CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

Canadian Gas Association

Recommended Practice

OCC–1–2013

Control of External Corrosion on Buried or Submerged Metallic Piping Systems

Distributed by Canadian Gas Association OCC-1 Task Force

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ASSOCIATION CANADIENNE DU GAZ

This "Recommended Practice" applies to the control of external corrosion on buried or submerged metallic piping systems. This Recommended Practice is intended as a reference only. It is a company's own responsibility to produce procedures that will satisfy all regulations and their own requirements for effective, safe, and proactive corrosion control.

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OCC-1-2013 supersedes OCC-1-2005.

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RECOMMENDED PRACTICE OCC-1-2013

Control of External Corrosion on
Buried or Submerged Metallic Piping Systems

SECTION 1: GENERAL

1.1 Introduction

The Recommended Practice OCC-1-2013 has been produced by the Canadian Gas Association OCC-1 Task Force. It presents the essential requirements and minimum practices to control external corrosion found on buried or submerged metallic piping systems. These systems consist of pipe and associated components. However, it does not include the requirements and practices to control external corrosion found on above ground piping systems and structures. It does not address the control of internal corrosion. Appendix D lists related standards and practices that either complement or are referenced in this document. Users shall use the most up-to-date version of these standards and practices.

1.1.1 Scope of the Recommended Practice

The intent of Recommended Practice OCC-1-2013 is to provide companies with guidance and direction when they develop and maintain external corrosion procedures for buried or submerged piping systems. The practices contained in this document apply to steel, cast iron, ductile iron, copper, and aluminum piping systems.

Corrosion control requirements within this document are for piping that is active or inactive; until it is abandoned and is considered incapable of delivering product.

Coatings and cathodic protection are the methods used to control external corrosion. This Recommended Practice details minimum requirements for the design, installation, operation, and maintenance of both coating and cathodic protection systems. Methods for the detection of external corrosion and the requirements for corrosion control records are also included.

Information that is considered supplemental or may be subject to more frequent revision has been incorporated into the appendices.

In the context of this Recommended Practice, the term "shall" defines minimum practices. "Should" is used for practices that are recommended, and the term "may" is used for practices considered optional.

Appendix A provides definitions for certain terms contained within this Recommended Practice. For easy identification these terms have been italicized.

1.1.2 Application of Corrosion Control

The provisions of this Recommended Practice shall be applied under the direction of a person who is competent in the practice of corrosion control, as it applies to buried or submerged metallic piping systems.

1.1.3 Deviation from Recommended Practice

Deviation from this Recommended Practice may be warranted in specific situations. This should only be done by personnel competent in the control of corrosion found on buried or submerged metallic piping systems and who can demonstrate that the intent of this practice has been achieved.

1.2 External Corrosion Control Practices

1.2.1 New Piping Systems

Requirements for corrosion control shall be considered during the design of a piping system. All new piping systems shall be externally coated and cathodically protected. The installation of cathodic protection shall be done as soon as practicable and shall be energized no later than 12 months after pipe installation.

1.2.2 Existing Coated Piping Systems

Cathodic protection shall be provided and maintained on all existing, coated piping systems.

1.2.3 Existing Bare Piping Systems

Where external corrosion is found to be present, studies shall be made to determine the extent and susceptibility of external corrosion on existing bare piping systems. Where these studies conclude a significant risk to the safe or economic operation exists, piping shall be cathodically protected, rehabilitated, or replaced.

2.1 Introduction

This section describes design practices for the selection and evaluation of coatings and cathodic protection systems. Also discussed are considerations for facilitating in-line inspection and AC mitigation. The design of piping systems includes various auxiliary facilities. These are discussed in sub-section 3.3.4.

2.2 Coatings

2.2.1 General

For buried or submerged piping, an external protective coating is the first line of defense against corrosion. Its primary function is to physically isolate a reactive material, such as steel, from the electrolyte, such as the soil surrounding it, thus eliminating opportunities for corrosion to occur.

Properly applied coatings also help to reduce cathodic protection current requirements and improve current distribution as less metal is exposed to the electrolyte.

2.2.2 Selection and Evaluation

Coatings shall be selected after a careful analysis of the specific characteristics of each piping system to be coated by competent personnel.

The list of coating properties that shall be considered include, but are not limited to:

- Cathodic disbondment
- Adhesion
- Water absorption
- Water vapour transmission
- Flexibility
- Impact resistance

- Wear abrasion
- Gouge resistance
- Temperature resistance
- Dielectric strength
- Chemical resistance
- Microbial resistance
- Soil stress
- Plant and field applied coating compatibility

For plant-applied fusion bond epoxy and polyethylene applied externally to steel pipe, CSA Z245.20 Series 10, Plant-applied external coatings for steel pipe, shall be followed.

Considerations for coating specifications can be found in the CSA standard Z662, Oil and gas pipeline systems, section 9.2, Selection of external protective coatings for buried or submerged piping, and Annex L, Alternative or supplementary test methods for coating property and characteristics evaluation.

2.3 Cathodic Protection

2.3.1 General

The purpose of cathodic protection is to provide effective corrosion control that satisfies the requirements outlined in Appendix B, "Criteria for Cathodic Protection". Cathodic protection is provided by impressed current and/or galvanic anode systems.

The Canadian Electrical Code, Part I (CSA Standard C22.1, Section 80 – Cathodic Protection) shall be used for electrical design.

2.3.2 Cathodic Protection Design Requirements

In the design of a cathodic protection system, the following shall be considered:

a) Sufficient direct current shall be provided and distributed so that the selected criteria for cathodic protection are achieved throughout the piping system. See Appendix B "Criteria for Cathodic Protection" of this Recommended Practice.

b) Interference currents to foreign structures shall be either eliminated or minimized so that the selected criteria for cathodic protection are attained. See Appendix C, "Control of Direct Current Interference".

c) Cathodic protection is required for the life of the piping system. This may require periodic rehabilitation or replacement of the cathodic protection system components.

d) Cathodic protection anodes, associated cables, rectifiers, and test stations should be placed where the possibility of disturbance and damage to the facility will be minimal, and permanent access is available.

2.3.3 Selection of Cathodic Protection Systems

Various design requirements and factors to be considered when selecting either a galvanic or an impressed current system include, but are not limited to, the following:

- Availability of electrical power
- Initial and projected current requirements
- Costs, which include initial capital, operation, and maintenance
- Physical characteristics of the environment such as electrolyte resistivities, foreign structures, and surface conditions
- Mitigation and management of interference effects

- Physical space limitations and easement or right-of-way procurement
- Future changes to the piping system, and right-of-way development
- Electrical isolation

2.3.3.1 Galvanic Anode Systems

2.3.3.1.1 General Description

Galvanic anode systems do not require an external power source because of the natural potential difference that exists between a galvanic anode and a coated, metallic piping system. Cathodic protection current is provided by galvanic anodes, which are connected to the piping system by insulated wires. These wires may be directly connected to the pipeline or brought up to a test station as necessary to evaluate cathodic protection performance.

2.3.3.1.2 Galvanic Anodes

Galvanic anodes are manufactured in different shapes and sizes from materials such as magnesium, zinc or aluminum alloys. The chemical composition and the current efficiency of the materials used are factors that will affect the performance of the galvanic anode.

The materials should conform to the appropriate standard (e.g. ASTM B843 and ASTM G97 standards for magnesium, and ASTM B418 standard for zinc).

In most cases, a special low-resistivity chemical backfill consisting of gypsum, bentonite and sodium sulfate is used to enhance performance and prevent passivation of the galvanic anodes.

The efficiency of the galvanic anodes will also be affected by the electrolyte conditions, as well as the characteristics of the structure to be protected.

2.3.3.2 Impressed Current Systems

2.3.3.2.1 General

Impressed current systems consist of an external direct current source connected to impressed current anodes and the piping system by insulated cables. The anodes are connected to the positive terminal of the direct current source. The piping system is connected to the negative terminal of the direct current source. Correct polarity of these connections is critical.

As-built drawings of impressed current systems shall be kept in accordance with Sub-section 6.2.2 of this Recommended Practice. A drawing showing the location of underground wiring, polarity and anodes shall be kept inside the rectifier cabinet or in a location near the cabinet.

Warning signs near the direct current source and cables shall be prepared in accordance with all applicable regulations, codes, including The Canadian Electrical Code, Part I (CSA Standard C22.1, Section 80 – Cathodic Protection). Consideration should be given to including company identification and emergency telephone numbers on warning signs.

2.3.3.2.2 Direct Current Sources

Direct current sources for impressed current systems include:

- Rectifiers powered by alternating current supplied by an electrical utility

- Generators
- Solar energy sources
- Thermoelectric generators
- Fuel cells
- Batteries

2.3.3.2.3 Impressed Current Anodes

Impressed current anodes are usually manufactured from material such as high silicon cast iron (HSCl), graphite, lead-silver alloy, precious metals (e.g. MMO, titanium), steel, or conductive polymers.

Anodes must be connected to the positive side of the direct current source with insulated cables. The anodes are installed either individually or in groups as remote, distributed, or continuous ground beds.

A special backfill consisting of coke (metallurgical, petroleum, or graphite) is typically used to enhance performance. The backfill material may be supplied loose or prepackaged with the anode.

Venting may be required to avoid possible detrimental effects of entrapped anodic reaction gases (e.g. in deep vertical ground beds).

2.3.3.3 Electrical Isolation

Where contact with foreign metallic structures may adversely affect cathodic protection or cause a corrosion condition to exist, piping systems should be electrically isolated from such structures. Foreign structures may include the following:

- Pipe supports

- Bridge structures
- Tunnel enclosures
- Pilings
- Reinforcing steel in concrete (e.g. river weights and weight coatings)
- Pipe anchors
- Metallic curb boxes, valve boxes or other metallic enclosures
- Electrical grounding systems

Note: Because electrical continuity within a cathodically protected structure is necessary, consideration shall be given to the electrical properties of non-welded joints to determine if bonding is required.

2.3.3.3.1 Separation from Foreign Structures

Separation is necessary between underground piping systems and foreign structures. In order to ensure electrical isolation, a minimum 0.3 m separation distance should be maintained between these structures. Where this separation cannot be maintained, electrical isolators can be placed between the structures in a manner that would prevent shielding. This separation/isolation does not necessarily preclude the use of electrical bonds for the control of cathodic protection direct current.

2.3.3.3.2 Within a Piping System

Electrical isolation may be necessary within an electrically continuous piping system. For example, typical locations where electrical isolation devices may be considered are:

- Changes of facility ownership
- Connections to mainline piping systems, such as gathering or distribution laterals
- Inlet and outlet piping at stations or facilities, such as metering, regulating, compressor, or pumping stations
- Well heads
- Termination of service pipeline connections
- Facility entry points to prevent electrical continuity with other metallic systems
- Junction of dissimilar metals for protection against galvanic corrosion
- Junction of bare and coated pipe
- Locations that sectionalize or separate cathodic protection systems for monitoring and maintenance purposes
- Stray current areas

2.3.3.3.3 Casings

Casings can pose future maintenance issues and should be avoided when possible. However, if required as part of the piping system, the pipeline shall be electrically isolated from the casing.

Electrical isolation can be achieved by the correct use of spacers and end seals, and consideration may also be given to using inert casing filler that prevents corrosion on the carrier pipe. Casing end seals shall be installed to prevent the entry of foreign matter into the casing.

Provisions shall be made to monitor the electrical isolation between the casing and carrier pipe.

2.3.3.3.4 Safety Practices

Installation of isolation devices should be avoided in areas in which combustible atmospheres are likely to be present. When these devices are found in such areas they should be safeguarded. Above ground isolation devices include, but are not limited to, isolation kits in flanges and isolating unions. The need for lightning and fault current protection at isolating devices should be considered.

Where pipeline facilities exist in proximity to electric power facilities, effects shall be assessed for coordination/adverse interaction by a competent engineer per CSA C22.3 No. 6, IEEE 80, and other applicable design practices.

2.3.3.3.5 Coordination of Cathodic Protection Design and Electrical Grounding Design

Close proximity of copper grounding and structures intended for cathodic protection shall be avoided in the electrical design. Where grounding is required in proximity to piping, alternative materials shall be considered, such as coated copper cable and steel, zinc or aluminum ground electrodes in areas containing buried structures intended to receive cathodic protection. The presence of bare copper in close proximity to structures requiring cathodic protection may make protection difficult to achieve.

2.3.3.3.6 Coordination of Cathodic Protection Design and Electrical Utility Design

Caution is advised where electrical utility design requests electrical continuity with the buried piping system. Such electrical continuity with the utility's facilities and potentially its customers may make protection difficult to achieve.

2.3.3.3.7 Structural Supports and Pilings

Electrical continuity between buried piping and a large number of steel pilings may make cathodic protection difficult to achieve.

2.3.3.4 Auxiliary Facilities

2.3.3.4.1 Test Stations

Test stations shall be provided to ensure effective testing or monitoring of cathodic protection performance.

Such locations may include, but are not limited to, the following:

- Pipe casing installations
- Foreign metallic structure crossings and tie-ins
- Isolation joints
- Waterway crossings
- Bridge crossings
- Valve, regulating and meter stations
- Steel distribution risers
- Galvanic anode installations
- Road and railroad crossings
- Transitions between dissimilar metals and/or non-metallic piping
- At regular intervals (such as 2 km) or as required
- Isolated sections of metallic piping that do not come above ground at any point

All test station materials, connections and locations shall be suitable for the site conditions where they are installed. Piping system locations subject to hazardous induced AC voltages that have been identified by test results, and are defined in CSA Standard C22.3 No.6, shall have test stations with dead front construction.

2.3.3.4.2 Wires and Cables

Insulated wires and cables are used as electrical conductors for cathodic protection systems and corrosion control monitoring. Typically they are used for anode lead wires, impressed current positive and negative leads, test station leads and various types of continuity and interference control bonds. Selection of suitable conductors and connection methods shall meet all local and national electrical codes. The following factors shall also be considered:

a) Conductors shall be sized according to expected current and voltage drop requirements and suited for direct burial.

b) Wire to wire, or cable to cable connections are typically made with split bolts or positive compression crimps. Such connections shall be suitably coated to maintain the integrity of the wiring insulation system.

c) To ensure no damage occurs to the piping system, the physical characteristics and operating conditions of the structure shall be considered when selecting a method of connection. This would include the following:

- Piping system material
- Wall thickness
- The possibility of pipe wall defects

- Operating pressure (including during the connection procedure)

d) Methods to connect copper conductors to steel and other ferrous pressure piping include thermite welding, pin brazing, and mechanical means. Refer to Sub-section 3.3.4.2. for specific details.

e) Methods to connect aluminum conductors to aluminum piping systems include high energy joining, welding and mechanical means. Refer to Sub-section 3.3.4.2. for specific details.

f) Methods to connect copper conductors to copper piping systems include arc welding (TIG, MIG, shielded metal), electrical resistance welding, brazing, soldering and mechanical means. Refer to Sub-section 3.3.4.2 for specific details.

g) Connections shall be mechanically secure and electrically conductive. When specifying mechanical connectors care is required to guard against connections which loosen, become highly resistant or lose electrical conductivity. This is especially important in the cathodic protection circuit.

h) Connections shall be sealed to prevent moisture penetration and corrosion.

i) Conductors shall be specifically identified as connected to either the piping system or anodes.

2.4 Other Considerations

2.4.1 In-Line Inspection

To monitor the effectiveness of corrosion control facilities, consideration should be given to the design of piping systems to facilitate and accommodate the use of in-line inspection tools. Such designs should include the use of full open bore valves, the installation of tool launching and receiving traps and exclusion of reducers and tight radius bends that may prevent the use of in-line inspection tools.

2.4.2 Alternating Current Corrosion

AC corrosion may be caused by the exchange of alternating current (AC) between a metallic structure and an electrolyte. This current flows as the result of an AC potential difference between the structure and the electrolyte, where this potential difference may be due to either an induced AC voltage on the pipeline, or an AC voltage gradient in the soil.

AC corrosion can occur on structures which are cathodically protected according to industry standards, and generally cannot be mitigated by applying increased amounts of cathodic protection current. In fact in some cases, AC corrosion rates have been found to increase as cathodic protection potentials become more electronegative.

While the mechanism of AC corrosion is still not completely understood, it is generally accepted that both the risk of AC corrosion and AC corrosion rates increase with increasing AC current densities, and that there may be a current density threshold below which AC corrosion will not occur.

3.1 Introduction

This section describes the installation and inspection procedures for coatings and cathodic protection facilities. These procedures will help to ensure optimum performance in the corrosion control of metallic piping systems.

3.2 Installation and Inspection of Coating Systems

3.2.1 Application

Coating systems shall be applied in accordance with the appropriate CAN/CSA Z245 and Z662 series standards. When CSA standards do not exist for a specific type of coating, an applicable industry or company standard or specification shall be used. The specification or standard should include details regarding coating materials and their storage, application procedures, production inspection, production testing and coating repair.

Consideration should also be given to the requirements for identification, handling and storage of coated pipes and the associated certificates and test reports.

New coatings and coating application procedures are continuously being developed. A discussion of each coating and its associated application and installation procedures are beyond the scope of this Recommended Practice. When selecting a coating, recent developments should be considered.

3.2.2 Installation

Prior to backfilling, the entire pipe surface, including the girth weld area, shall be coated. Girth welds shall be coated with a material that is compatible with the pipe coating.

Coated pipe shall be installed in a manner that minimizes damage to the coating by using equipment and procedures that are compatible with the coating system.

The ditch bottom and the backfill materials contacting the pipe should be free from rocks, frozen lumps of soil and other foreign matter that would damage the coating during pipe installation or during service. Special ditch preparation, backfilling procedures and backfill materials may be required to minimize coating and pipe damage.

If rock guards, shields, foam, etc. are used to provide additional mechanical protection to coating, consideration shall be given to the possible creation of cathodic protection shielding.

If insulation materials are used to provide temperature control, consideration shall be given to minimize the risk of cathodic protection shielding.

3.2.3 Inspection

Competent personnel shall be used to inspect the coating application and the installation of coated pipe. The coating shall be inspected for unacceptable flaws just prior to installation in the ditch. The preferred method of inspection is by using a holiday detector. The holiday detector shall be appropriate for the pipe size and the electrical characteristics of the coating material.

Unacceptable coating flaws shall be repaired and re-inspected prior to installation of the pipe in the ditch.

3.3 Installation and Inspection of Cathodic Protection Systems

3.3.1 Introduction

To ensure the proper installation of cathodic protection systems, construction specifications and drawings shall be prepared in accordance with regional and/or company requirements.

All installation and inspection of cathodic protection systems shall be performed by competent personnel.

All materials supplied shall be inspected for defects and to ensure conformance to manufacturer and company specifications.

"As-built" drawings shall be made and kept in accordance with Section 6.2.2, and shall reflect the most up-to-date status of the system.

3.3.2 Impressed Current Systems

3.3.2.1 Rectifiers and Power Sources

Rectifiers and power sources shall be inspected to ensure that electrical connections are mechanically secure, electrically conductive and that no damage exists. The rating of the direct current power source shall comply with design specifications.

This installation shall comply with local and national electrical codes and the requirements of the utility supplying power. In all cases, a lockable external disconnect switch shall be provided in the A.C. circuit and the rectifier case shall be properly grounded. All personnel performing any rectifier tasks shall complete suitable safety training to be able to recognize and manage safety risks. Note that some provinces require specific certifications be completed in this regard. Some operators have found that company specific training, procedures, and low voltage interruption plug installations to be useful in minimizing worker exposure to hazardous voltages or arc flash.

After energizing the system, the polarity of the connection shall be verified by measuring the pipe-to-soil potential, paying particular attention to the polarity of the reading. This is done to ensure that the positive connection is made to the anodes and the negative connection is made to the piping.

The output of the rectifier or the direct current power source shall be adjusted to satisfy the selected cathodic protection criteria. Refer to Appendix B, "Criteria for Cathodic Protection. Consideration should be given to conducting a baseline cathodic protection, coating, and/or stray current survey on the newly installed pipeline and adjacent structures.

3.3.2.2 Impressed Current Anodes

Prior to installation, impressed current anodes shall be inspected for damage and inspected for conformance to specifications concerning anode material, size, length of lead cable, anode lead connection, and integrity of seal. All cables should be carefully inspected to detect defects in insulation. Any defects shall be repaired.

Anodes should be centered in a backfill material in a manner to eliminate voids. Backfilling procedures shall ensure that breakage and other anode damage do not occur.

Whenever possible, anodes should be installed below the typical frost line depth. The native soil backfill and padding shall be free of rock and foreign material that could damage the anodes or wires.

3.3.3 Galvanic Anode Systems

Galvanic anodes should be inspected as detailed in Section 3.3.2.2. In addition, the following precautions may apply:

a) Prepackaged anodes shall be kept dry during storage.

b) Prior to installation, waterproof anode wrappers shall be removed.

c) Anodes may be wetted to activate the anode more quickly.

d) Coatings used on the internal surface of bracelet anodes, should be inspected and damage repaired prior to installation.

e) When installing bracelet anodes, the pipe coating under the anode shall be free of holidays. Care should be taken to prevent damage to the coating when installing bracelets anodes.

f) If concrete is applied to the pipe surface, all traces of concrete shall be removed from the surface of the anode bracelet. If reinforced concrete is used, there shall be no metallic contact between the anode and the reinforcing mesh, or between the reinforcing mesh and the pipe. The outside diameter of the bracelet anode should not exceed the outside diameter of the concrete coating.

3.3.4 Auxiliary Facilities

3.3.4.1 Wires and Cables

All wires and cables shall be inspected for defects in insulation and care should be taken to avoid damage to cable and wire insulation. Insulation defects that may jeopardize the operation of the system shall be repaired. Damage to the anode wire insulation may cause failure of the wire due to corrosion.

Sufficient slack should be provided to avoid strain on all cables and wires. Backfill around the cable shall be free of rocks and foreign matter that may cause damage to the insulation.

3.3.4.2 Connections

The number of underground splices on the positive lead wire header cable to the anode bed shall be kept to a minimum. Connections between the header cable and the conductors from the anodes shall be mechanically secure and electrically conductive. Connections which are buried or submerged shall be sealed to prevent moisture penetration.

Connections of wires and cables to the piping system shall be in accordance with the methods specified in Section 2.3.3.4.2. The pipe surface and lead wire shall be clean and dry prior to attachment. Thermite weld connections to steel pipe using a specially designed low-temperature copper oxide and aluminum charge shall be limited to one standard 15 g cartridge per connection, as per CSA Z662 Section 9.8.5. Thermite weld connections to cast iron pipe using a low-temperature shall be limited to one standard 25 g Pipe Cast Iron (PCI) cartridge per connection.

Where the application involves the attachment of a conductor larger than No.6 AWG, a multi-strand conductor shall be used and the strands shall be arranged into groups no larger than No.6 AWG, as per CSA Z662 Section 9.8.8. Each group shall be attached to the pipe separately. Consideration shall be given for the location of multiple thermite welds to avoid interaction of the heat affected areas.

Aluminum tabs, with TIG (Tungsten Inert Gas shielded arc) welded conductors can be attached to aluminum pipe by an explosive bonding technique called HEJ (High Energy Joining). Aluminum test wires can be welded to aluminum pipe using either the TIG or MIG (Metal Inert Gas shielded arc) process. All test wire welding should be made to flanges or at butt weld joints where the material thickness is more suitable for welded connections. Thermite welding on aluminum pipe, copper pipe, or components is not allowed.

Attention should be given to the method of attaching wires and cables to copper pipe to avoid possible embrittlement or loss of mechanical properties of the metals from the heat of welding or brazing. Flux residues shall be removed.

Mechanical connections shall be secure and electrically conductive. Care shall be taken to minimize bi-metallic coupling between the connector materials, cable and the pipe and to ensure the connection area is sealed against moisture.

Wire and cable connections shall be coated with an insulating material that is compatible with the pipe coating and the wire or cable insulation.

Alternate methods of connections include pin brazing, stainless steel banding, etc.

All above ground connections shall be protected against atmospheric degradation.

3.3.4.3 Casings

Test wires and test station(s) shall be installed to confirm the insulation integrity between the casing and carrier pipe.

3.3.4.4 Test Stations

Test stations should be in an accessible area without creating an obstacle or becoming subject to unintentional damage.

3.3.4.5 Bonds

Bond connections to other structures or across insulating devices shall be mechanically secure, electrically conductive and suitably coated. Interference bonds shall be accessible for testing and monitoring.

3.3.4.6 Below Ground Electrical Isolation

Test wires and test stations shall be installed where electrical isolation devices (e.g. in-line isolators, insulating flange sets, dielectric unions) are used.

3.3.5 Inspection

At the time of installation, the effectiveness of all auxiliary facilities shall be confirmed.

4.1 Introduction

This section provides an outline for the operation and maintenance of corrosion control systems. It provides guidance to assess the condition of external coatings, the effectiveness of cathodic protection, and the requirements for remedial action.

4.2 Coatings

4.2.1 Visual Examination During Excavations

Whenever buried piping is exposed, it should be visually inspected for condition of the coating and signs of corrosion.

The results of a coating examination will determine whether re- coating or a coating repair is required.

The following are some of the most common coating defects that may be observed during visual examination:

- Disbonded coating
- Holidays or blisters
- Wrinkling or tenting
- Mechanical damage, caused by equipment or backfill material
- Cracking or spalling
- Missing coating

Where corrosion is found, it shall be assessed as detailed in Sub-section 5.3.

4.2.2 Above Ground Surveys

Under certain conditions it is possible to evaluate the performance of external coatings and detect the existence of coating defects by the use of above ground survey techniques.

These above ground methods include AC and DC Voltage Gradient Surveys, DC pipe-to-soil potential surveys, coating conductance surveys, and electromagnetic field loss evaluation surveys.

In AC and DC Voltage Gradient Surveys, current is applied to the pipeline, which then returns to the source ground via coating holidays. Peaks in the voltage gradient indicate the location of coating holidays.

DC pipe-to-soil potential surveys with close-interval spacing may indicate the presence and general location of coating holidays at significant potential depressions.

Coating conductance surveys involve the measurement of pipeline currents and voltage drops to calculate leakage conductance. High conductance values indicate the presence of coating defects.

Electromagnetic field loss evaluation is a method that applies an alternating current to the pipeline, which creates a magnetic field around the pipe. A sharp decrease in the measured strength of magnetic field would indicate a coating defect.

With all above ground survey methods, detection of coating defects depends on the contact between the bare portion of pipe and the surrounding electrolyte. Results will vary depending on the size of the defect, electrolyte resistivity and moisture content. Above ground methods do not work in locations where disbonded coating creates a shielding effect.

4.3 Cathodic Protection

4.3.1 Overview

Cathodic protection systems shall be monitored and maintained to ensure applicable criteria are met. Refer to Appendix B, “Criteria for Cathodic Protection”.

The location, number and type of cathodic protection measurements to be taken should be based upon sound engineering practices that suit the monitoring requirements of each piping system. This will ensure that corrosion control has been achieved throughout the entire piping system. Remedial programs are required when deficiencies are found.

The conditions that affect cathodic protection systems (e.g. stray current conditions, electrolyte characteristics, coating conductance, etc.) are subject to variation with time. Therefore changes to the recommended practices, procedures, or frequency may be required.

4.3.2 Monitoring Frequency

4.3.2.1 Initial Survey of New Piping Systems

Initial survey shall be performed as soon as practicable, but no more than 12 months after piping system installation. Consider conducting baseline surveys on the newly installed pipeline compatible with applicable company cathodic protection criteria.

4.3.2.2 Subsequent Surveys

Subsequent pipe-to-soil potential surveys, to verify cathodic protection, should be done as follows:

a) As a minimum, once per calendar year, on test stations recommended in sub-section 2.3.3.4.1, except as specified in sub-section 4.3.2.2 (b).

b) As a minimum, once every five years, where a structure is a short, electrically isolated length of pipe, such as a ten meter metallic main, or a metallic service that is connected to a plastic main.

c) As an alternative to (a) and (b), the frequency of pipe-to-soil potential surveys may be adjusted if it can be proven that the objective of corrosion prevention has been achieved. Proof will consist in tests made on a sampling basis and consistent with accepted engineering principles.

4.3.2.3 Monitoring and Inspection

Cathodic protection facilities should be monitored and inspected in accordance with the following:

a) All impressed current sources should be monitored at a frequency of once every 2 months. Longer or shorter intervals may be appropriate. Evidence of proper functioning may be current output, normal power consumption, a signal indicating normal operation, or satisfactory cathodic protection potential levels on the protected piping.

b) Once per calendar year, all impressed current facilities should be inspected and maintained as part of a preventative maintenance program. This will minimize the risk of in-service failure and improve worker and public safety.

c) If the failure of interference bonds, DC decoupling devices, and unidirectional devices would jeopardize structure protection or public safety, they should be monitored for proper functioning at a maximum of 10-week intervals. Monitoring may be accomplished by onsite inspection or by evaluating corrosion survey data. In some circumstances, longer or shorter intervals for monitoring may be appropriate.

d) The effectiveness of isolating devices, bonds and casing insulators should be checked during the pipe-to-soil potential survey in accordance with Sub-section 4.3.2.2. This may be accomplished by onsite inspection or by evaluating corrosion survey data.

4.3.3 Monitoring Techniques

4.3.3.1 Measurements

The following electrical measurements may be considered when conducting a periodic survey as defined in Sub-section 4.3.2.2:

a) Pipe-to-soil potential at test stations as specified in sub-section 2.3.3.4.1

b) Close-interval pipe-to-soil potentials

c) Pipe-to-soil potentials at compressor stations, meter stations, terminals and storage facilities

d) Impressed current rectifier output

e) Induced AC potential and current levels on pipelines

f) Interference activity (e.g. Telluric, LRT, and other currents)

g) Pipeline current

h) Coating conductance surveys

i) Electromagnetic field loss evaluation surveys

4.3.3.2 Test Equipment

Suitable test equipment should be used to obtain each electrical value. Instruments and related equipment should be maintained in good operating condition, calibrated as required and checked annually.

4.4 Remedial Measures

Remedial measures should be carried out as soon as practical after surveys, tests or inspections indicate that corrosion protection is not adequate, when the cause has been identified. These measures may include the following:

a) Repair, replace or adjust components of cathodic protection facilities
b) Install additional cathodic protection facilities
c) Install additional AC mitigation facilities
d) Repair or replace damaged or deteriorated coating
e) Apply a protective coating to bare piping systems
f) Repair, replace or adjust continuity of interference bonds
g) Remove detrimental metallic contacts
h) Investigate and mitigate potential interference sources
i) Install or repair electrical isolation devices
j) Repair shorted casings by re-establishing electrical isolation, and/or using an inert casing filler

These remedial methods can be prioritized, based on results from test methods such as In-Line Inspection or External Corrosion Direct Assessment (ECDA).

5.1 Introduction

This section outlines methods for detecting external corrosion and the requirements for examination.

5.2 Detection of External Corrosion

Various methods can be used to detect external corrosion, stress corrosion cracking and other flaws on buried or submerged metallic piping systems. Use of the above ground survey methods described in section 4.2.2 may indicate that a condition exists for the possibility of external corrosion to occur. Better detection of external corrosion can be accomplished by direct physical examination of the pipe, buried corrosion probes and coupons, and the use of in-line inspection tools.

The NACE Standard Practice SP0502 – Pipeline External Corrosion Direct Assessment Methodology (ECDA) contains procedures useful in detecting the presence of corrosion and coating damage, with some exceptions. Generally ECDA is not applicable for shielding coatings. These procedures are primarily intended for unpiggable pipelines.

In-line inspection tools are used to detect areas of metal loss by magnetic flux leakage, ultrasonic and eddy current techniques. In addition, periodic re-surveys with internal inspection tools can provide further information on the effectiveness of corrosion control. This method of detection is particularly useful in locations where shielding may occur.

Although these tools record pipe wall anomalies, expertise is required to interpret the data which may be indicative of external corrosion, internal corrosion, pipe wall inclusions, dents, gouges, foreign ferrous objects or other features.

Guidelines for the use of in-line inspection tools are provided in CAN/CSA Z662.

5.3 Examination of External Corrosion

Whenever piping is exposed, it should be visually inspected for both condition of the external coating and evidence of corrosion. Based on results, additional cathodic protection assessment shall be considered. The assessment of the corroded areas shall be in accordance with CAN/CSA Z662.

In addition, whenever the piping is exposed in areas known to be susceptible to stress corrosion cracking (SCC) an examination for the presence of SCC should be considered. Information on stress corrosion cracking susceptibility can be found in: Stress Corrosion Cracking Recommended Practices produced by Canadian Energy Pipeline Association.

6.1 Introduction

This section describes corrosion control records that document data pertinent to the design, installation, operation and maintenance of corrosion control systems. These would include records of the effectiveness of corrosion control measures and records associated with cause (metal loss or coating damage) determination.

Corrosion control records shall be retained for the life of a facility while active or inactive until such time as the piping is removed or abandoned.

6.2 Design and Installation

6.2.1 Coatings

Records of the coating selected for each component of the piping system shall be maintained in accordance with CSA Z662 and CSA Z245.20 Series-10. These include but are not limited to:

- Type of coating and specific coating specification
- Coating manufacturer and applicator
- Date and place of application
- Application specification and inspection data
- Transportation and storage records

6.2.2 Cathodic Protection

6.2.2.1 Impressed Current Systems

As-built drawings shall be retained for each impressed current cathodic protection installation. These drawings shall show details and location of components of the cathodic protection system with respect to the protected structure(s) and to major physical landmarks. As-built drawings and records of impressed current systems should include but not be limited to the following information:

- Location and date placed in service
- Specifications of rectifier or other energy sources
- Quantity, type, location and spacing of anodes
- Type of anode backfill material
- Point of attachment of negative lead(s)
- Cable size and type of insulation
- Right-of-way information
- Direct current interference facilities

6.2.2.2 Galvanic Systems

Galvanic anode installation records should include:

- Location and date placed in service
- Quantity, type, size, backfill and spacing of anodes
- Cable size and type of insulation
- Location of related test station installations

6.2.2.3 Auxiliary Systems

The location of all test stations and all above ground or buried isolation devices shall be recorded. Interference mitigation facility records shall include:

- Location and date placed in service
- Identification of bonded structures
- Bond parameters, such as resistance, current magnitude and direction or other pertinent information

Unidirectional current flow and AC mitigation facility records shall include:

- Location and date placed in service
- Identification of connected structures
- Type of device

6.3 Operation and Maintenance

6.3.1 Operation and Maintenance Records

Records of the operation and maintenance of the following corrosion control facilities shall be retained:

- DC power sources
- Interference bonds
- Unidirectional devices
- Isolation devices
- AC mitigation facilities
- Coupon test stations
- Corrosion rate probes

6.3.2 Additional Records

In addition to the foregoing information, the following records shall also be retained:

- Cathodic protection surveys
- Corrosion repairs and pipe replacements
- In-line inspection data, including logs, reports and excavation results
- Agreements, if applicable, for interference testing or any related work practices within a shared right-of-way

6.3.3 Test Records

Records of the following should also be retained:

- Coating tests, repairs and replacements
- Non-destructive test results

- Electrolyte salinity and resistivity test results
- Operation and maintenance of anodes, test stations, connections, cables and wires
- The location, duration, cause, and repair description of any fault that results in the loss of effective cathodic protection

APPENDIX A: DEFINITIONS

The following definitions reflect generally accepted and functional meanings used within the corrosion control community.

DEFINITIONS	
ABANDONED	A facility which is permanently out of service.
AC MITIGATION	Facilities or procedures to reduce and/or limit the effect of AC voltages on pipeline facilities.
ACTIVE SERVICE	A facility which is capable of performing its designed function.
AMPHOTERIC METAL	A metal that is susceptible to corrosion in both acid and alkaline environments.
ANODE	The electrode of a corrosion cell where oxidation occurs and current leaves the structure to enter the electrolyte. The anode is usually the electrode where corrosion occurs.
ANODE BACKFILL MATERIAL	A special, low resistance material immediately surrounding a buried anode for the purpose of increasing the effective area of contact with electrolyte and/or holding moisture.
ANODE CAPS	A covering to protect the anode and lead wire where they are joined.
BOND	A metallic connection that provides electrical continuity between structures that can conduct electricity.
CABLE	A current carrying conductor larger than AWG#10.
CASING INSULATOR	A spacer made of non-conducting material which is placed around the carrier pipe to electrically isolate the carrier pipe from the casing.
CATHODE	The electrode of a corrosion cell where reduction occurs and current leaves the electrolyte to enter the structure. The cathode is usually the electrode where corrosion does not occur.
CATHODIC PROTECTION	A technique to reduce the corrosion rate of a metal surface by making that surface the cathode of an electrochemical cell.
CLOSE INTERVAL POTENTIAL	A detailed pipe-to-soil survey in which potentials are measured at close spaced intervals along the pipeline. Typical intervals between measurements can vary from one to 10 meters.

COATING	A dielectric material applied to a structure to separate it from the environment.
COATING CONDUCTANCE	The ease with which electric current flows onto the surface of a coated metallic buried pipeline. The standard unit of conductance is the Siemens and is symbolized by the uppercase letter G in
COMPETENT	A person who is adequately qualified, suitably trained, and sufficiently experienced to complete the task/procedure in question in a safe and effective manner and certified as required by provincial and national governing bodies.
CORROSION	The deterioration of a material, usually a metal, because of an electrochemical reaction with its environment.
CORROSION POTENTIAL	The potential of a corroding surface in an electrolyte measured under open-circuit conditions relative to a reference electrode. Also known as
CORROSION RATE	The time rate of change of corrosion. Typically expressed as mass loss per unit area per unit time, penetration per unit time, etc.
COUPON	A device used to measure IR drop free potentials and/or current in areas where it may not be practical to interrupt cathodic protection or interference currents.
CURRENT DENSITY	The electric current flowing per unit area.
DC DECOUPLING DEVICE	A device that allows the flow of alternating current while substantially reducing the flow of direct current.
DEAD FRONT CONSTRUCTION	Type of construction of test station and electric panels that prevents direct personal contact with conductors subject to AC interference potentials.
DIODE	A device that permits electric current to flow more easily in one direction than the other.
DISBONDED COATING	A portion of pipeline coating which is no longer adhering to the surface of the pipe.

ECDA	External Corrosion Direct Assessment: A methodology for assessing the likelihood and severity of external corrosion on pipelines that are difficult or impossible to inspect with in-line tools. The methodology formalizes the use of several commonly used above ground cathodic protection survey techniques.
ELECTRICAL ISOLATION	The condition of being electrically separated from other metallic structures or the environment.
ELECTROLYTE	The soil or liquid adjacent to and in contact with a buried or submerged metallic structure.
ELECTROMAGNETIC INDUCTION	The generation of voltage and electrical current in a pipeline as the result of current flowing in an overhead electrical power line.
ELECTROSTATIC INDUCTION	The generation of an electric charge in a pipeline section due to the proximity of another charged body, such as power line conductors.
FOREIGN STRUCTURE	Any metallic structure that is not intended as a part of the piping system under cathodic protection.
GALVANIC ANODE	A metal which provides sacrificial protection to any metal more noble in the galvanic series when they are electrically coupled in an electrolyte. The anode is the current source in galvanic cathodic protection systems.
GALVANIC CORROSION	Corrosion caused by dissimilar metals in contact in an electrolyte.
GALVANIC SERIES	A list of alloys and metals arranged according to their corrosion potential in a given environment.
GROUND BED	A group of buried anodes that are connected together through which direct current is discharged to provide cathodic protection to the piping system.
HOLIDAY	A discontinuity in a protective coating that exposes unprotected surface to the environment.
INACTIVE	A facility which is presently not performing its designed function, but could be brought back into service.
INERT CASING FILLER	A material pumped into the annulus of a pipeline casing, and which fills the void to prevent the accumulation of water that could lead to corrosion of the pipeline.

IN-LINE INSPECTION	The inspection of a pipeline using a spaced instrument or tool that travels inside the pipeline.
INSTANT-OFF POTENTIAL	The polarized half-cell potential of an electrode taken immediately after the cathodic protection
INTERFERENCE	Any electrical disturbance on a metallic structure caused by stray current.
INTERFERENCE BOND	A direct metallic, resistive, electrolytic, or diode connection designed to control electrical current interchange between metallic pipeline systems.
INTERFERENCE CURRENT (STRAY CURRENT)	Electrical current flowing in paths other than the intended circuit.
IR DROP	The voltage (v) across a resistance (R) when current (I) is applied in accordance with Ohm's law (V = IR).
ISOLATION DEVICE	A deliberately installed electrical discontinuity inserted in a piping system such as an insulating flange or monolithic isolating joint.
MONOLITHIC ISOLATING JOINT	A welded inline device for electrically isolating two sections of pipeline without using a flange connection.
ON POTENTIAL	The pipe-to-soil potential of a structure with the cathodic protection system fully operational and connected to the structure.
PIPE-TO-SOIL POTENTIAL	The potential difference between a buried metallic structure and the electrolyte, measured with a reference electrode in contact with the electrolyte.
POLARIZATION	The change from the corrosion potential as a result of current flow across the electrode/electrolyte interface.
RECTIFIER	An electrical device for converting alternating current into direct current.
REFERENCE ELECTRODE (HALF CELL)	An electrode, the open-circuit potential of which is reproducible, and that serves as a basis of reference in the measurement of potential in another structure. For example copper-copper sulphate and silver-silver chloride.
SHIELDING	Preventing or diverting the cathodic protection current from its intended path.
SHORTED CASING	A casing, which is in electrical contact with the carrier pipe.

STRESS CORROSION CRACKING (SCC)	Cracking of a pipeline which may be caused by the combined action of ineffective cathodic protection, tensile stresses and/or a corrosive environment.
TEST STATION	A device where wires are connected to the piping system and are accessible for electrical measurements.
TELLURIC CURRENT	Electric current flowing near the earth surface as a result of geomagnetic fluctuation.
THERMITE WELDING	A specific technique for attaching cables to the piping system using a controlled exothermic reaction.
UNIDIRECTIONAL DEVICE	A device that prevents the reversal of direct current through a metallic conductor.
VOLTAGE	An electronic force or a difference in electrode potentials expressed in volts.
WIRE	A conductor of AWG #10 or smaller.

B.1 Introduction

The objective of cathodic protection is to control the corrosion of metallic surfaces in contact with electrolytes.

The effectiveness of cathodic protection or other corrosion control measures can be confirmed by visual inspection, or by measurement of material loss from the original structure. Since these actions are not always practical, meeting any one of the criteria presented in this appendix for a particular material can be considered as evidence that cathodic protection has been achieved.

The criteria in this appendix have been developed through laboratory experiments or empirically determined by evaluating data from successfully operated cathodic protection systems. The selection of a particular criterion depends upon past experience with similar structures and environments where the criterion has been used successfully. In some situations, deviation from the criteria discussed in Sub-section B.2 may be permitted, provided that it can be demonstrated that corrosion control has been achieved (e.g. documented historical data, External Corrosion Direct Assessment results etc.).

Note: Unless otherwise specified, voltages or potentials are with respect to a saturated copper-copper sulphate reference electrode.

B.2 Criteria

B.2.1 Steel and Cast or Ductile Iron Structures

Any one of the three following criteria shall be considered as evidence that cathodic protection has been achieved:

a) A negative polarized (instant-off) potential of at least 850 mV.

b) A negative (cathodic) potential of at least 850 mV with the cathodic protection applied accounting for the voltage (IR) drops listed in Sub-section B.3.

c) A minimum of 100 mV of cathodic polarization between the structure and a reference electrode, as measured by the formation or decay of polarization.

Note: Where steel piping systems are susceptible to stress corrosion cracking (SCC), caution is advised when selecting polarized potentials more electropositive than negative 850 mV when using the 100 mV polarization criterion. Other more stringent criteria may be necessary based on conditions including temperature, sulphate reducing bacteria, AC current density, coating type and condition, and general electrolyte corrosivity.

B.2.2 Copper Structures

A minimum of 100 mV of cathodic polarization between the structure and a reference electrode, as measured by the formation or decay of polarization.

B.2.3 Aluminum Structures

A minimum of 100 mV of cathodic polarization between the structure and a reference electrode, as measured by the formation or decay of polarization.

Note: Aluminum polarized potentials that are more electronegative than negative1200 mV may result in corrosion, because of alkali build-up on the metal surface. This is especially important in environments with a pH in excess of 8.0.

B.2.4 Dissimilar Metal Piping

A negative polarized potential between all structure surfaces and a reference electrode, which is equal to that required for the protection of the most anodic metal should be maintained.

B.2.5 Environmental Effects

In some instances, such as the presence of sulfides, bacteria, elevated temperatures, acid environments and dissimilar metals, the criteria given in (a) and (b) of Sub-section B.2.1. may not be sufficiently electronegative.

In some environments (concrete, dry or aerated high resistivity electrolyte, etc.) values more electropositive than criteria given in (a) and (b) of Sub-section B.2.1 may be sufficient.

Situations involving stray currents may require the use of criteria different from those listed in Sub-section B.2. For additional information, refer to Appendix C, “Control of Direct Current Interference”.

B.3 Special Considerations

B.3.1 Voltage (IR) Drop

Potential measurements on structures shall be made with the reference electrode in contact with the electrolyte and located as close as practical to the structure. A reference electrode placed near a coated pipe surface may not significantly reduce voltage (IR) drop in the measurement if the nearest coating holiday is distant from the reference electrode location.

The following factors shall be accounted for when interpreting potential measurements for compliance with the criteria listed in B.2:

- Voltage (IR) drop between the structure and reference electrode
- IR drop in the pipe steel and the lead wire during close interval surveys
- Presence of dissimilar metals

- Influence of risers and other structures
- Presence of stray and telluric currents
- Proximity to an anode

Methods for determining voltage drops shall be selected and applied using sound engineering practices (e.g. installing coupons and evaluating coupon data). Once determined, the voltage drops may be used to correct subsequent measurements at the same location, provided conditions (such as piping and cathodic protection facility operating conditions, electrolyte characteristics and coating quality) remain similar.

B.3.2 Aluminum Piping Systems

Amphoteric materials, such as aluminum, that could be damaged by high alkalinity created by cathodic protection should be electrically isolated and protected separately.

Aluminum may suffer from corrosion under high pH conditions. Because the application of cathodic protection tends to increase the pH at the metal surface, careful investigation or testing should be made before applying cathodic protection to stop pitting attack on aluminum in environments with a natural pH in excess of 8.0.

B.4 Alternative Reference Electrodes

Other standard electrodes may be substituted for the saturated copper-copper sulphate reference electrode. An alternative metallic material or structure may be used in place of the saturated copper-copper sulphate reference electrode if:

- The stability of its electrode potential is ensured.
- Its voltage equivalent, when referenced to a saturated copper-copper sulphate reference electrode, is established.

C.1 Introduction

This appendix details practices for the detection and control of direct current interference (stray current), which may lower the level of cathodic protection or may cause metal loss.

Interference current corrosion on buried or submerged metallic structures occurs where current from a foreign source is discharged from an affected structure to the electrolyte. It should be noted that coatings may become disbonded in the area where the interference current collects on the affected structure.

This can increase the demand for cathodic protection current and may create shielding problems. In addition, structures of amphoteric metal, such as aluminum and lead, may be subject to alkaline corrosion damage at or near locations where interference currents are collected.

Efforts shall be made to eliminate or minimize the adverse effects of direct current interference.

Mitigation of interference current corrosion can usually be achieved through coordination and cooperation between the owners of the structures.

C.2 Sources of Interference Currents

C.2.1 Types of Interference Currents

Interference currents include the following:

- Static current - Essentially constant direct current output, e.g., cathodic protection rectifiers, thermoelectric generators and HVDC power transmission systems.
- Dynamic current - Fluctuating direct current output, e.g., direct current electrified railway systems and light rail transit (LRT) systems.

- Coal mine haulage systems and pumps, welding machines, HVDC power transmission systems, and telluric currents.

C.2.2 Interference Current Conditions

The following conditions contribute to interference currents:

- Relative location of interfering and affected structures
- Proximity of interfering current source
- Magnitude and density of the current
- Poor quality or absence of a coating on the affected structures
- Improper design or maintenance of cathodic protection on affected structures
- Presence and location of mechanical joints, which may change their electrical resistance values over time

C.3 Detection of Interference Currents

C.3.1 Interference Current Indicators

The following changes in conditions may indicate the presence of interference currents:

- Pipe-to-soil potential changes of the affected structure
- Changes in either magnitude or direction of the pipeline current
- Localized pitting in areas near a foreign structure
- Breakdown of protective coatings in a localized area near a foreign ground bed or other source of direct current

In areas where interference currents are suspected, all affected structure owners shall be notified and appropriate tests shall be conducted. Notification of interference tests may also be channeled through regional Electrolysis Coordinating Committees, where such committees exist.

C.3.2 Interference Current Detection

Various test methods may be used to detect interference currents.

These methods include but are not limited to:

a) Regularly scheduled surveys, measurements of pipe-to-soil potential and/or current flow over the period of time necessary to characterize the interference problem.

b) Measurement of current output variations from a suspected source of interference current, correlated with measurements obtained in (a).

c) Measurement of the affected pipe-to-soil potential while interrupting the suspected interfering rectifier to determine if the change in potential is unacceptable.

d) Increase in frequency of surveys or continuous use of a data logger.

e) Use of interruptible coupons.

f) Use of instruments specifically designed to detect interference currents.

g) Development of beta curves to locate the area of maximum current discharge from the affected structure (see NACE Standard Practice SP0169).

C.4 Resolution of Interference Current Problems

C.4.1 Techniques

C.4.1.1 Interference Current Resolution Activities

It should be noted that interference current problems are unique and their resolution should be satisfactory to all of the involved structure owners. Where possible, the detrimental effects of interference currents are best managed on rectifier systems by prevention of current pick-up, and on direct current traction power systems by reducing the current discharged at the source.

Where current pick-up cannot be prevented the following steps may be taken:

- Counteract the effect of the interfering current by modifying the cathodic protection
- Remove or relocate the interfering current source
- Reduce the current output from the cathodic protection energy sources causing the interference
- Reroute the proposed pipelines
- Locate the isolating fittings in the affected structure
- Apply a coating to the current pick-up area(s) to reduce or resolve the interference
- Install direct or resistive bonding

C.4.1.2 Interference Current Bonding

In some cases, the adverse effects of interference currents can be mitigated by means of a bond. Where bonds are installed, approval shall be obtained from all affected structure owners. In addition, the following should be noted:

a) Unidirectional current control devices, such as diodes, may be required in conjunction with electrical bonds when dynamic currents are present.

b) A resistor may be necessary in the bond circuit to control the flow of electrical current.

c) The attachment of electrical bonds can reduce the level of cathodic protection on the interfering structure. Supplementary cathodic protection may therefore be required on the interfering structure to compensate for this effect.

d) Where there is a poorly coated pipeline interfering with a well-coated pipeline, a bond can protect against interference at the current discharge point, but it may leave the well-coated pipeline with either high or low potentials. High potentials are possible near the interfering ground bed. Low potentials remote from the interfering ground bed are possible.

C.4.2 Confirmation of Mitigation

The following may confirm that direct current interference has been mitigated:

a) The pipe-to-soil potentials of the affected structure have been adjusted to values acceptable to the structure owners.

b) Measurement of pipeline currents on the affected structure show that current is not being discharged to the electrolyte.

c) Adequate cathodic protection values are measured when current output from the interfering rectifier is interrupted.

d) The slope of the beta curve shows that current discharge has been eliminated at the location of maximum exposure. Refer to NACE Standard Practice SP0169.

ASTM International (American Society for Testing and Materials)

ASTM B843

Standard Specification for Magnesium Alloy Anodes for Cathodic Protection

ASTM B418

Standard Specification for Cast and Wrought Galvanic Zinc Anodes

ASTM G97

Standard Test Method for Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications

ASTM A518/A518M

Standard Specification for Corrosion Resistant High Silicon Iron Castings

CEPA (Canadian Energy Pipeline Association)

Stress Corrosion Cracking Recommended Practices, 2nd Edition

CSA (Canadian Standards Association)

CAN/CSA-Z662

Oil and Gas Pipeline Systems

CAN/CSA-Z662, Section 9.2

Selection of external protective coatings for buried or submerged piping,

CAN/CSA-Z662, Annex L

Alternative or supplementary test methods for coating property and characteristics evaluation

CSA-Z245.1

Steel Pipe

CSA-Z245.20 Series-10

Plant-applied external coatings for steel pipe

CSA-Z245.20-10

Plant-applied external fusion bond epoxy coating for steel pipe

CSA-Z245.21-10

Plant-applied external coatings for steel pipe

C22.1

Canadian Electrical Code, Part I

C22.1, Section 80

Canadian Electrical Code, Part I – Cathodic protection

C22.2 No. 0

Canadian Electrical Code, Part II - General Requirements

C22.2/No. 75

Thermoplastic-Insulated Wires and Cables.

C22.3 No. 4

Control of Electrochemical Corrosion of Underground Metallic Structures

CAN/CSA-C22.3 No. 6

Principles and Practices of Electrical Coordination between Pipelines and Electric Supply Lines

NACE International

SP0169

Control of External Corrosion on Underground or Submerged Metallic Piping Systems

SP0502

Pipeline External Corrosion Direct Assessment Methodology