolarized PSP Surveys

The depolarized potential of a structure is the potential of the structure with respect to surrounding soil *after* all CP systems that affect the system have been de-energized and the structure has been allowed to completely depolarize. Given the extensive use of bonds between pipelines and other metallic structures at the Hanford Site, this essentially means that all active rectifiers in that 200 East and 200 West areas must be de-energized (i.e., turned "off") prior to the survey. Depolarized test station PSPs are collected in the same manner as annual survey PSPs, but after the rectifiers have been de-energized. Depolarized test station terminal potentials must be known if the NACE 100 mV of polarization criterion is to be used to evaluate the level of protection being provided to a pipe by a CP system. Depolarized potentials are measured at test stations after rectifiers have been de-energized for at least one week.

Depolarized PSP test station surveys are currently conducted every five years or after major construction work (i.e., changes that impact rectifier or anode output) is conducted around protected pipelines. These surveys will continue. Hanford Site Work Order TFC-WO-13-03562, *200G Perform Testing of the Cathodic System*, was used to obtain depolarized PSP test station data in 2013.

4.1.4 Anode Output Surveys

Anode output data have not been collected on the CP system since system installation. Typical industry expectation for anode life is 25 to 30 years. Anode output data are needed to determine the need for anode replacements, cable repairs, and other repairs/upgrades that may be required to restore the protective capacity of the CP system.

NOTE: It will not be possible to collect individual anode output data on every anode as some anodes are spliced directly into header cables (i.e., do not pass through junction boxes that

facilitate these measurements). In cases where the anodes are spliced to the header cable alternate methods will be used to determine anode health.

A survey of anode outputs was completed in October 2013 (3-CATH-782, *Cathodic Protection System Individual Anode Output Measurement*). Additional surveys will be performed on anodes associated with any rectifier whose current or voltage output changes by more than 10% between subsequent rectifier inspections.[3]

4.1.5 AZ-301 Catch Tank Assessment

The AZ-301 catch tank will be assessed to determine if this tank needs CP. This assessment is required per RPP-28538, Table G-1, Item B-13; and Table G-2, Item 29. If the assessment indicates the tank needs CP (i.e., if the tank is not currently bonded into the existing CP system and receiving adequate protection), an analysis will be performed to determine the best way of applying CP to the tank (e.g., bond into existing CP system, install supplemental CP, etc.). Based on this analysis, field work will be performed to provide adequate CP to the tank.

4.1.6 Rectifier Adjustments

Rectifier adjustments will be made using a systematic and iterative process of rectifier adjustment, test station data collection, and data processing and analysis. This iterative process will be repeated until the maximum number of test stations possible are in compliance with NACE criteria for effective CP (criteria established in NACE SP0169-2007, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems,* and NACE SP0285-2011, *Standard Practice External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*).

This iterative process will likely take many months to complete, depending required system repairs, and data analyses. The use of the CP GIS to analyze the relationship between rectifier output adjustments and test station PSP data will be used to make this iterative process efficient.

4.1.7 Existing ER Sensor Surveys

Electrical resistance sensors made of carbon steel have been installed on Lines SL-509, SL-510, SN-609, and SN-610 in the 241-AP Farm; Lines SN-285 and SN-286 in the 241-SY Farm; and Line PW-4531 in the 241-AY Farm.[4] Data will be collected from these sensors (and any new electrical resistance (ER) sensors installed as part of new direct assessment activities) each year

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[3] Note that there is no ANSI/NACE standardized basis for the exact percentage change in rectifier output necessary to trigger a repeat anode output survey. The value of 10% is based on discussions with NACE Certified CP Specialists regarding common indicators of anode failure.

[4] For ER sensor installation details, see ECN 10-000567, *Electrical Resistance Sensor Installation on 241-AP Farm Lines SL-509, SL-510, SN-609, and SN-610;* ECN 10-000994, *Electrical Resistance Sensor Installation on 241-AP Farm Lines: Electrical Enclosure*); ECN 10-000772, *Electrical Resistance Sensor Installation on 241-AY Farm Line PW-4531;* and ECN 10-000672, *Electrical Resistance Sensor Installation on 241-SY Farm Lines SN-285 and SN-286.*

in conjunction with the annual test station PSP survey. Data from these sensors will be used to trend corrosion rate and effectiveness of protection on the associated lines over time.

4.1.8 Rectifier Inspections

Rectifiers are vulnerable to electrical damage from lightning strikes or other voltage spikes and are often situated in aggressive environments. The periodic readings facilitate timely detection of rectifiers that have failed or are otherwise de-energized. In addition, periodic readings allow for the timely detection of stack failures or the failure of other electrical components within the rectifier (e.g., transformer, diodes, fuses, surge suppressors, meters, breakers, lightning arrestors, etc.). Periodic rectifier readings also provide for rapid detection of changes in the system as a whole (e.g., underground shorts to other structures, failed or severed anode header cables, depleted anodes, etc.). Readings can also be used to track seasonal variations in anode bed resistance related to soil moisture changes and are useful in troubleshooting activities currently being performed.

Regulatory requirements associated with the installation, startup, operation, and maintenance of the CP systems at Hanford are defined in 40 CFR 265.195, "Inspections." Per 40 CFR 265.195, once a CP system is installed and energized, all sources of impressed current must be inspected and/or tested at least bimonthly (i.e., every other month).

Routine rectifier inspections are conducted on a bi-monthly basis. A more thorough rectifier inspection is also performed once each year in conjunction with the annual PSP test station survey. These inspections will be continued. Hanford Site Procedures 5-CATH-221, *Inspection of Cathodic Protection System Rectifiers,* and 2S22036, *Inspect 222-S and 219-S Cathodic Protection Rectifiers*, provide guidance for the routine bi-monthly rectifier inspections. The more thorough annual rectifier inspection is performed as part of Hanford Site Procedure 3-CATH-690.

4.1.9 Annual PSP Surveys

Pipe-to-soil potential surveys are performed to evaluate the performance of the CP system and to meet the reporting requirements of 40 CFR 265.195. During the annual surveys, pipeline potentials are generally measured relative to a portable copper sulfate electrode (CSE) placed in contact with the soil. Insulated cables running to the buried pipeline terminate at grade in test stations to facilitate these measurements. Historically, measurements of PSPs were made in each test station between the CSE and one terminal of a terminal pair or between the CSE and the terminal pair that has been jumpered together. Data collection procedures require taking measurements at each terminal of each terminal pair in each test station. The PSP data are then compared with established NACE criteria for effective CP (criteria established in NACE SP0285-2011).

Test points located within test stations are the principal means of evaluating the level of CP on pipelines at the Hanford Site. Test station PSP surveys are conducted on an annual basis on the TFO CP system. These annual PSP surveys will be continued. Hanford Site Procedures 2S22045, *Cathodic Protection System Testing,* and 3-CATH-690, *Cathodic Protection System*

Testing, cover PSP measurements and documentation. NACE Standard TM0497-2012, *Standard Test Method Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems*, provides general guidance and best practices for the collection of PSP data.

4.1.10 Comprehensive CP System Evaluation

A system evaluation will be performed at the end of year three of this plan and the plan updated and modified as necessary. Amongst other performance metrics, the evaluation will include a comprehensive cost benefit analysis to help determine if the existing CP system should be replaced or if efforts to keep the system running should be maintained.

4.2 LONG-TERM ACTIVITIES

Assuming Site mission changes do not require revisions to this plan, and pending available program funding, overall system analysis, and Department of Energy approval, near-term CP-related activities such as periodic PSP data collection, rectifier adjustments, and other regular O&M activities will be continued as part of the long-term activities in years four through six.

Additional data collection, inspections, and analyses will be added in years four through six to continue improving system performance and reliability, and to bring system O&M requirements into line with NACE and industry-recommended best practices. Together with implementing procedures, these activities will form the core of the long-term CP system operation and maintenance program.

4.2.1 Pipeline Excavation and Evaluation

The present condition of the buried encasement piping surrounding many of the waste transfer lines is largely unknown beyond the fact that these encasements have passed periodic pressure tests. Similarly, the condition of unencased water, ventilation, and utility lines is unknown beyond the fact that they have not yet leaked.

Pipe-to-soil and rectifier data alone cannot provide a comprehensive view of the condition of buried pipe. As pipelines age, direct assessments are often necessary to confirm damage or pipeline condition inferred by indirect assessments such as PSP measurements. NACE SP0169 notes that special conditions sometimes exist where CP that meets NACE criteria is ineffective, including "elevated temperatures, disbonded coatings, thermal insulating coatings, shielding, unusual contaminants in the electrolyte, and especially sulfate-reducing bacteria living under anaerobic conditions." In RPP-25299, the IQRPE noted that all of these special conditions are known to exist, have historically existed, or could potentially exist in the lines associated with the TFO CP system. As such, the IQRPE recommended direct assessment of a representative number of buried pipes at the Site.

Items R20 and R44 in Table G-2 of RPP-28538 address the IQRPE recommendations regarding direct examination of pipelines. Recommendation R20 suggests inspecting "as many different

pipelines configurations as possible." Recommendation R44 suggests that "at least 5% of the lines shown in Appendix A of RPP-27591" be inspected (i.e., approximately 13 lines).

A few small areas of seven buried transfer lines were recently exhumed and inspected (RPP-RPT-42487, *Evaluation of Buried Transfer Lines with Cathodic Protection*). Assuming the IQRPE recommendation of 13 lines is sufficient, six additional lines will be exhumed and inspected. These inspections will be performed as part of the development of a ***more comprehensive*** External Corrosion Direct Assessment (ECDA) program as described below.

Please note that although the IQRPE set a recommended number of lines to be inspected, it should be kept in mind that the goal of these direct inspection activities is to develop an understanding of the condition of the various types of buried lines and the effectiveness of the CP system. As such, location of excavation activities and types of lines to be inspected must be carefully considered and, depending on the results of these initial evaluations, additional lines may need to be inspected to give an accurate representation of the condition of the balance of the system.

4.2.2 External Corrosion Direct Assessment

It is of course impractical to exhume numerous buried lines in the Hanford tank farms. If, however, direct and indirect assessments of a representative number of pipelines and CP system components are made, and these data are compared with historical CP system data, a better understanding can be gained of the health of other similar non-exhumed lines. Ongoing direct assessment programs that function on this principle are regularly employed throughout the industry to monitor the condition of protected lines and the performance of the associated CP systems. These programs are known as ECDA programs. A comprehensive ECDA program will be developed to guide future direct inspection activities associated with the TFO CP system.

A complete description of an ECDA program for the TFO CP system is beyond the scope of this program plan. Detailed guidance for developing ECDA programs is available in ANSI/NACE SP0502-2010, *Pipeline External Corrosion Direct Assessment Methodology*. In general, however, ECDA programs describe a structured process of continuous improvement intended to improve pipeline safety and reliability by assessing and reducing the impact of external corrosion on pipeline integrity. By identifying and addressing corrosion activity, repairing corrosion defects, remediating the cause, and applying this information to similar lines in the system, ECDA programs proactively seek to prevent external corrosion from impacting structural integrity.

4.2.3 New ER Sensor Installation/Survey

The installation of ER sensors on exhumed lines will be included as a fundamental part of each excavation and inspection. In most cases, at least two ER sensors will be installed at each excavation location, one attached to the pipe (i.e., receiving protection from the CP system) and one unattached to the pipe. Following backfill operations, ER sensors can be used to monitor the corrosion rate on the associated line, possibly precluding the need to excavate the line for additional direct examinations and assessments. In addition, the sensor not connected to the pipe

can be used to infer the corrosion rate of steel not protected by the CP system, the depolarized potential of the pipeline without interrupting the CP system, and other useful corrosion data.

4.2.4 Mid-Rectifier PSP Measurements

Pipe-to-soil potential measurements using a standard CSE will be evaluated at certain selected test stations approximately centered between rectifiers or rectifier clusters on a bi-monthly basis. These measurements provide a simple check on rectifier and ground bed performance, and can help identify damage to cables or the depletion of anodes in a timely manner. A list of recommended test stations for bi-monthly measurements is presented in Table 4-1. Note that alternate test stations are provided in Table 4-1 in the event that the recommended test station cannot be used. However, once a test station at a given location is selected, only that test station should be used for subsequent measurements.

Table 4-1. Bimonthly Rectifier Output Survey PSP Test Stations.

Associated Rectifiers	Test Station	Alternate Test Station
AP241-CATH-RECT-100, AP241-CATH-RECT-101 and AW241-CATH-RECT-100	78-T1B	78-T2
AW241-CATH-RECT-100 and A242-CATH-RECT-018	93-T4	T(33-36A)
A242-CATH-RECT-018 and AW241-CATH-RECT-016	T(42-16)	T(42-45)
AW241-CATH-RECT-016, AY241-CATH-RECT-101, AY241-CATH-RECT-103, and AY241-CATH-RECT-102	T(41-1)	T(46-14)
AY241-CATH-RECT-101, AY241-CATH-RECT-103, AY241-CATH-RECT-102, and AZ241-CATH-RECT-041	T(06-9)	T(41-4)
AZ241-CATH-RECT-041 and AZ241-CATH-RECT-101	T(46-9)	T(46-11)
AZ241-CATH-RECT-041, AN241-CATH-RECT-100, and AN241-CATH-RECT-102	T(41-2)	N/A
AZ241-CATH-RECT-102 and AZ241-CATH-RECT-101	T(46-2)	T(46-3)

4.2.5 Over The Line Surveys

Close Interval Potential (CIP) surveys, Direct Current Voltage Gradient (DCVG), and Alternating Current Voltage Gradient (ACVG) surveys are often used to evaluate the condition of coatings on buried pipelines and the effectiveness of the CP system at locations along buried pipelines between test stations. Often, data from one technique can be used to confirm the results of another technique. There are presently no Hanford Site procedures for conducting CIP, DCVG, or ACVG surveys. NACE SP0207-2007, *Standard Practice Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines*, covers the performance and documentation of CIP and DCVG surveys. NACE Standard TM0109-2009, *Standard Practice Aboveground Survey Techniques for the Evaluation of Underground Pipeline Coating Condition,* covers the performance and documentation of ACVG surveys.

The feasibility of applying the CIP, DCVG, and ACVG survey techniques on the lines associated with the TFO CP system is unknown. The IQRPE has recommended the application of over the line survey techniques such as the CIP and DCVG techniques, but has also noted that the amount

of bonding between lines may make application of these techniques difficult or impossible in some areas (RPP-28538).

An analysis will be performed to determine areas of the TFO CP system where over the line survey techniques can most effectively be applied and surveys of these areas will be performed. If these surveys produce useful information that will help trend the status of protective potentials and condition of coatings on these lines, similar surveys will be repeated every five years.

4.2.6 Depolarized Over the Line Surveys

A depolarized over the line survey is a CIP, DCVG, or ACVG survey performed on a depolarized pipeline. Pending the analysis to determine areas of the TFO CP system conducive to over the line survey techniques, in year five of this program a depolarized CIP survey will be performed. If these surveys produce useful information that will help trend the status of protective potentials and condition of coatings on these lines, similar surveys will be repeated every five years.

4.2.7 Soil Corrosivity Testing

It is important to know the corrosivity of the soil surrounding pipelines, particularly during initial CP system design. Factors that contribute to corrosion of metal in soils include the presence of soluble salts (especially chlorides and sulfates), resistivity, pH, and the presence of oxygen.

Field tests and laboratory analyses are used to determine soil corrosivity. Soil corrosivity will be tested whenever a portion of the CP system is replaced or upgraded, or when soil conditions in an area substantially change.

There are presently no general Hanford procedures for measuring soil corrosivity. The standard method for measuring soil pH is described in ASTM D4972-01(2007), *Standard Test Method for pH of Soils*. The standard method for measuring soil resistivity is described in ASTM International (ASTM) G57-06(2012), *Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*. Electromagnetic conductivity surveys may also be used to determine soil resistivity (Bell, et. al., *Electromagnetic Conductivity Survey of Pipeline Alignment for Soil Corrosivity Assessment and Corrosion Control Design for Large Diameter Water Pipelines)*.

4.2.8 Operation and Maintenance Improvements

Effective pipeline corrosion control through the use of CP systems is heavily dependent on the proper operation and maintenance of these systems. The following activities will be built into the CP operation and maintenance program in years four through six, then continued as indicated as regular parts of the program.

4.2.8.1. Pipeline Coating Maintenance

Although coated pipelines are buried and inaccessible under normal conditions, there are things that can be done to maintain the coatings on these lines. If, for instance, a coated line is inadvertently damaged during construction or earth work activities, the coating will be repaired with an equal or better coating before reburial. Maintenance personnel will be trained in good coating application procedures, care of materials, and compliance with specifications so that acceptable coating work will result. Additionally, a performance record of pipeline coatings will be kept to help engineering personnel make recommendations for materials to be used in new construction.

When lines are exposed during construction or earth work activities, operations personnel will notify corrosion engineering personnel. Condition reports on exhumed lines will include date, specific location, coating type, manufacturer, temperature at the coating surface in place, general condition of the coating, bond quality, evidence of cold flow, evidence of moisture under the coating, evidence of soil stress effects, presence of pitting or holidays, and data on environmental conditions surrounding the pipe that could have an adverse effect on coating.

If low or changed potentials are identified during pipeline potential surveys, or if a review of historical data indicates that potentials are declining on a specific area of pipeline over time for no apparent reason, pipeline exhumation may be necessary. If coating damage is locally severe, it may be necessary to replace the coating on that section of line. Recoating the section usually restores CP to proper levels. If a section of pipeline needs to be recoated, it is likely that the original coating material was not suitable for that area or was improperly applied. Coating repairs will be inspected by a NACE Level III coating inspector. Thus, the replacement coating will be selected for its ability to withstand the particular environmental conditions in that area. Economic justification for recoating versus simply adding local CP in the affected area will be evaluated for each case.

4.2.8.2. Cased Crossing Assessment

Where buried pipelines cross under roads, the primary pipeline is typically annularly surrounded by a larger-diameter encasement pipeline to protect the primary pipeline from damage due to heavy loads on the road. Maintaining electrical isolation between the primary and encasement pipes is essential for the CP system to function effectively. Electrical shorts between the primary and encasement pipes are common. If it is not possible to isolate the casing and the carrier pipe, steps will be taken to eliminate (by methods other than CP) conditions conducive to corrosion on the carrier pipe within the casing.

An analysis of cased crossings in the TFO CP system will be performed. This analysis will include identification of cased crossings and an attempt to determine the status of CP at each cased crossing. If electrical shorts or other problems are identified at cathodically-protected cased crossings, attempts will be made to rectify these problems. After this initial analysis, the status of isolation at cased crossings will be assessed annually, possibly as part of annual PSP surveys.

4.2.8.3. Foreign Line Assessment

Although the existing Select List lines at the Hanford Site are all under control of the tank farm contractor, interface with the Vitrification Plant may result in static or dynamic interference between the tank farm and Vitrification Plant CP systems. An analysis of the potential for interference between lines protected by the TFO CP system and lines protected by the Vitrification Plant CP system will be performed. If areas of potential interference are identified, field tests (if possible) will be conducted to evaluate the extent of the interference and, as required, efforts will be initiated to address the impact of the interference on the affected lines.

4.2.9 Remote Monitoring Systems

Remote monitoring of CP systems is a relatively recent development that automates the data collection process and provides operators with a proactive surveillance system. In remote monitoring systems, CP data are transmitted from the field units to an operational center. Cellular telephone data systems or low earth orbit satellite data systems are commonly used to transmit CP data. Remote monitoring systems have been shown to be cost-effective, with a typical payback of less than two years. They also increase safety by minimizing personnel time in the field as well as eliminating electrical hazards to technicians.

An analysis of installing remote monitoring CP systems will be performed. If the analysis shows favorable results, remote monitoring systems will be phased in, where appropriate, over years four through six of this program.

5.0 CONCLUSIONS

The activities and analyses described in this plan, plus their implementing procedures, form the core of a detailed CP O&M program based on ANSI and NACE standards plus "industry best practices." Elements of the program are summarized in Table 5-1.

Table 5-1. Summary of CP O&M Program Activities. (2 sheets)

Activity	Program Plan Section	Initial Performance	Subsequent Performance
Near-Term Activities (Years One Through Three)			
GPS-Based Current Interrupters	4.1.1	One-time installation as part of Near-Term Activities	Use annually thereafter during annual PSP test station survey (also as needed for system troubleshooting)
GPS-Based Data Loggers	4.1.2	One-time purchase as part of Near-Term Activities	Use annually thereafter during annual PSP test station survey (also as needed for system troubleshooting)
Depolarized PSP Surveys	4.1.3	Existing ongoing activity; surveys started in 2007	Every five years after initial survey or after major construction work around pipelines
Anode Output Surveys	4.1.4	Existing ongoing activity; surveys started in 2013	As required after initial survey, typically if greater than 10% change in rectifier output between bi-monthly rectifier inspections
AZ-301 Catch Tank Assessment	4.1.5	One-time assessment as part of Near-Term Activities	Annual assessment of tank potential thereafter as part of annual PSP survey
Rectifier Adjustments	4.1.6	Existing ongoing activity; adjustments started during rectifier commissioning	Multiple adjustments thereafter, as required, to bring test stations into compliance with NACE criteria for adequate CP
Existing ER Sensor Surveys	4.1.7	Existing ongoing activity; surveys started in 2009	Annual measurements as currently performed
Rectifier Inspections	4.1.8	Existing ongoing activity; inspections started during rectifier commissioning	Bi-monthly (routine) and annually (comprehensive) as currently performed
Annual PSP Surveys	4.1.9	Existing ongoing activity; surveys started during rectifier commissioning	Annually as currently performed
Comprehensive CP System Evaluation	4.1.10	One-time assessment as part of Near-Term Activities	As indicated by system performance
Long-Term Activities (Years Four Through Six)			
Pipeline Excavation and Evaluation	4.2.1	Existing ongoing activity; excavations/evaluations started in 2009	Multiple additional direct assessments, as required, as part of ECDA program

Table 5-1. Summary of CP O&M Program Activities. (2 sheets)

Activity	Program Plan Section	Initial Performance	Subsequent Performance
External Corrosion Direct Assessment	4.2.2	Develop and implement ECDA program as part of Long-Term Activities	Follow ECDA program in all subsequent years of operation
New ER Sensor Installation/Survey	4.2.3	As required as part of Long-Term Activities	Annual measurements as currently performed for existing ER sensors
Mid-Rectifier PSP Measurements	4.2.4	Once as part of Long-Term Activities	Every other month in all subsequent years of operation
Over The Line Surveys	4.2.5	Once as part of Long-Term Activities	If effective, every five years thereafter
Depolarized Over The Line Surveys	4.2.6	Once as part of Long-Term Activities	If effective, every five years thereafter
Soil Corrosivity Testing	4.2.7	As required as part of Long-Term Activities	As required when a portion of the CP system is being replaced or upgraded, or when soil conditions in an area substantially change
Operation and Maintenance Improvements	4.2.8		
Pipeline Coating Maintenance	4.2.8.1	As required as part of Long-Term Activities	As required as part of Long-Term Activities
Cased Crossing Assessment	4.2.8.2	Once as part of Long-Term Activities	Annually, possibly as part of annual PSP survey
Foreign Line Assessment	4.2.8.3	Once as part of Long-Term Activities	Annually as part of PSP survey in all subsequent years of operation
Remote Monitoring Systems	4.2.9	Analyze and incorporate as part of Long-Term Activities	Use in all subsequent years of operation

6.0 REFERENCES

3-CATH-690, 2010, *Cathodic Protection System Testing*, Revision C-3A, Washington River Protection Solutions, LLC, Richland, Washington.

3-CATH-782, *Cathodic Protection System Individual Anode Output Measurement*, Current Revision, Washington River Protection Solutions, LLC, Richland, Washington.

5-CATH-221, 2010, *Inspection of Cathodic Protection System Rectifiers*, Revision G-0A, Washington River Protection Solutions, LLC, Richland, Washington.

40 CFR 265.195, "Inspections," *Code of Federal Regulations*, as amended.

2S22036, 2009, *Inspect 222-S and 219-S Cathodic Protection Rectifiers*, Revision H-1, Washington River Protection Solutions, LLC, Richland, Washington.

2S22045, 2010, *Cathodic Protection System Testing*, Revision C-0, Washington River Protection Solutions, LLC, Richland, Washington.

ANSI/NACE Standard Practice SP0502-2010, *Pipeline External Corrosion Direct Assessment Methodology*, NACE International, Houston, Texas.

ASTM D4972-01(2007), 2007, *Standard Test Method for pH of Soils*, ASTM International, West Conshohocken, Pennsylvania, 2006, DOI: 10.1520/D4972-01R07.

ASTM G57-06 (2012), 2012, *Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*, ASTM International, West Conshohocken, Pennsylvania, 2006, DOI: 10.1520/G0057-06R12.

Bell, G. E. C., et. al., 1998, *Electromagnetic Conductivity Survey of Pipeline Alignment for Soil Corrosivity Assessment and Corrosion Control Design for Large Diameter Water Pipelines* in *Pipelines in the Constructed Environment, Proceedings of the 1998 Pipeline Division Conference*, San Diego, California.

ECN 10-000567, 2010, *Electrical Resistance Sensor Installation on 241-AP Farm Lines SL-509, SL-510, SN-609, and SN-610*, Washington River Protection Solutions, LLC, Richland, Washington.

ECN 10-000672, 2010, *Electrical Resistance Sensor Installation on 241-SY Farm Lines SN-285 and SN-286*, Washington River Protection Solutions, LLC, Richland, Washington.

ECN 10-000772, 2010, *Electrical Resistance Sensor Installation on 241-AY Farm Line PW-4531*, Washington River Protection Solutions, LLC, Richland, Washington.

ECN 10-000994, 2010, *Electrical Resistance Sensor Installation on 241-AP Farm Lines: Electrical Enclosure*, Washington River Protection Solutions, LLC, Richland, Washington.

Ebasco, 1982, *Upgrade of Hanford 200 Areas Cathodic Protection System Project B-234 Corrosion Field Survey*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ebasco, 1983, *B-234 Upgrade of 200 Areas Cathodic Protection-Hanford Site*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

HW-33504, 1954, *Cathodic Protection of Stainless Steel Waste Lines, Interim Report No. 1, Underground Pipeline and Structure Corrosion Study Program,* Revision 0, General Electric, Richland, Washington.

HW-35009, 1955, *An Evaluation of Buried Waste Line Design Practice, Interim Report No. 2, Underground Pipeline and Structure Corrosion Study Program,* Revision 0, General Electric, Richland, Washington.

NACE SP0169-2007, 2007, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, NACE International, Houston, Texas.

NACE SP0207-2007, 2007, *Standard Practice Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines*, NACE International, Houston, Texas.

NACE SP0285-2011, 2011, *Standard Practice External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*, NACE International, Houston, Texas.

NACE Standard TM0109-2009, 2009, *Standard Practice Aboveground Survey Techniques for the Evaluation of Underground Pipeline Coating Condition,* NACE International, Houston, Texas.

NACE Standard TM0497-2012, 2012, *Standard Test Method Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems*, NACE International, Houston, Texas.

RPP-20556, 2007, *Volume 7: IQRPE DST System Integrity Assessment – Evaluation of the Dome Load Program for Double-Shell Tanks*, Revision 01, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22604, 2007, *Volume 6: IQRPE DST System Integrity Assessment – Evaluation and Documentation of DST Secondary Liner Issues*, Revision 01, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25153, 2007, *Volume 3: IQRPE DST System Integrity Assessment – Waste Compatibility*, Revision 01, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25243, 2007, *Assessment of Hanford Site Cathodic Protection Systems for Post-2005 Buried Piping Installations*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25299, 2007, *Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-27097, 2007, *Volume 5: IQRPE DST System Integrity Assessment – Waste Transfer Line Encasement Integrity Technology Study*, Revision 01, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-27591, 2007 *Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*, Revision 01, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-28538, 2008, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14,* Revision 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-35915, *Work Plan for Hanford CP Compliance Improvement,* Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-35917, 2008, *Program Plan for the Management of the Hanford Site Cathodic Protection System*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-45268, 2010, *Hanford Site Cathodic Protection Monitoring Program Plan*, Revision 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-33664, 2007, *Independent Assessment of Cathodic Protection-Related Findings in the 2006 Double-Shell Tank Integrity Assessment Report,* Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-42487, 2009, *Evaluation of Buried Transfer Lines with Cathodic Protection,* Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-54152, 2013, *System Design Description of Double-Shell Tank Cathodic Protection System,* Revision 0, Washington River Protection Solutions, LLC, Richland, Washington.

SD-WM-ES-033, 1984, *Justification for Applying Cathodic Protection to Underground Waste Lines in the 200 Areas,* Revision 1, Rockwell Hanford, Richland, Washington.

TFC-WO-13-03562, *200G Perform Testing of the Cathodic System*, Washington River Protection Solutions, LLC, Richland, Washington.

Thompson, N. G., Vaaler, L. E., Divine, J. R., Nelson, J. L., Payer, J. H., and Barlo, T. J., 1981, *Analysis of Complex Corrosion Conditions Project B-234*, Rockwell Hanford Operations, Richland, Washington.

WAC 173-303-640, "Tank Systems," *Washington Administrative Code,* as amended.

WHC-SA-0648-FP, 1992, *Cathodic Protection System Operating Experience for Underground Piping at the Hanford Site*, Westinghouse Hanford Company, Richland, Washington.

WHC-SA-2690-FP, 1995, *Corrosion Control at the Hanford Site,* Westinghouse Hanford Company, Richland, Washington.