REVIEW OF CATHODIC PROTECTION SYSTEMS AT THE VALDEZ MARINE TERMINAL

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NACE CP Specialist #5407

Project 5998.20.01: Cathodic Protection Systems Review

"The opinions expressed in this PWSRCAC – commissioned report are not necessarily those of PWSRCAC."

April 14, 2021

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Executive Summary:

National Pipeline Services, LLC (NPS) was retained by the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) to evaluate the cathodic protection of the Alyeska Pipeline Service Company (Alyeska) – Valdez Marine Terminal (VMT) crude piping system. This review and report were performed by Keith Boswell, NACE CP Specialist #5407, with National Pipeline Services.

The initial scope of this project was intended to review cathodic protection (CP) of the crude oil piping and storage tanks at the VMT. However, this scope was adjusted to just the crude oil piping due to difficulties in obtaining historical information from Alyeska.

An initial site visit to the VMT by Keith Boswell was conducted on Wednesday, September 25, 2019. This site visit included meetings with Alyeska personnel and their cathodic protection contractor, Coffman Engineers. A site tour of the facility and representative cathodic protection systems and equipment was completed. Additionally, answers and inquiries were provided by Jonathan Michaud (Alyeska) and Coffman Engineers corrosion personnel.

Historical reports and procedures were reviewed prior to and after this site visit. This information was evaluated to compare with standard industry practices and procedures. By and large, these reports and procedures are well constructed and thorough.

Overall, it appears Alyeska has a very good corrosion and cathodic protection program for the VMT. However, some important discrepancies need to be addressed and recognized by Alyeska and their CP personnel.

1. Re-evaluate and improve testing procedures to more accurately measure polarized potentials along the crude piping system.
2. Re-evaluate utilization and measurement of 100 mV CP system testing criteria.
3. Update procedures to reflect changes to testing, analysis, and utilization of alternative measurement tools.

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Cathodic Protection Introduction:

Cathodic protection is a method to deter corrosion of an underground or submerged metal. It functions by making active areas on a steel pipeline more noble or passive. This is achieved by introducing an alternate metal or material into the circuit that becomes more active than steel. This can be achieved either by sacrificial anodes such as magnesium or zinc, which utilizes the potential (voltage) difference between itself and the steel; or with impressed current anodes that are less reactive but are energized by an alternate voltage source.

Most of the cathodic protection at the VMT is achieved through impressed current systems. Impressed current systems are more versatile than sacrificial systems as they allow for higher voltages and current to cathodically protect large areas of buried steel. These systems are operated through cathodic protection rectifiers. These rectifiers operate off incoming alternating current (AC) sources and the AC current is converted to a direct current (DC) voltage that energizes the anodes. Any loss of incoming AC (e.g., unexpected power outage, planned system outages, maintenance) results in loss of cathodic protection until power is restored.

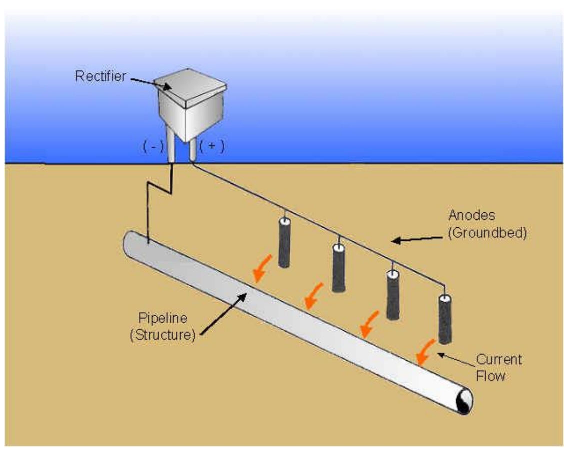

Figure 1: Impressed Current Cathodic Protection Detail

Evaluation for the effectiveness of the cathodic protection is demonstrated through field measurements utilizing a copper-copper sulfate reference electrode. This is the standard electrode utilized in the industry for this type of service and arrangement. Use of this electrode allows for a direct potential (voltage) measurement of the structure with respect to the earth or surrounding soil. The electrode is placed on the surface of the ground over the structure, as close as practical, as shown in Figure 2.

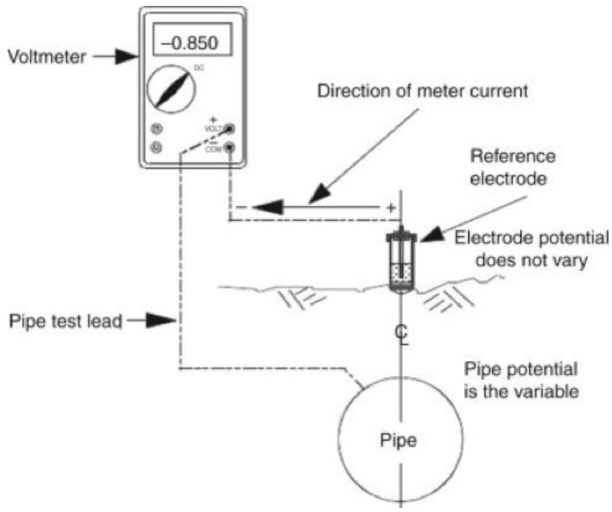

Figure 2: Cathodic Protection Measurement

Cathodic protection adequacy is achieved with potential measurements more negative than -0.850 volts. A more in-depth review and discussion of criteria for cathodic protection is presented further in this report.

Cathodic Protection Systems at VMT

Cathodic protection systems at the VMT are comprised of the following types:

1. Deep Anode Groundbeds
2. Surface Distributed Anode Groundbeds
3. Linear Anode Groundbeds
4. Galvanic Anode Groundbeds

Original construction of the cathodic protection system at the VMT consisted primarily of deep anode groundbeds in and around the East and West, Ballast Water, and Fuel Oil tank farms. Supplemental cathodic protection was installed in the form of surface distributed anode groundbeds buried remote from the piping and continuous linear anode groundbeds buried in a common trench next to the piping. Some galvanic anode systems are utilized where power is not available and practical.

Deep Anode Groundbed Systems

Deep anode groundbeds are an impressed current system where anodes are installed in a single vertical hole, typically several hundred feet deep. These systems offer distribution of CP current to a large area, depending on the overall depth of the anodes and their remoteness to the structures being protected. They're typically installed to protect piping within the facility or along a pipeline right-of-way (ROW). These systems are typically unsuitable for tank bottoms or discrete protection of structures.

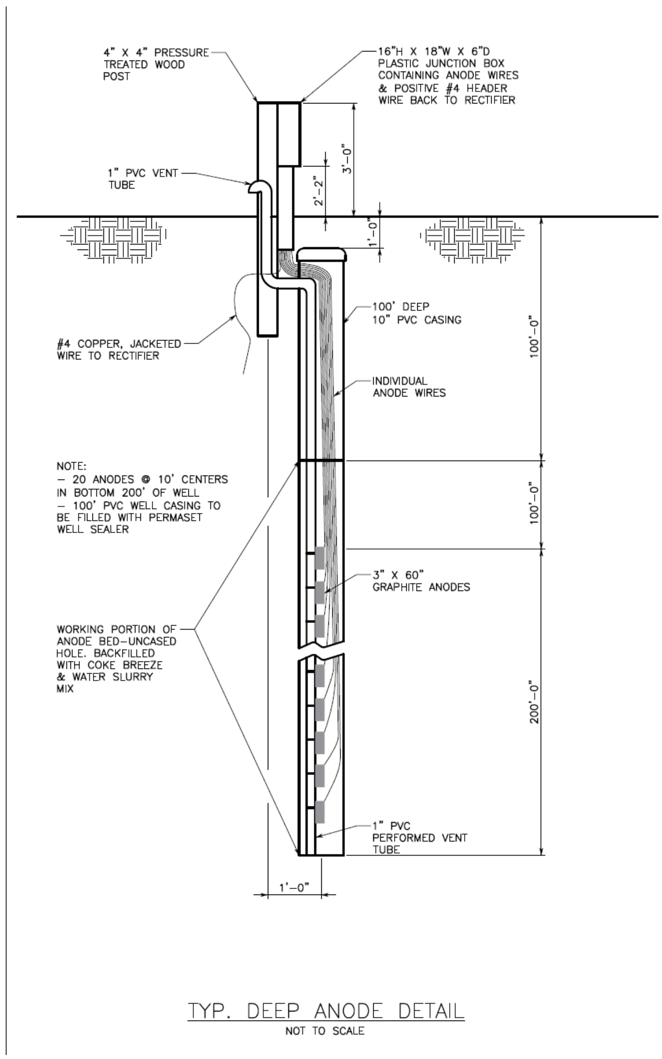

Figure 3: Typical Deep Anode Cathodic Protection Groundbed System

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Surface Distributed Groundbed Systems

Surface distributed groundbeds are an impressed current system where anodes are installed either vertically or horizontally, remote from the structures to be protected. Again, the remoteness of this system allows for larger areas of protection. Multiple anodes are installed on specified center to center spacing (anywhere from 10 to 20 feet).

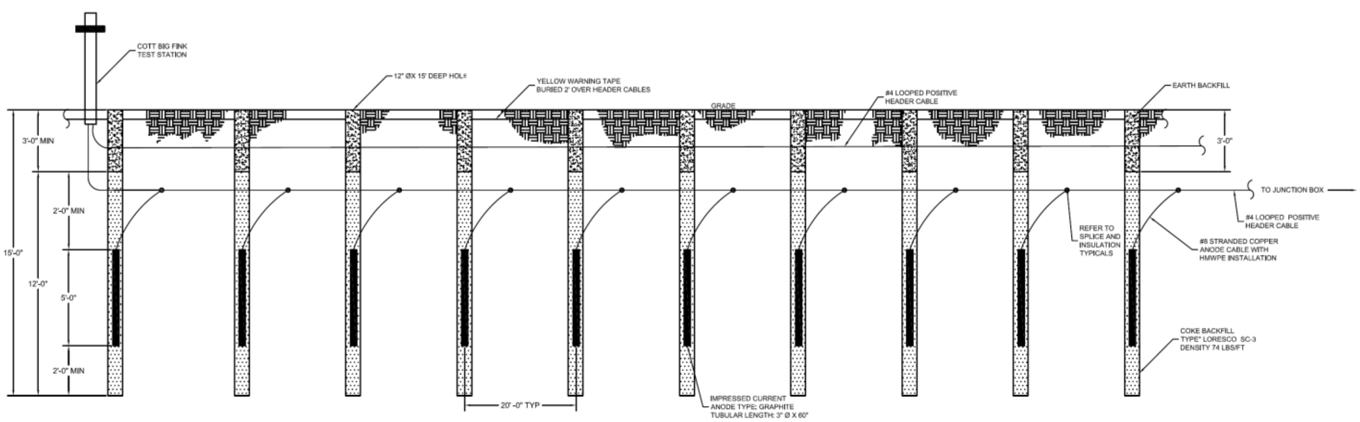

Figure 4: Typical Surface Distributed Cathodic Protection Groundbed System

Linear Anode Groundbed Systems

Linear anode systems at the VMT are comprised of linear conductive polymer anode manufactured by AnodeFlex™. These systems are installed parallel to the structure intended for protection and offer more discrete current distribution to the structure. At the VMT, this system is installed along the 48" A/B crude piping. It was installed to provide additional cathodic protection that the deep anode and surface distributed groundbed systems are not able to provide sufficiently.

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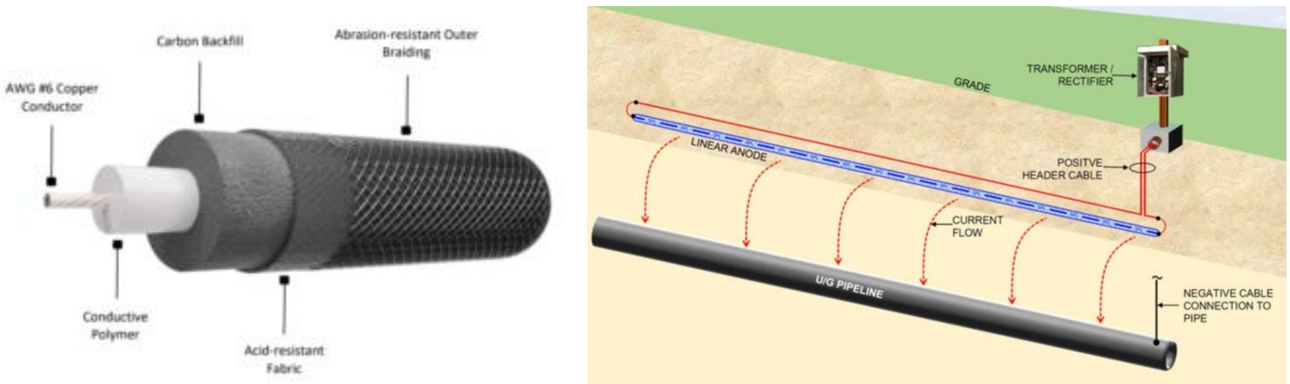

Figure 5: Typical Linear Anode Cathodic Protection Groundbed System

Cathodically Protected Structures

Cathodic protection at the VMT is intended for some or all of the buried piping (crude oil, ballast water, recovered crude, and fuel), tanks (internal and external), and loading/unloading berths. For the purpose of this report, only the crude oil piping and its associated cathodic protection systems were considered and studied.

Cathodic Protection System Age and Life Expectancy

Typical industry standard for cathodic protection system life is 20 – 30 years of service. This life expectancy is based on many factors such as: number of anodes, type of anodes, efficiency of the anode types, and overall current output/year (amp/yr) of the anode groundbed system. Most anode types are hindered by a maximum anode current output. Exceedance of this output can drastically diminish the anticipated life expectancy of the anode or groundbed system.

Cathodic Protection Monitoring and Testing

Cathodic protection monitoring is conducted in accordance with the Code of Federal Regulations (CFR) document 49 CFR 195 Subpart H “Corrosion Control” and National Association of Corrosion Engineers (NACE) document NACE SP0169 “Control of External Corrosion on Underground or Submerged Metallic Piping Systems.” Additionally, Alyeska maintains procedures and standards that are utilized for directives on cathodic protection monitoring and testing. These Alyeska procedures and standards will be discussed in further detail within this report.

Bi-monthly Rectifier Survey

Impressed current rectifiers providing cathodic protection to VMT crude piping are regularly monitored on a bi-monthly basis (at a minimum). Code requirements are to confirm rectifier operation six (6) times per calendar year, not to exceed 75 days between inspections. These inspections allow for confirmation that rectifiers are operating and offering cathodic protection. Additionally, rectifier voltage and amperages are recorded to track and trend any deviations from their normal, historical output.

Alyeska currently utilizes Mobiltex brand remote monitoring devices on all of these rectifiers within the VMT. These devices continually monitor operation of these rectifiers and transmit email and/or text message alerts to the Alyeska corrosion personnel when rectifiers stop operating or are operating above or below user-defined threshold levels. Additionally, Alyeska corrosion personnel can remotely view each rectifier and monitor them for any trends or changes in output.

Annual Cathodic Protection Survey

These surveys are performed each calendar year, not to exceed fifteen (15) months between survey intervals. Cathodic protection voltage potential measurements are obtained at predefined test stations and aboveground appurtenances (e.g., valves, piping manifolds) to get a representative overview of cathodic protection levels around the VMT. Pipe-to-soil potentials are obtained with the impressed current rectifiers in synchronized interruption cycles, so ON and Instant OFF (polarized) pipe-to-soil voltage readings can be measured. This data helps indicate if the cathodic protection systems are offering adequate protection against corrosion at these locations measured.

Cathodic protection measurements are obtained at fifty-four (54) test locations for the 48” Crude “A” and “B” piping and East and West metering sites for the 36” Relief and 48” Crude “A” and “B”.

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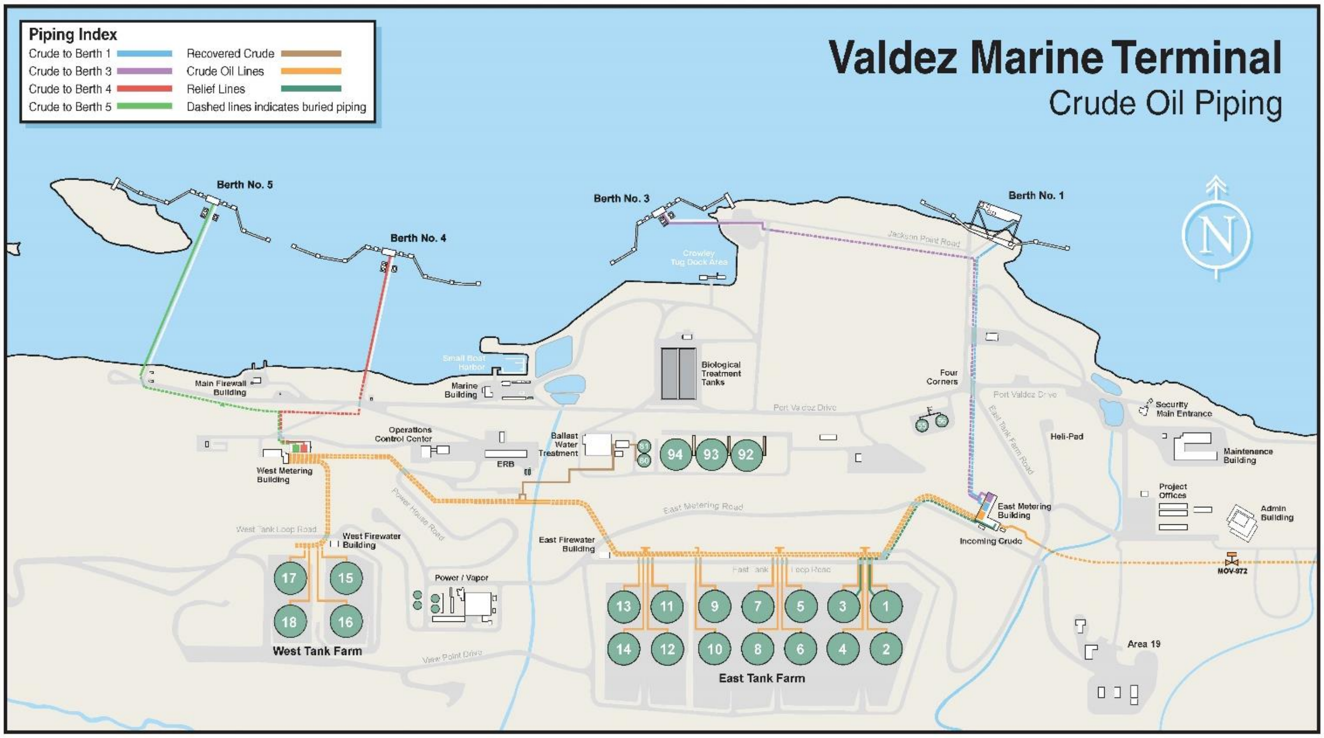

Figure 6: Overview of 48" A/B Crude Piping System at the VMT.

Note, this is a dated map. Berths 1 & 3 and the West Tank Farm are out-of-service – and the crude oil piping to those assets has been disconnected.

Annual Survey Observations and Comments

The 2016 – 2018 Annual Cathodic Protection data has discrepancies that conflict with regulatory requirements and industry standards. These conflicts are noticed in the application of acceptable criterion for adequate cathodic protection.

Polarized Potential -0.850 Volts Criterion

NACE SP0169 defines this criterion with the following definitions:

- Section 6.2.2.1.1 "A negative (cathodic) potential of at least 850 mV with the CP applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement."

Alyeska utilizes synchronous interruption of influencing rectifiers to eliminate these voltage drops to obtain polarized (Instant OFF) potentials for consideration of this criterion.

- Section 6.2.2.1.2 states "A negative polarized potential of at least 850 mV relative to a saturated copper/copper sulfate reference electrode."

The concern identified is that the polarized potentials that were measured are more negative than -1.150 Volts. NACE CP 3 Certification Manual states "evidence suggests a theoretical limit of the most negative true polarized potential of a structure in the presence of sufficient moisture is approximately -1.15V_{CSE}." Polarized potentials more negative than -1.150 volts are kinetically improbable and thus are indicative of "other factors" influencing these readings.

5A	At Grade; Tanks 9 and 10 Header Risers; T.S. 54-CTT-5	-0.904	-0.814	7/1/2016 12:00:00 AM
		-3.578	-1.549	11/30/2017 08:59:22 AM
		-3.919	-1.699	6/8/2018 09:05:53 PM

Figure 7: Example of Erroneous Polarized Potentials

The measurements highlighted above are examples of measured polarized potentials at an annual testing location. These polarized potentials are more negative than one can expect to experience and should be recognized as an abnormal condition by a qualified operator (CP technician).

Comments have been made that these high polarized potentials are due to proximity to existing linear anode systems. Granted, lingering voltage gradients from the linear anode may be present when these polarized readings are obtained. However, simply noting that they're not valid is not being prudent or proactive for maintaining adequate cathodic protection. Further testing and measurements can be utilized to help validate this data. Suggestions for complimentary testing and equipment to consider are:

1. Interruption of impressed current systems at extended OFF cycles to eliminate voltage gradients
    a. Utilization and analysis of waveforms to validate these interruption cycles
2. Utilization of CP measurement coupons to help validate these polarized potentials
3. Utilization of electrical resistance (ER) or ultrasonic testing (UT) probes to monitor corrosion rates for validation of adequate cathodic protection
4. Correlation of In-line inspections to monitor corrosion growth rates

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100 mV Polarization Criterion

In some instances, Alyeska has relied on the utilization of the 100 mV cathodic polarization criterion for determining adequacy for protection. This criterion is a supplemental criteria that is more intensive to test and utilize but has as much, if not more, merit in validating corrosion is being deterred. NACE SP0169 “Control of External Corrosion on Underground or Submerged Metallic Piping Systems” defines 100 mV criterion:

- Section 6.2.2.1.3 states “A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.”

Alyeska is justifying validation of 100 mV polarization based on old depolarized potential data (pre – 2016). In my experience, I see many operators trying to utilize and justify this method as being acceptable. However, professionally it is invalid and does not meet the intent of NACE and CFR standards and regulations. Depolarized potentials can vary over time due to many factors, such as: temperatures, moisture, soil chemistry and resistivity, pH levels, and the application of cathodic protection. Additionally, any changes to the system itself, such as: adding or removing piping, bonding to other structures, and/or recoating of piping can affect these values.

To properly utilize the 100mV polarization criterion, one should test and record this polarization decay or formation each time polarized potentials less negative than -0.850 volts are measured. Alyeska’s procedures (MP-166-3.23 paragraph 4.1.7) requires the level or polarization be measured by either the formation or decay of polarization for any location not meeting the -850 mV polarized criteria for CP.

Alyeska has utilized coupon test stations on their main pipeline systems, to some degree of confidence. Coupons are bare steel apparatuses designed to represent a typical coating fault on the structure. There are typically two (2) coupons as part of this assembly, one (1) is connected to the pipeline and CP system. The other coupon is allowed to freely corrode and represents a natural or native potential of steel for that environment. The coupon connected to the pipeline and CP system can be temporarily disconnected to measure the polarized potential of the coupon. This potential is assumed to be the same as the polarized potential of the pipeline at the same location. Utilization of coupon test stations within the VMT may be considered a viable option to resolve the shortcoming of lingering voltage gradients causing the typical potential measurements to appear more negative that kinetically possible. The coupons are typically unaffected by these voltage gradients causing errors in other measurements.

It is important to note, those measurement errors discussed previously very likely negate the validity of polarized potentials that are measured less negative than -0.850 volts. Hence, these errors bear uncertainty of any potentials measured within the VMT without further testing and clarification.

Bi-Monthly Rectifier Observations and Comments

Bi-monthly rectifier inspection data was not provided by Alyeska for the purpose of this report. However, Alyeska utilizes Mobiltex brand remote monitoring devices to continually track the operation of their facility rectifiers. This is a great tool that notifies personnel of non-functioning or out of parameter operations of these rectifiers and their impressed current systems. This helps assure reliability that cathodic protection systems continue to stay "on" and protecting assets.

Close-Interval Survey Observations and Comments

Close-interval survey (CIS) potentials were obtained on the 48" A/B Crude Header piping in 2018. CIS differs from annual survey measurements in that potentials are obtained continuously along the structure, as opposed to one singular location randomly along the structure. Typically, these measurements are less than 10 ft between readings and in most cases every 2.5 ft. The CIS allows for measurements between test points from the annual survey, to better determine what cathodic protection levels are along the entirety and not just spot locations.

A graph is typically generated to plot the "ON", "Instant OFF" or polarized potential, and a reference line showing -0.850 volt criterion threshold. The "ON" potential is when the cathodic protection system is energized. This reading is generally irrelevant as it has known measurement errors due to current flowing through resistance of the soil. The "Instant OFF" or polarized potential is more critical in validating adequate cathodic protection. Typically, one would look to have these polarized potentials between -0.850 volts and -1.150 volts. Those polarized potentials less negative than -0.850 volts (e.g., -0.750 volts) would be indicative of inadequate cathodic protection. Likewise, polarized potentials more negative than -1.150 volts (e.g., -1.300 volts) would be indicative of erroneous readings. Figure 8 shows a sample close interval survey graph one might expect to see.

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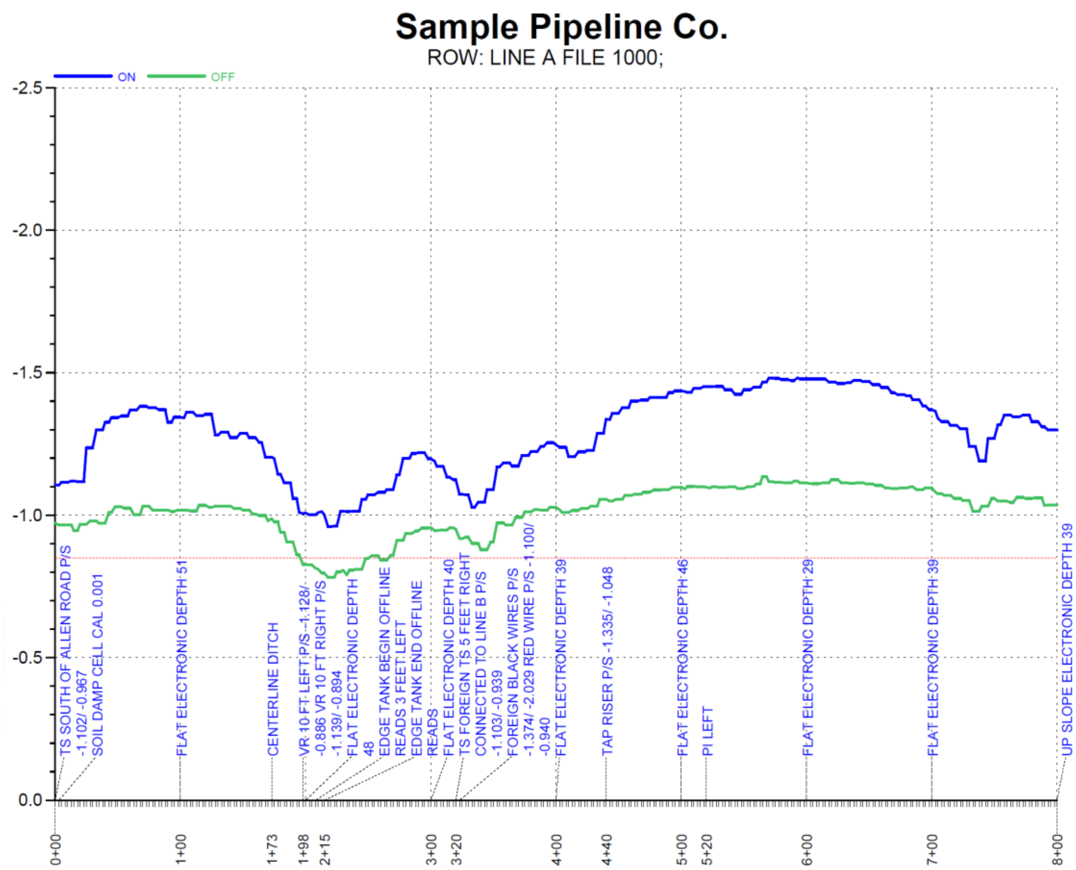

Figure 8: Sample Close Interval Survey Graph

In the case of the CIS that was provided by Alyeska, most of the "Instant OFF" or polarized potentials measured were more negative than -1.150 volts. And in many instances, these polarized readings are more negative than -1.500 volts. All of these readings from this CIS are impacted by the same errors previously discussed above and are thus inconclusive to the true cathodic protection levels along this piping.

Alyeska recognizes these potentials as being erroneous as they're adjacent to the AnodeFlex™ cathodic protection system. This is noted on their graph in a text box underneath the Legend that reads, "Areas with high instant-off readings are adjacent to AnodeFlex systems." The close proximity of the AnodeFlex cathodic protection to the pipeline inherently causes some voltage gradients to remain in the soil. Obtaining potential

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measurements within these voltage gradients causes readings to appear more negative than actual. The magnitude of the error will be based on the voltage gradient and may impact all CP readings, not just those that are obvious.

Low cathodic protection levels were documented in the Alyeska CIS graph at the east end of the crude piping system. These low potentials are approximately the last 50 ft of piping on the east end. Section 4.8 of MP-166-3.23 specifies depolarized potential measurements be obtained “at any monitored location that exhibited INSTANT OFF potentials more positive than -850 mV.” In a conference call with Alyeska personnel on March 10, 2021, Tom Van Muysen indicated these low potentials have already been addressed and remediated. We requested confirmation documentation during this meeting but this request still has not been provided by Alyeska. The PWSRCAC Terminal Operations and Environmental Monitoring Committee should request follow up confirmation that this has been addressed since 2018.

Integrity Management Reports

As part of this project, the 2017 Integrity Management report was reviewed for completeness and usefulness. In my professional opinion, this report is one of the best produced by a facility operator within the industry. It is very comprehensive and organized for easy delineation of the different programs associated with Integrity Management. The RIM Action Tracker is a useful tool for tracking projects and remediation.

Review of Cathodic Protection Procedures

Cathodic protection procedures for the VMT crude piping and storage tanks were reviewed for completeness, applicability to current standards and engineering practices, and uniqueness to the facility and the environment.

Applicable procedures for cathodic protection that were provided by Alyeska and reviewed for this project are:

- MP-166 “Integrity Management Monitoring Programs Manual"
- MP-166-3.03 “Facility Corrosion Integrity Monitoring”
- MP-166-3.07 “Bimonthly Inspection for Rectifiers and Other Devices”
- MP-166-3.23 “Facilities Cathodic Protection Systems”

The following procedures were not provided and thus not reviewed for this project:

- MP-166-3.05 “Cathodic Protection Monitoring Data Analysis”
- MP-166-3.09 “Valdez Marine Terminal Cathodic Protection Systems”

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MP-166 “Integrity Management Monitoring Programs Manual”

This document provides the general direction and guidance for personnel and management for implementing Integrity Management principles and processes for ensuring accurate and reliable condition assessment of piping and structures.

This document appears to be adequate for the purpose of this review.

MP-166-3.03 “Facility Corrosion Integrity Monitoring”

This procedure identifies the process for defining work scopes, identifying regulatory inspection requirements for aboveground and belowground piping, and maintaining records generated by inspections.

This procedure appears to be adequate for the purpose of this review.

MP-166-3.07 “Bimonthly Inspection for Rectifiers and Other Devices”

This procedure identifies the process for monitoring rectifiers of Impressed Current Cathodic Protection systems (ICCP) and cathodic protection electrical bonds and diodes between two or more structures. The rectifiers provide the energy and power to operate the ICCP and thus are monitored regularly to ensure operation for supplying cathodic protection.

Cathodic protection electrical bonds are physical wired connections between two or more structures that are not typically electrically continuous. These bonds are typically installed to mitigate any stray current interference between structures or for providing additional cathodic protection to a structure that is deficient of adequate protection. These are bonds are monitored regularly to ensure operation.

This document adequately reflects the Federal Requirements for proper evaluation of these systems.

The only suggestion for improvement to this procedure is to standardize proper hookup of data measurement meter leads. It is simply noted to identify where the positive lead of the meter is connected to. Standardizing to place the negative or positive lead to the company or foreign side of the bond could help eliminate any current direction misinterpretations.

MP-166-3.23 “Facilities Cathodic Protection Systems”

This procedure identifies the process for performing annual Cathodic Protection monitoring of all cathodically protected structures for Alyeska and thus includes Valdez Marine Terminal.

Section 4.8 of this document specifies depolarized potential measurements be obtained “at any monitored location that exhibited INSTANT OFF potentials more positive than -850 mV.” Hence, Alyeska is not adequately following their own procedure for validating out of criteria INSTANT OFF or polarized potential measurements from their surveys or testing.

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Conclusion and Recommendations

Generally, the processes and procedures implemented by Alyeska for cathodic protection implementation and monitoring are adequate and within standard industry practices and Federal guided requirements. In many instances, it appears Alyeska is proactive and pre-emptive with their CP program and maintenance. The utilization of remote monitoring systems for continuous monitoring and evaluation of CP systems is commended. Usage of test coupons to help determine accurate potential measurements is acknowledged, although it is not as prevalently used in the VMT as it appears to be on the pipeline.

Annual reporting for integrity management is exceptional and well documented. This report allows for tracking of maintenance and compliance items identified and addressed in said report.

Conversely, there are a few significant exceptions to how Alyeska is actually implementing these processes and procedures that are of concern. Measurement, interpretation, and validation of test point survey and close interval survey data is insufficient. There appears to be a lack of effort to truly identify accurate polarized potentials on the crude piping within the VMT. Excessive polarized potentials are observed and recognized by Alyeska CP personnel, but they're discounted as being influenced by the nearby linear anode's voltage gradient. Further testing and justification should be performed to help justify these potential measurements. It is not an easy task and may still be inconclusive, but additional data and testing is more prudent.

This inherently inaccurate polarized potential data continues to create further error in the application of the alternative criteria for 100 mV polarization. The formation or decay of 100 mV of polarization must be tested when the collected polarized potentials are measured. Typically, the decay of 100mV polarization is measured when polarized potentials less negative than -0.850 volts is measured. This decay should be tested within weeks of discovery.

If Alyeska wishes to utilize historical depolarized potential data for consideration of the 100 mV polarization criteria, further justification should be presented for validation of this process and should be documented in their ensuing processes and procedures. Some acceptable justifications could include:

1. Monitoring of corrosion rates through the utilization of coupons, ER probes, and/or UT probes.
2. Monitoring of corrosion rates through regularly scheduled inline inspection tool inspections.
3. Utilization of potential measurement coupons on the crude piping within the VMT.

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Overall, my professional opinion is Alyeska has a very good corrosion and cathodic protection program for the VMT. Some additional effort on their part to recognize and acknowledge some of the discrepancies identified in this report will only help to ensure safe, reliable operation of the crude piping system at the VMT.

The following table summarizes the recommendations and action items discussed in this report.

Task #	Description of Problem	Action Item/Recommendations
1	Polarized potentials in excess of -1.150V due to close proximity of linear anode systems	Investigate alternative testing methods and/or measurement equipment to validate erroneous polarized potentials. Suggestions for alternate testing methods are described on Page 11 of this report.
2	Utilization of “old” depolarized potentials for meeting 100 mV polarization criteria	Modify policy to define a time period when to measure the formation or decay of polarization each time polarized potentials fail the -0.850 volt criterion. Polarization should be measured within weeks’ of discovery of failed potentials. Consider alternative testing methods and/or measurement equipment for obtaining depolarized potentials, such as coupons, as discussed on Page 12 of this report.
3	Inadequate polarized potentials on east metering end from close interval survey (CIS) graph	Alyeska to provide follow up testing or documentation to support resolution of these failed potentials.
4	Procedure MP-166-3.07 “Bimonthly Inspection for Rectifiers and Other Devices” modification.	Recommend to standardize proper hookup of data measurement meter leads. It is simply noted to identify where the positive lead of the meter is connected to. Standardizing to place the negative or positive lead to the company or foreign side of the bond could help eliminate any current direction misinterpretations.

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Works Referenced

R.A. Gummow, P.Eng. (November 2003) COR-03-9146-A "Review of the Cathodic Protection Design for the Bottom External Surfaces of Crude Oil Storage Tanks at the Valdez Terminal, Alaska"

R. Heidersbach (December 20, 2012) "Corrosion Survey of Valdez Marine Terminal"

Alyeska Pipeline Service Company (April 6, 2016) System Integrity Monitoring Program "2015 Annual Report on Cathodic Protection Monitoring"

Alyeska Pipeline Service Company (2016) Integrity Management "2016 Annual Report Facility Integrity"

Alyeska Pipeline Service Company (2017) Integrity Management "2017 Annual Report Facility Integrity"

Alyeska Pipeline Service Company RO-245 "Valdez Marine Terminal Cathodic Protection Systems Rectifier Operations Manual"

Alyeska Pipeline Service Company MP-166, Ed. 5, Rev. 2 (December 3, 2019) "Integrity Management Monitoring Programs Manual"

Alyeska Pipeline Service Company MP-166-3.03, Rev. 21 (November 27, 2019) "Facility Corrosion Integrity Monitoring"

Alyeska Pipeline Service Company MP-166-3.07, Rev. 25 (February 6, 2018) "Bimonthly Inspection for Rectifiers and Other Devices"

Alyeska Pipeline Service Company MP-166-3.23, Rev. 15 (November 18, 2019) "Facilities Cathodic Protection Systems"

National Association of Corrosion Engineers (NACE) CP-3 Cathodic Protection Technologist (January 2010)

T.J. Barlo and R. R. Fessler (Houston, TX: NACE, 1983) "Interpretation of True Pipe-to-Soil Potentials on Coated Pipelines with Holidays," CORROSION/83, paper no. 292.