Canadian Gas Association

Recommended Practice

OCC-1-2005

Control of External Corrosion on Buried or Submerged Metallic Piping Systems

Distributed by CGA Corrosion Control Sub-Committee Members

September 2005

September 15, 2005

Canadian Gas Association

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.

This “Recommended Practice” should be adapted to each user’s requirements. The CGA does not assume any liability for the application or suitability of the recommended practice. Responsibility and liability for the use and interpretation of this recommended practice rests with each user.

The Canadian Gas Association disclaims any liability for any damages, costs, or actions which may result, either directly or indirectly, in any way, from the use of these "Recommended Practices", and specifically states that the reader makes use of these materials at his, her, or its own risk.

The OCC-1-2005 supersedes OCC -1-1996

Canadian Gas Association

Contributing Members

Ashraf Abdel-Qader	Enbridge Gas Distribution, Chairperson
Ivan Mazur	Alta Gas Utilities Inc
Jim Phillipchuk	ATCO Gas
Brad Jefferies	Enbridge Gas Distribution
Michel Gervais	GazMetro
Stan Croall	Manitoba Hydro
Clay Smith	Pacific Northern Gas Ltd.
Jules Chorney	SaskEnergy/TransGas
Gerry Sarich	Terasen Gas
Robert Worthingham	TransCanada
Rod Reid	Union Gas
Mike Whittall	Canadian Gas Association

CONTENTS

SECTION 1: GENERAL 1
1.1 Introduction 1
1.1.1 Scope of the Recommended Practice 1
1.1.2 Application of Corrosion Control 2
1.1.3 Deviation from Recommended Practice 2
1.2 External Corrosion Control Practices 3
1.2.1 New Piping Systems 3
1.2.2 Existing Coated Piping Systems 3
1.2.3 Existing Bare Piping Systems 3

SECTION 2: DESIGN OF CORROSION CONTROL SYSTEMS 4
2.1 Introduction 4
2.2 Coatings 4
2.2.1 General 4
2.2.2 Selection and Evaluation 4
2.3 Cathodic Protection 5
2.3.1 General 5
2.3.2 General Design Requirements 5
2.3.3 Selection of Cathodic Protection Systems 6
2.3.3.1 Galvanic Current Systems 6
2.3.3.1.1 General Description 6
2.3.3.1.2 Galvanic Anodes 7
2.3.3.2 Impressed Current Systems 7
2.3.3.2.1 General 7
2.3.3.2.2 Direct Current Sources 8
2.3.3.2.3 Impressed Current Anodes 8
2.3.3.3 Electrical Isolation 9
2.3.3.3.1 Isolation from Foreign Structures 9
2.3.3.3.2 Within a Piping system 10
2.3.3.3.3 Casings 10
2.3.3.3.4 Installation Design Practices 11
2.3.3.3.5 Safety Practices 11
2.3.3.4 Auxiliary Facilities 12
2.3.3.4.1 Test Stations 12
2.3.3.4.2 Wires and Cables 13
2.4 Other Considerations 14
2.4.1 In-Line Inspection 14
2.4.2 Alternating Current Corrosion 15

SECTION 3: INSTALLATION OF CORROSION CONTROL SYSTEMS 16
3.1 Introduction 16
3.2 Installation and Inspection of Coating Systems 16
3.2.1 Application 16
3.2.2 Installation 17
3.2.3 Inspection 17
3.3 Installation and Inspection of Cathodic Protection Systems 18

3.3.1 Introduction 18
3.3.2 Impressed Current Systems 18
3.3.2.1 Rectifiers and Power Sources 18
3.3.2.2 Impressed Current Anodes 19
3.3.3 Galvanic Current Systems 20
3.3.4 Auxiliary Facilities 20
3.3.4.1 Wires and Cables 20
3.3.4.2 Connections 21
3.3.4.3 Casings 23
3.3.4.4 Test Stations 23
3.3.4.5 Bonds 23
3.3.4.6 Electrical Isolation 23

SECTION 4: OPERATION AND MAINTENANCE OF CORROSION CONTROL SYSTEMS 24
4.1 Introduction 24
4.2 Coatings 24
4.2.1 Visual Examination During Excavations 24
4.2.2 Above Ground Surveys 25
4.3 Cathodic Protection 26
4.3.1 Overview 26
4.3.2 Monitoring Frequency 26
4.3.2.1 Initial Survey of New Piping systems 26
4.3.2.2 Subsequent Surveys 26
4.3.2.3 Monitoring and Inspection 27
4.3.3 Monitoring Techniques 28
4.3.3.1 Measurements 28
4.3.3.2 Test Equipment 29
4.4 Remedial Measures 29

SECTION 5: DETECTION AND EXAMINATION OF EXTERNAL CORROSION 30
5.1 Introduction 30
5.2 Detection of External Corrosion 30
5.3 Examination of External Corrosion 31

SECTION 6: CORROSION CONTROL RECORDS 32
6.1 Introduction 32
6.2 Design and Installation 32
6.2.1 Coatings 32
6.2.2 Cathodic Protection 32
6.2.2.1 Impressed Current Systems 32
6.2.2.2 Galvanic Systems 33
6.2.2.3 Auxiliary Systems 33
6.3 Operation and Maintenance 34
6.3.1 Operation and Maintenance Records 34
6.3.2 Additional Records 34
6.3.3 Test Records 34

APPENDIX A: DEFINITIONS 36

APPENDIX B: CRITERIA FOR CATHODIC PROTECTION 41
B.1 Introduction 41
B.2 Criteria 41
B.2.1 Steel and Cast or Ductile Iron Structures 41
B.2.2 Copper Structures 42
B.2.3 Aluminum Structures 42
B.2.4 Dissimilar Metal Piping 42
B.2.5 Environmental Effects 43
B.3 Special Considerations 43
B.3.1 Voltage (IR) Drop 43
B.3.2 Aluminum Piping systems 44
B.4 Alternative Reference Electrodes 44

APPENDIX C: CONTROL OF DIRECT CURRENT INTERFERENCE 46
C.1 Introduction 46
C.2 Sources of Interference Currents 46
C.2.1 Types of Interference Currents 46
C.2.2 Interference Current Conditions 47
C.3 Detection of Interference Currents 47
C.3.1 Interference Current Indicators 47
C.3.2 Interference Current Detection 48
C.4 Resolution of Interference Current Problems 49
C.4.1 Techniques 49
C.4.1.1 Interference Current Resolution Activities 49
C.4.1.2 Interference Current Bonding 49
C.4.2 Confirmation of Mitigation 50

APPENDIX D: RELATED STANDARDS AND PRACTICES 52

Canadian Gas Association

RECOMMENDED PRACTICE OCC-1-2005

Control of External Corrosion on
Buried or Submerged Metallic Piping Systems

SECTION 1: GENERAL

1.1 Introduction

The Recommended Practice OCC-1-2005 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-1-2005 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 removed, abandoned or incapable of delivering product.

Coatings and cathodic protection are the methods used to control external corrosion. This 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.

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 a person 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 practical and shall be energized not 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 conditions indicate that safety may be a concern, studies shall be made to determine the extent of external corrosion on existing bare piping systems. When justified, piping shall be cathodically protected, rehabilitated, or replaced.

SECTION 2: DESIGN OF CORROSION CONTROL SYSTEMS

2.1 Introduction

This section describes design practices to be considered in the use of coatings and cathodic protection for the corrosion control of buried or submerged piping systems. The design of piping systems shall include auxiliary facilities to accommodate corrosion control systems (see Sub-section 3.3.4 for specific details).

Corrosion control of piping systems is achieved by the application of coatings and cathodic protection. At the design stage of the piping system, consideration shall be given to casing isolation, electrical isolation, and to facilitate in-line inspections to ensure the effectiveness of the corrosion control facility.

2.2 Coatings

2.2.1 General

The purpose of this sub-section is to recommend practices for selecting and evaluating coating systems. The functions of the coating systems are two fold:

- To isolate the external surface of the pipe from the environment.
- To reduce the amount of bare metal.

2.2.2 Selection and Evaluation

The selection of an appropriate coating system should be based on the following:

- The specific piping system design characteristics
- The performance characteristics of the coating systems under consideration.

The considerations for evaluating and selecting coatings can be found in CSA Z662 Appendix L

Appendix D “Related Standards and Practices” should be used in the evaluation and selection of coating systems.

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) shall be used for electrical design.

2.3.2 General 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, as described in Appendix B, “Criteria for Cathodic Protection” of this document, is attained throughout the piping system.

b) Interference currents to foreign structures shall be either eliminated or minimized so that the selected criteria for cathodic protection are attained. Reference shall be made to Appendix C, “Control of Direct Current Interference” and CSA Standard C22.3 No.6.

c) The cathodic protection system shall be designed to operate for the life of the piping system. This may require periodic rehabilitation of the cathodic protection system to suit anticipated changes in current requirements.

d) Cathodic protection anodes, associated cables, rectifier, 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 may be considered when selecting either a galvanic or an impressed current system. These factors 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 limitations of the environment such as soil 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.

2.3.3.1 Galvanic Current Systems

2.3.3.1.1 General Description

Galvanic current systems do not require an external power source because of the natural potential difference that exists between the galvanic anode and a coated piping system. Cathodic protection current is provided by galvanic anodes, which are connected to the piping system by insulated wires. Consideration may be given to providing an above ground test station to allow for a disconnect mechanism or testing.

2.3.3.1.2 Galvanic Anodes

Galvanic anodes are usually manufactured from materials such as magnesium, zinc or aluminum alloys. The soil conditions, chemical composition, and efficiency are factors that will affect the performance of the galvanic anode. Chemical composition for the common anodes, such as magnesium and zinc, will include varying quantities of aluminum, manganese, silicon, nickel, copper and iron. A special chemical backfill consisting of gypsum, bentonite and sodium sulfate is typically used to enhance performance. Ribbon type anode is usually trenched or ploughed in, generally parallel to the piping system. When used, it may be installed with or without a special chemical backfill.

2.3.3.2 Impressed Current Systems

2.3.3.2.1 General

An impressed current system consists of an external direct current source connected to anodes and the piping system by 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.

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

Warning signs near the direct current source and cables shall be in accordance with all applicable regulations, codes, and Section 80 of the Canadian Electrical Code Part 1. Signs shall show company identification and emergency telephone numbers.

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.

Direct current sources shall have a diode to prevent galvanic action between the anode bed and the pipe in the event of a direct current generator failure.

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, steel or conductive polymers. When the anodes are consumed, they shall be replaced.

Typically, anodes are connected to the direct current source with insulated cables. The anodes are installed either individually or in groups as remote, distributed or continuous ground beds.

Anode backfill material such as coal coke, petroleum coke or natural/manufactured graphite is used with the anodes. The backfill material may be prepackaged with the anode or supplied as a metal-canned anode.

Facilities to allow ground bed watering in dry or high resistivity soils should be considered.

To avoid possible detrimental effects of entrapped anodic reaction gases in deep vertical ground beds, venting may be required.

2.3.3.3 Electrical Isolation

2.3.3.3.1 Isolation from Foreign Structures

Electrical isolation is necessary between underground piping systems and foreign structures. In order to achieve electrical isolation, a minimum 0.3 m separation distance should be maintained between these structures. Where this separation cannot be maintained, electrical isolators shall be placed between the structures. 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 a 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 line 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 section or separate cathodic protection systems for monitoring and maintenance purposes
- Stray current areas.

2.3.3.3.3 Casings

When metallic casings are 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. Casing end seals shall be installed to prevent the entry of foreign matter into the casing. Consideration may also be given to filling the annular space with an inert, protective material.

2.3.3.3.4 Installation Design Practices

Where metallic contact may adversely affect cathodic protection or cause a corrosion condition to exist, piping systems should be electrically isolated from such structures. These 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.

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.

2.3.3.3.5 Safety Practices

Installation of isolation devices should be avoided in areas in which combustible atmospheres are likely to be present. When these devices are used 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.

Adequate separation should be maintained between pipelines and electric transmission tower footings, ground cables and counterpoise. CSA Standard C22.3 No.6 provides guidance on this subject.

2.3.3.4 Auxiliary Facilities

2.3.3.4.1 Test Stations

Test stations for potential or current, measurements should be provided at sufficient locations to ensure effective testing or monitoring of cathodic protection. 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
- Galvanic anode installations
- Road and railroad crossings
- Transitions between steel piping and non-metallic piping
- At regular intervals (such as 2 km) or as required.

All test station materials, connections and locations shall be suitable for the site conditions where they are installed. Piping system locations subject to induced AC voltage levels 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 requirements and be suited for direct burial.
b) Wire to wire, or cable to cable connections are typically made with split bolts or positive compression crimps.
c) To make sure 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
d) Methods to connect copper conductors to steel and other ferrous pressure piping include thermit welding 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.

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

Metal loss attributable to stray alternating current may occur, but is less common than damage caused by stray direct current. Mitigation methods include, but are not limited to, many of the same methods employed in the mitigation of stray direct current corrosion. Technical literature indicates that current densities above a certain threshold are required for metal loss to occur.

SECTION 3: INSTALLATION OF CORROSION CONTROL SYSTEMS

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. In the absence of these standards, 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 minimises 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.

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.

Rock guards, shields, foam, etc. may be used to provide additional mechanical protection to the coating. Care shall be exercised when using these materials due to the possible creation of shielding, reducing the effectiveness of cathodic protection.

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 the requirements described in Sub-sections 2.4 and 6.2.2.

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, an external disconnect switch shall be provided in the A.C. circuit and the rectifier case shall be properly grounded. Personnel

installing or modifying rectifiers shall be competent. Rectifiers and external switches shall be locked to prevent vandalism and protect the public.

After energizing the system, the polarity of the connection shall be verified. 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.

3.3.2.2 Impressed Current Anodes

Prior to installation, impressed current anodes shall be inspected for damage and anode caps (if used) shall be secure. Anodes should be 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.

Metal canned anodes shall be perforated to allow moisture penetration to the anode. Continuous anodes may be installed by trenching or plowing. Anodes should be centered in a backfill material which has been tamped 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 Current 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) Cardboard packaged 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. 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

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. Thermit weld connections to steel pipe using a specially designed low-temperature copper oxide and aluminum charge shall be limited to one 15 g cartridge per connection. Thermit weld connections to cast iron pipe using a low-temperature copper oxide and aluminum charge shall be limited to one 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. Each group shall be attached to the pipe separately. A thermit weld shall not be attempted on the site of a previous thermit weld, weld attempt, or pipe seam weld.

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 lead wires can be welded to aluminum pipe using either the TIG or MIG (Metal Inert Gas shielded arc) process. All test lead welding should be made to flanges or at butt weld joints where the material thickness is more suitable for welded connections. Thermit welding on aluminum pipe or pipe 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, especially when aluminum lines are involved.

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

All above ground connections shall be protected against atmospheric degradation.

3.3.4.3 Casings

Inspections and tests shall be made to make sure there is no metallic contact between the casing and the 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 Electrical Isolation

Where electrical isolation devices (e.g. in-line isolators, insulating flange sets, dielectric unions) are used to achieve electrical isolation, inspections and tests should be performed to make sure that electrical isolation is achieved.

SECTION 4: OPERATION AND MAINTENANCE OF CORROSION CONTROL SYSTEMS

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 when remedial action is required.

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 indicate the presence and general location of coating holidays at significant “ON” potential depressions.

Coating conductance surveys involve the measurement of line currents and potential 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 drop 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 soil. Results will vary depending on the size of the defect, soil resistivity and soil moisture content. Above ground methods do not work in locations where disbonded coating creates an electrical shield.

4.3 Cathodic Protection

4.3.1 Overview

Cathodic protection systems shall be monitored and maintained to make sure that the 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 make sure that corrosion control has been achieved throughout the entire piping system. Remedial cathodic protection or other programs are required when deficiencies are found.

The conditions that affect cathodic protection systems 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

The cathodic protection system shall be energised and the initial survey performed within 12 months of piping system installation.

4.3.2.2 Subsequent Surveys

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

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

b) 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 of tests made on a sampling basis, 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 of 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 minimise the risk of in-service failure and improve worker and public safety.

c) If the failure of interference bonds, polarisation cells and unidirectional devices would jeopardize structure protection, they should be monitored for proper functioning at intervals of two months (not to exceed

10 weeks). 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.
b) Close interval pipe to soil potentials.
c) Structure to soil and pipe to soil potentials at compressor stations, meter stations, terminals and storage facilities.
d) Impressed current rectifier output.
e) Checks for shorted casings.
f) Isolation fitting and bond checks.
g) Induced AC potential and current levels on pipelines.
h) Telluric current effects.
i) Pipeline current effects.
j) Coating conductance surveys.
k) 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) Provide additional cathodic protection facilities.
c) Repair or replace damaged or deteriorated coating.
d) Apply a protective coating to bare piping systems.
e) Repair, replace or adjust continuity of interference bonds.
f) Remove detrimental metallic contacts.
g) Install or repair electrical isolation devices.
h) Repair shorted casings by re-establishing electrical isolation, and/or filling the annular space with protective material.
i) Review corporate corrosion prevention policies and procedures.
j) Review corporate preventative maintenance programs.

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

SECTION 5: DETECTION AND EXAMINATION OF EXTERNAL CORROSION

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 Recommended Practice RP0502 – Pipeline External Corrosion Direct Assessment Methodology (ECDA) contains procedures that might be useful in detecting the presence of coating and corrosion damage. These procedures are primarily intended for unpiggable transmission 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 electrical shielding may occur.

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

External coatings should be visually examined as detailed in Sub-section 4.2.1. If the coating is removed, the visual appearance of any corrosion products should also be noted. The color, texture and extent of corrosion products combined with information on the coating failure observations may provide insight into the cause(s) of external corrosion damage.

To assist in identifying the environment that caused the external corrosion damage, samples may be collected from water trapped underneath the coating, soil, existing coating material and corrosion deposits on the pipe surface, if present.

Prior to assessment of external corrosion damage, the affected pipe surface shall be cleaned of coating and corrosion deposits.

The assessment of the corroded areas shall be in accordance with *CAN/CSA* Z662.

In addition, whenever the pipe 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 (SCC) susceptibility can be found in: Stress Corrosion Cracking publication produced by Canadian Energy Pipeline Association.

SECTION 6: CORROSION CONTROL RECORDS

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 system is removed, abandoned or rendered incapable of delivering product.

6.2 Design and Installation

6.2.1 Coatings

Records of the coating selected for each component of the piping system shall be maintained. These may include:

- 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 the following information:

- Location and date placed in service
- Specifications of rectifier unit 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 considerations.

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; and
- 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 bond installation 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, AC mitigation and current-fault-control-device installation records shall include:

- Location and date placed in service
- Identification of connected structures; and
- 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
- Critical isolation devices
- AC fault current mitigation devices
- Coupon test stations.

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 (ROW).

6.3.3 Test Records

Records of the following should also be retained:

- Coating tests, repairs and replacements
- Non-destructive test results
- Soil salinity and soil resistivity test results
- Operation and maintenance of anodes, test stations, connections, cables and wires
- The location, cause, and repair description of any fault that results in the loss of effective cathodic protection (CP).

APPENDIX A: DEFINITIONS

DEFINITIONS	
ABANDONED	A facility which is permanently out of service.
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 soil 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.
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	The reduction or prevention of corrosion of a metal surface by making it cathodic.
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	A survey measurement used to evaluate the coating on a buried line in terms of resistance per unit area.

COMPETENT	A person is competent if they have received the required training and demonstrate the skills and abilities necessary to carry out their responsibilities in a safe and effective manner.
COPPER-COPPER SULPHATE REFERENCE ELECTRODE	A conductive half-cell consisting of a solid copper electrode in a saturated copper sulphate solution.
CORROSION	The deterioration of a material, usually a metal, because of an electrochemical reaction with its environment.
CORROSION RATE	The rate at which corrosion proceeds, expressed as either weight loss or penetration, per unit time.
COUNTERPOISE	Conductors used in power transmission systems to balance charges and voltages.
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 per unit area.
INACTIVE	A facility which is presently not performing its designed function, but could be brought back into service.
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 developed in the USA for assessing the likelihood and severity of external corrosion on pipelines that are difficult or impossible to inspect with in-line tools. The methodology formalises 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	For the purpose of this Recommended Practice, electrolyte refers to 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 of interest.
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
GROUNDING CELL	Two or more electrodes, commonly made of zinc, installed at fixed spacing and resistance, coupled through a prepared backfill mixture.
HOLIDAY	A void in a coating that may expose the underlying metal surface to corrosion.
INERT CASING GEL	A material pumped into the annulus of a shorted 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.
INTERFERENCE	Any electrical disturbance on a metallic structure caused by stray current.
INTERFERENCE BOND	A metallic connection designed to control electrical current interchange between metallic systems.
INTERFERENCE CURRENT (STRAY CURRENT)	Electrical current flowing in paths other than the intended circuit.

IR DROP	The voltage across a resistance in accordance with Ohm's Law.
ISOLATION DEVICE	A deliberately installed electrical discontinuity inserted in a piping system such as an insulating flange or monolithic joint
MONOLITHIC JOINT	A device for electrically isolating two sections of pipeline without using a flange connection.
OFF POTENTIAL	The pipe to soil potential of a structure with the Cathodic protection system fully operational and disconnected from the structure.
ON POTENTIAL	The pipe to soil potential of a structure with the Cathodic protection system fully operational and connected to the structure.
OPEN-CIRCUIT POTENTIAL	The difference in voltage between a structure and a reference electrode under a condition of no current flow.
OTHER STRUCTURE POTENTIAL	The potential or voltage measured on a structure not belonging to the pipeline operator, such as a foreign pipeline.
PIPE-TO-SOIL POTENTIAL	The potential difference between a buried metallic structure and the soil, measured with a reference electrode in contact with the soil.
POLARISATION	The change from the open circuit potential resulting from the current across the electrode/electrolyte interface.
POLARISATION CELL	An electrolytic decoupling device that blocks direct current, while offering low impedance to an alternating current.
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.
REMOTE MONITORING UNIT	A device that remotely collects field data, such as rectifier output and pipeline potential readings.
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.
SCC	Stress Corrosion Cracking: Brittle cracking caused by the combined action of a corrosive environment in combination with tensile stress.

TEST STATION	A device at ground elevation where wires connected to the piping system are accessible for electrical measurements.
TELLURIC CURRENT	Electric current flowing near the earth surface as a result of geomagnetic fluctuation.
THERMIT WELDING	A specific technique for attaching cables to the piping system.
TOUCH POTENTIAL	The voltage difference between a metallic structure and a person in contact with the earth's surface or another metallic structure.
UNDIRECTIONAL 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.

APPENDIX B: CRITERIA FOR CATHODIC PROTECTION

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 affirmed by visual inspection, or by measurement of material loss from the original structure. Since these actions are not always practical, meeting any criterion presented in this appendix 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 B2 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

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

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

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

Note: Where steel piping systems are susceptible to stress corrosion cracking (SCC), caution is advised when selecting polarised potentials more electropositive than negative 850 mV when using the 100 mV polarisation criterion.

B.2.2 Copper Structures

A minimum of 100 mV of cathodic polarisation between the structure and a reference electrode in contact with the electrolyte, as measured by the formation or decay of polarisation.

B.2.3 Aluminum Structures

A minimum of 100 mV of cathodic polarisation between the structure and a reference electrode in contact with the electrolyte, as measured by the formation or decay of polarisation.

Note: Aluminum polarised potentials that are more electronegative than negative1200 mV may result in corrosion, because of alkali build-up on the metal surface.

B.2.4 Dissimilar Metal Piping

A negative polarised potential between all structure surfaces and a reference electrode in contact with the electrolyte, 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 soil, 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 exist that require the use of criteria different from those listed in Sub-section B2. 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 soil voltage (IR) drop in the measurement if the nearest coating holiday is remote 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. 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, soil 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.

APPENDIX C: CONTROL OF DIRECT CURRENT INTERFERENCE

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

There are two major types of interference currents:

- 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, 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
- 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:

- Structure to soil potential changes of the affected structure
- Changes in either magnitude or direction of the line current
- Localized pitting in areas near a foreign structure
- Breakdown of protective coatings in a localised 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 structure-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 structure 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 recorder.
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 Recommended Practice RP0169).

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 rectifiers 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.

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 structure to soil potentials of the affected structure have been adjusted to values acceptable to the structure owners
b) Measurement of line 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 Recommended Practice RP0169).

APPENDIX D: RELATED STANDARDS AND PRACTICES

1. CSA Standard CAN/CSA-Z662
   Oil and Gas Pipeline Systems

2. CSA Standard CAN/CSA-Z245.1
   Steel Line Pipe

3. CSA Standard CAN/CSA-Z245.20
   External Fusion Bond Epoxy Coating for Steel Pipe

4. CSA Standard CAN/CSA-Z245.21
   External Polyethylene Coating for Pipe

5. CSA Standard C22.1, Canadian Electrical Code, Part 1

6. CSA Standard C22.2 No. 0
   Canadian Electrical Code, Part II - General Requirements

7. CSA Standard C22.3 No. 4
   Control of Electrochemical Corrosion of Underground Metallic Structures

8. CSA Standard CAN/CSA-C22.3 No. 6
   Principles and Practices of Electrical Coordination Between
   Pipelines and Electric Supply Lines

9. NACE Standard Recommended Practice RP0I69
   Control of External Corrosion on Underground or Submerged
   Metallic Piping Systems

10. NACE Standard Recommended Practice RP0502
    Pipeline External Corrosion Direct Assessment Methodology

11. CEPA Recommended Practice – Stress Corrosion Cracking