

Australian Standard™

Cathodic protection of metals

Part 2: Compact buried structures



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This Australian Standard was prepared by Committee MT-014, Corrosion of Metals. It was approved on behalf of the Council of Standards Australia on 6 May 2003 and published on 27 June 2003.

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Corrosion engineers and consultants
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This Standard was issued in draft form for comment as DR 02281.

STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 2832.2—2003

Cathodic protection of metals

Part 2: Compact buried structures

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Technical Committee MT-014 has reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

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Approved for reconfirmation in accordance with Standards Australia procedures for reconfirmation on 14 July 2016.

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NOTES

Australian Standard™

Cathodic protection of metals

Part 2: Compact buried structures

Originated as AS 2832.2—1991.
Second edition 2003.

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Published by Standards Australia International Ltd
GPO Box 5420, Sydney, NSW 2001, Australia
ISBN 0 7337 5320 5

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee MT-014, Corrosion of Metals, at the request of industry to supersede AS 2832.2—1991, *Guide to the cathodic protection of metals, Part 2: Compact buried structures*. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard.

The objective of this Standard is to specify the technical requirements for the cathodic protection of compact buried structures.

This Standard is Part 2 of the AS and AS/NZS 2832 series of Standards, titled *Cathodic protection of metals*, currently comprising four parts. The other three parts are as follows:

AS or AS/NZS

2832 Cathodic protection of metals

2832.1 Part 1: Pipes and cables

2832.3 Part 3: Fixed immersed structures

2832.4 Part 4: Internal surfaces

To enable this Standard to be referred to in regulations, it now contains requirements for cathodic protection and differs from the other Standards in the AS 2832 series which give guidelines for cathodic protection.

There are no International Standards (ISO) on the cathodic protection of metals.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Corrosion of a metal is an electrochemical reaction between it and its environment which results in wastage of the metal. Thus, corrosion is a combination of chemical effects with an associated flow of electrical energy (corrosion current).

In many practical situations, where it is impossible to change the nature of the environment, corrosion may be prevented by employing cathodic protection on a buried or submerged structure. This is achieved by applying an appropriate direct current flowing in opposition to the original corrosion current, thus preventing the natural tendency of the metal to react with its environment. In practice, the electrical potential of the metal at risk is used to judge whether adequate protection is being achieved.

To employ cathodic protection, a circuit is established by connecting a suitable source of direct current to the structure to be protected.

Two types of cathodic protection systems are available, as follows:

- (a) Galvanic anode systems, which employ metallic anodes that are consumed to provide the source of direct current for protection of the structure. The driving voltage for the protective current comes from the natural potential difference that exists between the structure and a second metal (the galvanic anode).
- (b) Impressed current systems, in which the driving voltage for the protective current between the structure and the anode is supplied by an external direct current power source.

Corrosion control for a structure should be considered at the conceptual design stage. Factors that affect the corrosion of metallic structures are listed in Paragraph A3 of Appendix A. The practices recommended in this Standard relate to steps that need to be taken following a decision to apply cathodic protection to a structure. These steps are as follows:

- (i) Designing the structure to be compatible with cathodic protection and including cathodic protection facilities during construction. For existing structures, determine the measures to be taken to apply cathodic protection effectively, and the facilities necessary for cathodic protection monitoring.
- (ii) For new structures, deciding whether to coat, and if so, deciding which particular coating system should be employed. The nature and condition of any coating on existing structures needs to be considered when determining the requirements for the cathodic protection system.
- (iii) Designing the cathodic protection system. If the structure is already installed, the design parameters may be measured and an optimum design provided. If the structure is not installed, a number of assumptions, especially in regard to interference, will be required for the estimation of design parameters.
- (iv) Installing the cathodic protection system.
- (v) Commissioning the cathodic protection system and achieving a balance of cathodic protection current to enable the entire structure to be protected with minimum current, and with as uniform a potential distribution as is practicable.
- (vi) Monitoring cathodic protection at regular intervals, adjusting the system as necessary, and maintaining complete records of its operation.

STANDARDS AUSTRALIA

Australian Standard

Cathodic protection of metals

Part 2: Compact buried structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the cathodic protection of external surfaces of compact buried structures, including tank farms, service station tanks, tower footings, steel pilings (in soil), short well casings, compressor and pump stations and associated pipe work.

The Standard specifically covers the following subjects which relate to cathodic protection:

- (a) Pertinent aspects of the design of structures requiring cathodic protection.
- (b) Coatings for use on buried structures.
- (c) Criteria for the cathodic protection of a structure.
- (d) Measuring techniques and equipment.
- (e) The design of cathodic protection systems.
- (f) The installation of cathodic protection systems.
- (g) The control of interference currents on foreign structures.
- (h) The cathodic protection of structures subject to stray direct current.
- (i) The operation and maintenance of cathodic protection systems.
- (j) Electrical hazards.

NOTES:

- 1 Guidance on the general use and design of cathodic protection systems and factors affecting the corrosion of buried metallic structures are given in Appendix A.
- 2 This Standard employs conventional (positive) current flow, for consistency with accepted practice, and uses the potential sign conventions specified in AS/NZS 1852 (all parts). In order to understand the various electrochemical reactions that occur at electrodes during cathodic protection, it should be recognized that electron flow occurs in the opposite direction to conventional current flow.
- 3 Voltage and current referred to in this Standard is direct voltage and direct current, unless otherwise stated.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1100 Technical drawing

1100.401 Part 401: Engineering survey and engineering survey design drawing

AS

- 1627 Metal finishing—Preparation and pretreatment of surfaces
- 1627.2 Part 2: Power tool cleaning
- 1627.4 Part 4: Abrasive blast cleaning
- 1697 Gas transmission and distribution systems (known as the SAA Gas Pipeline Code)
- 1768 Lightning protection
- 2239 Galvanic (sacrificial) anodes for cathodic protection
- 2374 Power transformers (all parts)
- 2430 Classification of hazardous areas
- 2430.1 Part 1: Explosive gas atmospheres
- 2885 Pipelines—Gas and liquid petroleum
- 2885.2 Part 2: Welding
- 3859 Effects of current passing through the human body
- 4321 Fusion-bonded medium-density polyethylene coating and lining for pipes and fittings
- 4799 Installation of underground utility services and pipelines within railway boundaries.

AS/NZS

- 1020 The control of undesirable static electricity
- 1518 External extruded high-density polyethylene coating system for pipes
- 1852 International Electrotechnical Vocabulary (all parts)
- 2430 Classification of hazardous areas
- 2430.3.1 Part 3.1: Examples of area classification—General
- 2430.3.4 Part 3.4: Examples of area classification—Flammable gases
- 2832 Cathodic protection of metals
- 2832.1 Part 1: Pipes and cables
- 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules)
- 3008 Electrical installations—Selection of cables
- 3008.1.1 Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV—Typical Australian installation conditions
- 3008.1.2 Part 1.2: Cables for alternating voltages up to and including 0.6/1 kV—Typical New Zealand installation conditions
- 3100 Approval and test specification—General requirements for electrical equipment
- 3108 Approval and test specification—Particular requirements for isolating transformers and safety isolating transformers
- 3862 External fusion-bonded epoxy coating for steel pipes
- 4352 Tests for coating resistance to cathodic disbonding
- 4853 Electrical hazards on metallic pipelines
- 5000 Electric cables—Polymeric insulated
- 5000.1 Part 1: For working voltages up to and including 0.6/1 kV

IEC

61024 Protection of structures against lightning

61024-1 Part 1: General principles

61024-1-1 Section 1: Guide A: Selection of protection levels for lightning protection systems

61024-1-2 Part 1-2: General principles—Guide B: Design, installation, maintenance and inspection of lightning protection systems

61312 Protection against lightning electromagnetic impulse

61312-1 Part 1: General principles

61312-2 Part 2: Shielding of structures, bonding inside structures and earthing

61312-3 Part 3: Requirements of surge protective devices (SPDs)

61312-4 Part 4: Protection of equipment in existing structures

1.3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.3.1 Anaerobic

Lacking free oxygen.

1.3.2 Anode (in general)

An electrode, placed in the electrolyte, to apply cathodic protection to the structure.

1.3.3 Anode screen

A safety barrier surrounding a submerged anode for the prevention of electrical shock or shorting.

1.3.4 Anode shield

A protective covering of insulating material applied to a coated structure in the immediate vicinity of an anode to reduce local cathodic current density.

1.3.5 Back e.m.f.

An instantaneous open-circuit opposing voltage between an anode and cathode of an operating cathodic protection system.

NOTE: Back e.m.f. may have other definitions in other technologies.

1.3.6 Backfill (anode)

Material surrounding, and in contact with, a buried anode for the purpose of maintaining or improving the performance of the anode.

1.3.7 Bond (electrical)

A metal connection between points on the same structure or on different structures.

1.3.8 Bond (coating)

Adhesion between the coating materials and the substrate.

1.3.9 Cathode

The structure that is to be protected by cathodic protection.

1.3.10 Cathodic disbonding

Detachment of a coating due to the effects of cathodic polarization.

1.3.11 Cathodic protection

The prevention or reduction of corrosion of metal by making the metal the cathode in a galvanic or electrolytic cell.

1.3.12 Cathodic protection unit

A unit which converts alternating or direct current by another energy source into cathodic protection current.

NOTE: This includes transformers, rectifiers, solid state converters and direct current input from batteries, thermo-electric generators, closed circuit vapour turbines and other sources of direct current.

1.3.13 Converter

A device that converts electrical energy to extra low voltage (ELV) direct current.

NOTE: A rectifier is considered to be a converter.

1.3.14 Copper/copper sulfate (Cu/CuSO₄) reference electrode

A reference electrode consisting of copper in a saturated solution of copper sulfate.

1.3.15 Corrosion

The deterioration of metal caused by its electrochemical reaction with its environment.

1.3.16 Corrosion cell anode

The electrode at which metal dissolution (corrosion) takes place.

1.3.17 Corrosion current

The current flowing in a corrosion cell and which is electrochemically equivalent to the anode and cathode reactions.

1.3.18 Coupon

A section of metal of similar size to a coating defect, used to monitor the corrosion of a coated structure that is subjected to cathodic protection (see resistance probe).

1.3.19 Current density (at anode)

Current output of anode divided by the anode surface area.

1.3.20 Current density (at cathode)

Current flowing into cathode divided by the cathode surface area.

1.3.21 Current density (at coated cathode)

Total current flow into cathode divided by the total surface area of the structure.

1.3.22 Drainage (stray current)

An electrical means whereby stray current is removed from the structure via a conductor.

1.3.23 Earth (noun)

The conducting mass of the general body of the earth.

1.3.24 Earth (verb)

The act of connecting any conductor to earth.

1.3.25 Electrode

An electronic conductor that allows current to flow either to or from an electrolyte with which it is in contact.

1.3.26 Electrode potential

The measured potential of an electrode in an electrolyte relative to the potential of a reference electrode.

1.3.27 Electrolyte

A liquid, or the liquid component in a composite material such as soil, in which electric current may flow by ionic charge transfer.

1.3.28 Extra low voltage (ELV)

Voltage not exceeding 50 V a.c. or 125 V d.c. (r.m.s.).

1.3.29 Ferrous metal structure

A structure comprising an iron-based alloy containing more than 50% iron.

1.3.30 Foreign (secondary) structure

A buried or submerged structure that may be subject to interference arising from the cathodic protection of a primary structure.

1.3.31 Galvanic action

A spontaneous electrochemical cell reaction in which a metallic anode in a dissimilar metal couple corrodes.

1.3.32 Galvanic anode

An electrode used to protect a structure by galvanic action.

1.3.33 Galvanic isolator (polarization cell)

Device installed in series with the a.c. protective earthing conductor to block low-voltage d.c. galvanic current flow, but permit the passage of alternating current normally associated with the protective earthing conductor.

1.3.34 Ground bed

A group of buried anodes.

1.3.35 Half-cell

(See reference electrode)

1.3.36 Impressed current

Direct current supplied by an external power source to cathodically protect a structure.

1.3.37 Impressed current anode

The electrode connected to the positive terminal of an impressed current power supply.

1.3.38 Instantaneous off-potential

A potential substantially free of voltage gradients.

1.3.39 Isolating joint (insulation joint)

A joint that breaks electrical continuity in a structure, but does not affect the mechanical integrity of the structure.

NOTE: Isolating joints include monolithic insulating joints, insulating flange assemblies and insulating couplings.

1.3.40 Interference

A significant change in current density on a foreign structure caused by a cathodic protection system; it may be detected by a resultant potential change on the structure.

1.3.41 Interrupter

A timing device that permits a cyclic off/on interruption to the flow of cathodic protection current.

1.3.42 IR drop

(See resistance potential).

1.3.43 Loop resistance

The total external circuit resistance at the output terminals of the cathodic protection impressed current rectifier.

1.3.44 Overprotection

The state that occurs when the cathodic polarization of a structure is at a level beyond that required for corrosion protection.

NOTE: Overprotection may cause effects that are detrimental to the structure.

1.3.45 Polarization

A change in the potential of a corroding metal from its natural steady state value (the corrosion potential), as a result of current flow.

1.3.46 Polarized potential

The potential of a structure at the structure-to-soil interface. (This potential is thus free of voltage gradients that may accompany current flow through the electrolyte.)

1.3.47 Primary structure

The structure that is subject to intentional cathodic protection.

1.3.48 Protective potential

The potential to which a metallic structure is lowered to achieve cathodic protection.

1.3.49 Protective current

The current made to flow into a metallic structure from its electrolytic environment, and which cathodically protects the structure.

1.3.50 Reference electrode

An electrode that has a stable potential in one or more electrolytes at a given temperature, thus enabling it to be used for the measurement of other electrode potentials.

1.3.51 Remote earth

A location sufficiently distant from the structure and the anode to be free from voltage gradients in the earth.

1.3.52 Ripple free d.c.

The ripple voltage content shall not exceed 1% of the d.c. output voltage.

1.3.53 Resistance potential

That part of a measured electrode potential attributable to the passage of current through the resistance between cathode surface and reference electrode.

1.3.54 Resistance probe

A corrosion monitoring device, which functions by exposing an element of metal of which the structure is comprised, to the environment in which the structure is exposed. As the element corrodes, its cross-sectional area is reduced, thus increasing its longitudinal resistance. The change in resistance is measured with a very sensitive resistance measuring circuit.

NOTE: When monitoring a cathodically protected structure the element is connected to the structure to simulate a coating defect on the structure.

1.3.55 Shielding

A reduction in cathodic protection current to a section of a protected structure caused by either obstruction by adjacent insulating materials, such as disbonded coating, coating structures, or non-metallic structures or the electrical field from cathodic protection applied to an adjacent structure.

1.3.56 Silver/silver chloride reference electrode (Ag/AgCl)

An electrode consisting of silver, coated with silver chloride, in an electrolyte containing chloride ions.

1.3.57 Stray current

Current flowing through paths other than the intended circuit.

1.3.58 Structure

A metal surface in contact with an electrolyte.

1.3.59 Structure potential

The potential of a structure relative to that of a specified reference electrode situated in the electrolyte immediately adjacent to the structure.

1.3.60 Structure potential shift

A change in the measured voltage of a metallic structure caused by the application of current from an external source.

1.3.61 Sulfate-reducing bacteria

A type of bacteria, which is capable of reducing sulfate to sulfide in anaerobic, near-neutral soils and natural waters.

1.3.62 Test point

A nominated point on a structure for electrical contact.

1.3.63 Transformer/rectifier (converter)

(See converter).

SECTION 2 COMPETENCE OF PERSONNEL

The design, installation, operation, inspection, testing and maintenance of cathodic protection systems shall be carried out by, or under the direction of, persons qualified by experience and training in the appropriate aspects of corrosion mitigation in structures. Where the structure is influenced by stray electrical currents, the persons shall have had experience with mitigation of such current.

NOTE: The Australasian Corrosion Association provides training and accreditation for personnel in the corrosion prevention industry.

SECTION 3 CRITERIA FOR CATHODIC PROTECTION

3.1 SCOPE AND GENERAL

3.1.1 Scope

This Section specifies the criteria for determining when the appropriate amount and distribution of direct current is being applied to the structure.

3.1.2 General

The corrosion of buried metal structures is controlled by the application of direct current to lower and maintain their potential at a sufficiently negative level with respect to the environment. The direct current is provided by the use of an impressed current system, galvanic anodes, or a combination of both.

Protection criteria based on potential measurement, and other references to potential in this Standard, use values relative to the copper/saturated copper sulfate reference electrode. Reference electrodes other than copper/copper sulfate may be used, provided that their relativity to copper/copper sulfate is established.

3.2 PROTECTION CRITERIA

3.2.1 General

The degree of protection shall be assessed by the use of one or more of the criteria set out in Clauses 3.2.2, 3.2.3 and 3.2.4. It is important that advice be obtained from a cathodic protection specialist to ensure that the criteria are correctly applied.

3.2.2 Potential criteria

3.2.2.1 General

The potential criteria specified in this Standard are applicable where the structure temperature is near ambient, and the electrolyte near the metal/electrolyte interface comprises natural soils and waters that are substantially free of active sulfate-reducing bacteria. If these conditions are not met, an evaluation of the conditions shall be carried out and an appropriate criterion determined.

The criteria given in Clauses 3.2.2.2, 3.2.2.3, 3.2.2.4 and 3.2.2.5 shall apply provided that there is not a significant voltage gradient in the electrolyte between the structure and the reference electrode. The criteria given in Clause 3.2.2.6 shall apply for structures subjected to variable stray current effects.

A method of preventing the cathodic protection electrolyte voltage gradient from affecting the measured potential readings is to measure an instantaneous off-potential, (see Appendix B).

3.2.2.2 Ferrous structure

The criteria for the protection of a buried ferrous structure shall be to maintain a potential on all parts of the structure equal to, or more negative than, -850 mV with respect to a saturated copper/copper sulfate reference electrode.

3.2.2.3 Copper/copper alloy structure

The criteria for the protection of a buried copper structure shall be to maintain a potential on all parts of the structure equal to, or more negative than -300 mV with respect to a copper/copper sulfate reference electrode.

3.2.2.4 *Lead structure*

The criteria for the protection of a buried lead structure shall be to maintain a potential on all parts of the structure equal to, or more negative than, -650 mV with respect to a copper/copper sulfate reference electrode when the structure is in aerated conditions, and equal to, or more negative than, -800 mV with respect to a copper/copper sulfate reference electrode when the structure is in anaerobic conditions.

3.2.2.5 *Mixed metal structure*

The criteria for the protection of a buried mixed metal structure shall be to maintain a potential on all parts of the structure equal to, or more negative than, that required for the most anodic metal.

3.2.2.6 *Structures subject to variable stray current effects*

The response of a structure to anodic stray current excursions is dependent upon many factors including soil resistivity, degree of soil aeration, moisture content and the structure coating quality. The extent of depolarization is determined by the frequency, magnitude and the duration of anodic excursions.

Variable stray traction effects shall be evaluated when there is an indication that the structure potentials are varying and there is evidence that the potentials are positive of the protection criteria defined in Clauses 3.2.2.2 to 3.2.2.5 for a period of time, no matter how short that period may be.

The measured potential is the sum of the polarized structure potential and the potential from the voltage gradient in the electrolyte. When potentials are affected by stray current, it may not be possible to determine whether they are free of voltage gradients, and thus to compare the measured potential with the protection criterion. In such cases, an estimation of the electrolyte voltage gradient will suffice to determine the protection criterion. This measured potential is used to determine the magnitude and duration of anodic excursions.

3.2.2.7 *Traction current effects*

Where structures are required to be evaluated for traction stray current effects in accordance with Clause 3.2.2.6 the potential shall be recorded over a sufficient period of time to ensure that the maximum exposure to the stray current effects is encompassed. This period shall include the morning and evening usage peaks and is nominally twenty hours. If a data logger is used for the monitoring of potential, its frequency of sampling shall be not less than one sample per minute.

NOTE: For determining stray current effect see Appendix N.

The protection criteria for structures subject to traction current effects varies with the structure polarization time as follows:

(a) *Structures with short polarization times*

Structures with sound coating characteristics, or have otherwise been proven to polarize and depolarize rapidly in response to stray current, shall comply with the following criteria:

- (i) The potential shall be not less negative than the protection criterion for more than 5% of the test period.
- (ii) The potential shall be not less negative than the protection criterion plus 50 mV, i.e. -800 mV for ferrous structures, for more than 2% of the test period.
- (iii) The potential shall be not less negative than the protection criterion plus 100 mV, i.e. -750 mV for ferrous structures, for more than 1% of the test period.

- (iv) The potential shall be not less negative than the protection criterion plus 850 mV, i.e. 0 mV for ferrous structures, for more than 0.2% of the test period.

(b) *Structures with long polarization times*

The potential of structures that exhibit deteriorated coating characteristics, or have otherwise been proven to polarize and depolarize slowly in response to stray current, shall be not less negative than the protection criterion for more than 10% of the test period.

3.2.3 100 mV polarization decay criterion

The criterion for the protection of a buried structure shall be to maintain an instantaneous off-potential on all parts of the structure, which is at least 100 mV more negative than the depolarized potential (see Appendix B).

This criterion is not applicable if the structure is affected by stray current or significant galvanic corrosion couples.

3.2.4 Alternative criteria

3.2.4.1 Coupon criterion

When using coupons, the criterion for the protection of a buried ferrous structure is when the instantaneous off-potential on the coupon is either equal to, or more negative than, –850 mV with respect to a copper/copper sulfate reference electrode, or is at least 100 mV more negative than the depolarized potential.

Coupons shall be installed and used in accordance with the requirements of Appendix C.

3.2.4.2 Resistance probe criterion

When using resistance probes, the criterion for the protection of a buried ferrous structure is when the corrosion rate of the resistance probes does not exceed 5 µm per year, and the instantaneous off-potential on the probe element is either equal to, or more negative than, –850 mV with respect to a copper/copper sulfate reference electrode, or is at least 100 mV more negative than the depolarized potential. Resistance probes shall be installed and used in accordance with the requirements of Appendix C.

3.2.4.3 Other criteria

Other protection criteria may be used, provided that their validity can be demonstrated.

3.3 OVERPROTECTION

To ensure that overprotection does not cause accelerated disbondment of a coating or other deleterious effects, the potential corrected for soil voltage gradient error shall be measured or estimated. This may be achieved by measuring the instantaneous off-potential as described in Appendix B.

NOTES:

- 1 For ferrous, lead, copper and copper-alloy structures, this potential (which is free of voltage gradient potential) should not be more negative, with respect to a copper/copper sulfate reference electrode, than –1.2 V. Less negative values may be appropriate for coatings that are more susceptible to cathodic disbonding.
- 2 For tests to determine coating resistance to cathodic disbonding, refer to AS/NZS 4352.

SECTION 4 MEASURING TECHNIQUES AND EQUIPMENT

4.1 GENERAL

All instruments and measuring equipment used for determining electrical values shall be of an appropriate type and accuracy and have a valid calibration certificate. Calibration of the equipment shall be carried out to the required level of accuracy, annually, or at intervals appropriate to its stability, or whenever service conditions may have resulted in loss of accuracy. Care shall be taken to ensure that the correct polarity is noted in all measurements.

Records shall be maintained to keep information on instruments used to conduct specific tests and any subsequent calibration adjustments.

The polarity of the test cables shall be checked to ensure that the correct sign is applied to the potential values.

The calibration and/or maintenance of reference electrodes shall be carried out as specified in Appendix D.

4.2 POTENTIAL MEASUREMENT AND EQUIPMENT

4.2.1 General

The influence of stray current shall be established on the structure by data logging over a nominal period of 20 hours or by other means as required. In areas free of significant stray current, potentials may be measured by a single observation.

The equipment used for potential measurements shall have the following characteristics:

- (a) An input impedance of at least 10 M Ω , unless it can be verified that a lower impedance is adequate to contain errors to less than 10 mV at the point(s) being tested.
- (b) An accuracy of better than ± 10 mV.
- (c) a.c. rejection of better than 60 dB, together with an ability to reject overload by a.c. signals of up to 30 V r.m.s., unless it can be verified that lesser a.c. rejection characteristics are adequate at the point(s) being tested.
- (d) Errors in d.c. measurements, due to the presence of a.c. signals, of less than 10 mV.

NOTES:

- 1 The half cell or electrode resistance to earth may be assessed by shunting the voltmeter with a resistor of about one tenth of the input resistance of the meter. A variation of 10% or more between the unshunted and shunted voltmeter readings, indicates unsatisfactory reference electrode resistance conditions and corresponds to an error in the unshunted voltmeter reading of approximately 1%. Alternatively, a voltmeter with a selectable input impedance may be used for assessing the acceptability of reference electrode contact resistance.
- 2 Contact resistance due to dry soil surface conditions may be reduced by moistening the soil in contact with the reference electrode.

4.2.2 Positioning of monitoring electrodes

When measuring potential, reference electrodes are preferably placed at locations of minimum soil voltage gradients, i.e. remote from anode beds and above and as close as possible to the structure. The effect of current flow from nearby impressed current ground-beds or sacrificial anodes shall be less than 10 mV, or be taken into account when determining potential readings. These considerations shall similarly apply when establishing the potential of fixed electrodes.

4.2.3 Off-potential measurements

Instantaneous off-potential measurements in areas that are not subject to the effects of stray currents shall be carried out in accordance with Appendix B ensuring that all current sources are interrupted synchronously. These current sources include galvanic anodes, earthing systems, cross-bonds and polarization cells. For measurement techniques in areas affected by stray currents refer to Clause 3.2.2.6 and 3.2.2.7.

SECTION 5 DESIGN OF STRUCTURES TO ACCOMMODATE CATHODIC PROTECTION

5.1 SCOPE AND GENERAL

5.1.1 Scope

This Section provides requirements and guidance for the design of compact buried structures, to accommodate cathodic protection.

For protection to be achieved, a structure shall—

- (a) be immersed or buried in an electrolyte; and
- (b) be electrically continuous.

NOTE: Usually the structure should be electrically isolated from structures not requiring protection.

5.1.2 General

Because many aspects of design and construction of compact buried structures can interfere with the corrosion prevention process, cathodic protection has to become an integral part of the design stage. This will minimize unnecessary and sometimes costly modifications and help to ensure the safe operation of the structure and maximize its economic life.

NOTES:

- 1 Cathodic protection should be applied at the completion of the construction of the structure.
- 2 Additional information on structure design is given in Appendix E.

5.2 MATERIALS OF CONSTRUCTION

Careful consideration shall be given to the proposed materials to be used in a structure that is to be protected by cathodic protection.

Cathodic protection shall be applied with caution to structures that are made from materials which are subject to attack under alkaline conditions (e.g. lead, aluminium and zinc), due to the high pH levels developed at the cathode surface.

The effects of dissimilar metals and alloys on the structure shall be considered, in order to mitigate unintended bi-metallic corrosion and to select an appropriate protection criterion that recognizes the interaction that can occur between different metals (see Section 2).

5.3 COATED AND UNCOATED STRUCTURES

Most structures shall be coated prior to installation. Cathodic protection of uncoated structures requires the use of higher levels of current than coated structures and, generally, a greater number of cathodic protection installations. The higher levels of current could significantly increase the risk of causing interference with foreign structures. Legislation may require that cathodic protection installations that cause interference be turned off.

NOTE: Information on coatings for use with cathodic protection is given in Appendix F.

5.4 ELECTRICAL HAZARDS AND DISTURBANCES

There are a number of mechanisms that can give rise to electrical hazards in buried structures.

NOTE: Details of hazard mechanisms, their interaction with cathodic protection and advice on how to overcome hazards are given in Appendix G.

The following forms of stray current can affect the structure or its operation:

(a) *Direct current*

Stray direct current can pose a corrosion hazard to a buried structure. A very rapid rate of corrosion can develop at the point where the current discharges from the structure surface. Such current can originate from railways, tramways, other cathodic protection installations or electrical distribution systems.

Generally it is not possible to quantify the problem or to design preventative procedures until the structure is installed and the environment has stabilized. It may be possible to reduce or remove the problem at the design stage by locating the structure away from sources of such current.

(b) *Surge current (short term conditions)*

Surge current (short term conditions) can arise from the following:

- (i) *Lightning* The results of lightning can include direct flash contact to the structure or its ancillaries and to, exposed valves and test points (see Appendix G, Paragraph G2.1).
- (ii) *Power transmission systems* The results of surge current in power transmission systems can include conductive coupling to the structure in the earth from power fault current to a nearby tower or electrical earthing system (see Appendix G, Paragraph G2.1).

In respect to the design of mitigative measures for hazards generated in accordance with Item (b) above, the attention of a specialist is required.

5.5 TEST POINTS

5.5.1 General

Test points shall be used to monitor structure potentials, and a sufficient number are needed to enable the assessment of the effectiveness of the cathodic protection.

5.5.2 Location

Test points shall be located to give an overall indication of the spread of protection, and encompass critical areas where problems are likely to be encountered or where extra precautions are required. Locations for test points shall include the following positions:

- (a) Adjacent to insulating joints and at structure terminations.
- (b) At likely sources of stray currents, and at discharge points for stray currents.
- (c) Adjacent to air/electrolyte interfaces.
- (d) Close to foreign structures.
- (e) Adjacent to anode locations.

Test points may require to be located outside hazardous areas, or alternatively be enclosed in an intrinsically safe box if inside a hazardous area, for example, if they contain current carrying connections that may cause a spark hazard.

Test point cabling requirements are given in Clause 6.5.

All test point terminal boxes shall be of durable construction and be suitably identified.

NOTE: Where posts and identification signs are painted, non-toxic paints should be used.

5.5.3 In situ reference electrodes

Consideration shall be given to the installation of in situ reference electrodes, especially in areas where the structure is affected by stray direct current or where the structure is located under a hardstanding area. Such reference electrodes shall either have a fixed and known

potential or should be capable of calibration at each time of use. Their potential should be stable during each period of use and shall not be polarized by current flow in the measuring circuit.

NOTE: Premature consumption of the electrode chemicals has been observed to occur where cells have been installed in direct current electric fields in permanently wet conditions, and care should be exercised in their placement to minimize early deterioration.

5.6 INSULATING JOINTS (ISOLATING JOINTS)

Insulating joints are used to electrically isolate parts of the structure to facilitate the use and control of cathodic protection systems. They may consist of flange assemblies, couplings or monolithic joints. The dielectric strength of such joints shall be compatible with the system design.

A structure containing a liquid electrolyte but requiring cathodic protection on the external surface may suffer serious corrosion at insulating joints or flanges. This may be minimized by coating the structure internally for a distance away from the flange. The coated length will depend on the conductivity of the electrolyte and shall be sufficient to ensure that the passage of cathodic protection current through the internal electrolyte does not adversely affect the integrity of the structure.

Mechanical requirements for insulating joints shall comply with the requirements of the appropriate design code.

Typical locations where the provision of insulating joints shall be considered include the following:

- (a) At ownership changeover points.
- (b) At connection points to other structures or piping.
- (c) At inline measuring and/or pressure regulating stations.
- (d) At compressor and pumping stations.
- (e) In stray current areas.
- (f) At junctions of dissimilar metals.
- (g) Where it is necessary to isolate the structure from electrical earthing.
- (h) At structure terminations.

Insulating joints should not be positioned in enclosed or defined hazardous areas where combustible gases may be present unless electrical surge protection is provided. Surge protection devices in such areas should be of a type that cannot cause an exposed arc.

Surge protection should be considered at isolating joints where incoming pipelines parallel high voltage transmission lines and in lightening prone areas.

NOTE: Cable connections should be short, direct, and of a size suitable for carrying short-term high-current loading.

Where an insulating joint is to be installed below ground and when both sides of the joint are to be cathodically protected, the joint shall be insulated from the electrolyte with a suitable coating.

NOTE: Where insulating joints are installed above ground, any gap between flanges should be filled with an electrically insulating compound and the outer faces of the flanges should be coated to minimize the possibility of accidental short-circuiting.

In hazardous areas where there is danger of sparks causing the ignition of flammable gases, the insulated joints should be suitably coated to prevent accidental short-circuiting.