



Cathodic protection of metals

Part 1: Pipes and cables



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 - Australian Chamber of Commerce and Industry
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 - Australian Industry Group
 - Australian Paint Manufacturers' Federation
 - Australian Pipeline Industry Association
 - Austroads
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 - Galvanizers Association of Australia
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 - New Zealand Abrasive Blasting Association
 - New Zealand Heavy Engineering Association
 - United Water International
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-

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Australian Standard[®]

Cathodic protection of metals

Part 1: Pipes and cables

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PREFACE

This Standard has been prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee MT-014, Corrosion of Metals, to supersede AS 2832.1—2004, *Cathodic protection of metals*, Part 1: *Pipes and cables*.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this Standard is to specify the technical requirements for the cathodic protection of buried pipes and cables.

The objective of this revision is—

- (a) to cater for changes in government legislation, which affect stray current control on cathodic protection systems on structures;
- (b) to make changes that better reflect the present understanding of corrosion caused by stray direct current interference; and
- (c) to generally update the technical aspects of the standard in line with current industry practice.

This Standard is Part 1 of the AS 2832 series of Standards. The other parts are as follows:

AS

2832	Cathodic protection of metals
2832.2	Part 2: Compact buried structures
2832.3	Part 3: Fixed immersed structures
2832.4	Part 4: Internal surfaces
2832.5	Part 5: Steel in concrete structures

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. Therefore, 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, therefore 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.

While cathodic protection can prevent corrosion there are circumstances where it may not be effective, even if protection is indicated by potential monitoring techniques carried out at test points. Therefore, the determination that cathodic protection is achieved is a risk based judgement dependent on an evaluation of a number of parameters.

STANDARDS AUSTRALIA

Australian Standard

Cathodic protection of metals

Part 1: Pipes and cables

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the cathodic protection of buried or submerged metallic pipes and cables. This Standard does not apply to offshore submarine pipelines.

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 submerged and 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 and telluric effects.
- (i) The operation and maintenance of cathodic protection systems.
- (j) Electrical hazards associated with the cathodic protection of buried structures.

NOTE: 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.

This Standard employs conventional (positive) current flow, for consistency with accepted practice, and uses the potential sign conventions specified in AS/NZS 1852 (series). 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.

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
- 1627 Metal finishing—Preparation and pretreatment of surfaces
- 1627.2 Part 2: Power tool cleaning
- 1627.4 Part 4: Abrasive blast cleaning of steel
- 2239 Galvanic (sacrificial) anodes for cathodic protection
- 2374 Power transformers (series)

AS

- 2885 Pipelines—Gas and liquid petroleum
- 2885.1 Part 1: Design and construction
- 2885.2 Part 2: Welding
- 4321 Fusion-bonded medium-density polyethylene coating and lining for pipes and fittings
- 4352 Tests for coating resistance to cathodic disbonding
- 4799 Installation of underground utility services and pipelines within railway boundaries
- 4822 External field joint coatings for steel pipelines
- 4827 Coating defect surveys for buried pipelines
- 4827.1 Part 1: Direct current voltage gradient (DCVG)
- 4832 Cathodic protection—Installation of galvanic anodes in soil

AS/NZS

- 1020 The control of undesirable static electricity
- 1518 External extruded high-density polyethylene coating system for pipes
- 1852 International electrotechnical vocabulary (series)
- 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
- 3100 Approval and test specification—General requirements for electrical equipment
- 3862 External fusion-bonded epoxy coating for steel pipes
- 4251 Electromagnetic compatibility (EMC)—Generic emission standard
- 4251.2 Part 2: Industrial environments
- 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 (1.2) kV
- 60079 Explosive atmospheres
- 60079.0 Part 0: Equipment—General requirements
- 61558 Safety of power transformers, power supplies, reactors and similar products (series)

AS/NZS CISPR

- 14 Electromagnetic compatibility—Requirements for household appliances, electric tools and similar apparatus
- 14.1 Part 1: Emission

EN

- 15280 Evaluation of a.c. corrosion likelihood of buried pipelines applicable to cathodically protected pipelines

CIGRE

- TB 290 AC corrosion on metallic pipelines due to interference from AC power lines

NACE

- IP 35110 AC Corrosion State-of-the-Art: Corrosion Rate, Mechanism, and Mitigation Requirements

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 EMF

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

NOTE: Back EMF may have other definitions in other technologies.

1.3.6 Bond (electrical)

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

1.3.7 Bond (coating)

Adhesion between the coating materials and the substrate.

1.3.8 Cathode

The structure that is to be protected by cathodic protection.

1.3.9 Cathodic disbonding

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

1.3.10 Cathodic protection

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

1.3.11 Cathodic protection unit

DC power supply controller for an impressed current cathodic protection system.

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

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

1.3.13 Corrosion

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

1.3.14 Corrosion cell anode

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

1.3.15 Corrosion current

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

1.3.16 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').

1.3.17 Current density (at anode)

Current output of anode divided by the anode surface area.

1.3.18 Current density (at cathode)

Current flowing into cathode divided by the cathode surface area.

1.3.19 Current density (at coated cathode)

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

1.3.20 Dial Before You Dig (DBYD)

Referral service for information on locating underground utilities anywhere in Australia.

1.3.21 Drainage bond

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

1.3.22 Earth (noun)

The conducting mass of the general body of the earth.

1.3.23 Earth (verb)

The act of connecting any conductor to earth.

1.3.24 Electrode

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

1.3.25 Electrode potential

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

1.3.26 Electrolyte

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

1.3.27 Extra low voltage (ELV)

Voltage not exceeding 120 V d.c. (max 10% ripple, see AS/NZS 3000).

1.3.28 Ferrous metal structure

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

1.3.29 Foreign (secondary) structure

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

1.3.30 Galvanic action

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

1.3.31 Galvanic anode

An electrode used to protect a structure by galvanic action.

1.3.32 Half-cell

(See 'reference electrode').

1.3.33 Impressed current

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

1.3.34 Impressed current anode

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

1.3.35 Instantaneous off-potential

A potential substantially free of voltage gradients.

1.3.36 Insulating joint (isolating joint)

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

1.3.37 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.

1.3.38 Interrupter

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

1.3.39 IR drop

(See 'resistance potential').

1.3.40 Loop resistance

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

1.3.41 Overprotection

The state that occurs when the cathodic polarization of a structure is at a level beyond that required for corrosion protection. Overprotection may cause effects which are detrimental to the structure.

1.3.42 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.

1.3.43 Polarization cell

A device which, at potential levels typical of cathodically protected structures, has low impedance to alternating current but high impedance to direct current.

1.3.44 Polarized potential

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

1.3.45 Primary structure

The structure that is subject to intentional cathodic protection.

1.3.46 Protective potential

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

1.3.47 Protective current

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

1.3.48 Quiescent traction period

Time period, usually overnight, when the traction services are at a minimum.

1.3.49 Reference electrode

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

1.3.50 Resistance potential

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

1.3.51 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.

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

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

1.3.53 Stray current

Current flowing through paths other than the intended circuit.

1.3.54 Structure

A metal which has a surface in contact with an electrolyte.

1.3.55 Structure potential

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

1.3.56 Structure potential shift

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

1.3.57 Sulfate-reducing bacteria

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

1.3.58 Telluric current

The current induced by the variations in the earth's magnetic field that intersects the structure.

1.3.59 Test point

A nominated point on a structure for electrical contact.

1.3.60 Transformer/rectifier

A form of cathodic protection unit.

1.4 COMPETENCE OF PERSONNEL

1.4.1 General

The design, installation, commissioning and operation of cathodic protection systems shall be carried out by personnel qualified by experience and training in the appropriate aspects of cathodic protection applied to pipelines and cables.

The Cathodic Protection Technician or Cathodic Protection Technologist, as defined in Clauses 1.4.2 and 1.4.3 respectively, shall sign off and accepts responsibility for any cathodic protection report that contains any testing results obtained during the design, installation, commissioning and operation of a cathodic protection system, and shall be satisfied that personnel who carried out the testing or provided the data for the report are competent. The report includes the interpretation of the data, review of the data for anomalies, justification of the use of any processes or protection criteria, and conclusions and recommendations.

1.4.2 Cathodic Protection Technician

Persons signing off reports relating to the routine operation of the system as described in Section 10 shall be a Cathodic Protection Technician, defined as—

- (a) an Australasian Corrosion Association (ACA) accredited Corrosion Technician who has passed the ACA CP Advanced courses, and who has had a minimum of 4 years' experience in CP monitoring under the direct supervision of a Cathodic Protection Technologist who complies with these requirements; or
- (b) a NACE accredited CP Technician; or
- (c) having obtained an Institute of Corrosion certification as a Level 2 Senior Cathodic Protection Technician; or
- (d) certified in accordance with EN 15257 as having Level 2 Cathodic Protection competence; or
- (e) having a demonstrated level of competency equivalent to any of the above.

1.4.3 Cathodic Protection Technologist

Persons signing off reports relating to the design (Sections 4 and 5), interference testing (Sections 6 and 8), commissioning (Section 9) and non-routine testing and problem solving outside the scope of Section 10 shall be a Cathodic Protection Technologist, defined as—

- (a) an ACA accredited Corrosion Technologist who has passed the ACA CP Advanced courses, and who has had a minimum of 10 years' experience in CP monitoring, design and installation, under the direct supervision of a Cathodic Protection Technologist who complies with these requirements; or
- (b) a NACE accredited CP Technologist;
- (c) certified in accordance with EN 15257 as having Level 3 Cathodic Protection competence; or
- (d) having obtained an Institute of Corrosion certification as a Level 3 Senior Cathodic Protection Technician; or
- (e) a Corrosion Engineer—defined as a person who has complied with any of the above requirements, and who has a science degree or an engineering degree, or is a professional engineer or scientist accredited by the Institution of Engineers Australia or other relevant professional scientific institute or other similar body; or
- (f) having a demonstrated level of competency equivalent to any of the above.

In addition, when the reports relate to a.c. interference, stray traction current effects or telluric effects, the Cathodic Protection Technologist shall have appropriate experience in these areas to ensure that they are competent to sign off a report involving these issues.

SECTION 2 CRITERIA FOR CATHODIC PROTECTION

2.1 SCOPE AND GENERAL

2.1.1 Scope

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

2.1.2 General

Metals may be protected from corrosion by the application of direct current to lower and maintain the potential of the metal sufficiently negative 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/copper sulfate reference electrode. Reference electrodes other than copper/copper sulfate may be used, provided that their relativity to copper/copper sulfate is established. Such electrodes may include silver/silver chloride for use in seawater environments.

2.2 PROTECTION CRITERIA

2.2.1 General

The degree of protection is assessed by the use of one or more of the criteria set out in Clauses 2.2.2, 2.2.3 and 2.2.4. While these criteria are most commonly used, it is important that advice be obtained from a cathodic protection specialist to ensure that the criteria are correctly applied.

There are a number of methods for evaluating the protection status to determine compliance with a protection criterion, each of which has its limitations as detailed in Appendix B. A measurement that indicates compliance with a protection criterion does not necessarily mean that the pipeline will not corrode under certain specific conditions. Such conditions include the following:

- (a) Metal surfaces that are shielded from receiving cathodic protection current by disbonded coating.
- (b) Metal surfaces that are shielded from receiving cathodic protection current by non-metallic or high resistance foreign materials.
- (c) Sections of the pipeline that are located in local areas of high soil resistivity.
- (d) Sections of the pipeline where coating damage has occurred by installation into a rock wall trench and contact with the rock wall shields the metal surface from receiving cathodic protection current.
- (e) Locations where a stone has penetrated the coating and is in contact with the metal of the pipe and therefore shields the steel from receiving cathodic protection current.
- (f) Sections of a pipeline subject to a high level of induced a.c. from paralleling powerlines under powerline load conditions.
- (g) Potential attenuation into a crevice between the pipe and disbonded coating where the potential may fall within the stress corrosion cracking range.
- (h) The pipeline has an elevated operating temperature.

- (i) Bacterial induced corrosion had initiated prior to the application of cathodic protection.

An assessment of cathodic protection according to the criteria as stated in this Standard is subject to some level of uncertainty because of the various factors described above. These factors are usually difficult to assess precisely, but shall be included, as far as reasonably practicable, in determining the likely overall effectiveness of cathodic protection on the structure.

2.2.2 Potential criteria

2.2.2.1 General

Potential criteria are applicable where the structure temperature is near ambient, and the electrolyte near the metal/electrolyte interface comprises natural soils and waters. If these conditions are not met, an evaluation of the conditions should be carried out and an appropriate criterion determined.

The potential criteria given in Clauses 2.2.2.2, 2.2.2.3, 2.2.2.4, 2.2.2.5 and 2.2.2.6 refer to the potential between the metal and the electrolyte immediately adjacent to it. The voltage gradient in the electrolyte between the structure and the reference electrode shall be evaluated and added to the protection criterion to determine the protection potential applicable for the structure. Methods of evaluating or eliminating the voltage gradient between the structure and the reference electrode and methods of evaluating the protection status are provided in Appendix B.

The potential of any reference electrode is also dependent upon temperature.

NOTE: A table of correction values to be used is included in Appendix L for assessing protection levels using criteria based on potential with respect to a reference electrode.

2.2.2.2 Ferrous structure

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

2.2.2.3 Copper/copper alloy structure

The criteria for the protection of a buried copper structure is 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.

2.2.2.4 Lead structure

The criteria for the protection of a buried lead structure is 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.

2.2.2.5 Mixed metal structure

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

2.2.2.6 *Structures subject to variable stray current effects*

2.2.2.6.1 *General*

The response of a structure to stray current excursions is dependent upon many factors, including soil resistivity, degree of soil aeration, moisture content and the structure coating quality. The magnitude of the stray current excursions may also be dependent on the proximity of the traction systems or in the case of telluric effects the orientation of the pipeline (see Paragraph A4). The extent of depolarization is determined by the frequency, magnitude and the duration of anodic excursions. 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 the magnitude of the voltage gradients along the pipeline and 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.

NOTE: Infrequent excursions less than 500 ms in duration may be excluded from the evaluation if they are not considered to be a corrosion risk.

Requirements for the protection of buried structures subject to traction and telluric current effects are specified in Clauses 2.2.2.6.2 and 2.2.2.6.3.

2.2.2.6.2 *Traction current effects*

Where structures are required to be evaluated for traction stray current effects in accordance with this Clause, it is necessary to record the potential during a sufficient period of time to ensure that the maximum exposure to the stray current effects is encompassed. This period shall include the quiescent traction period, the morning and evening usage peaks and is nominally twenty four hours with a minimum of not less than twenty hours. If a data logger is used for the monitoring of potential, its frequency of sampling shall be not less than four samples per minute.

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 not be more positive than the protection criterion for more than 5% of the test period.
- (ii) The potential shall not be more positive 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 not be more positive 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 not be more positive than the protection criterion plus 850 mV (i.e. 0 mV for ferrous structures) for more than 0.2% of the test period.

Where such structures do not comply with the above and are characterized by relatively brief anodic excursions interspersed with longer cathodic periods and can demonstrate protection through other means such as resistance probes, coupons or structure corrosion rate history shall still comply provided they are not more positive than the protection criterion for more than 5% 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 not be more positive than the protection criterion for more than 5% of the test period. The positive excursions shall be brief and have negative excursions between them.

2.2.2.6.3 *Telluric current effects*

Where structures are required to be evaluated for telluric stray current effects, it is necessary to record the potential over nominally twenty four hours with a minimum of not less than 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.

The potential of structures that are subject to telluric current effects shall not be more positive than the protection criterion for more than 5% of the test period. When determining the extent of the potential variations, an assessment shall be made of the degree of ionospheric disturbance at the time of the recording.

Telluric current shall be evaluated when there is an indication that the difference in potential between the most positive peak and most negative peak at a test point exceeds 200 mV. The evaluation shall be carried out before every potential survey. If the difference in potential between the most positive peak and most negative peak at a test point exceeds 200 mV, the entire pipeline protection section shall be subject to a data logger or chart recording survey of potentials.

NOTE: Where a pipeline has a demonstrated history of significant telluric activity, potential surveys should normally be performed using data loggers or chart recorders.

2.2.2.7 *Structures subject to a.c. interference corrosion*

Cathodic protection criteria are unaffected by a.c. interference provided that acceptable a.c. voltage levels are met.

Until relatively recently it was generally assumed that alternating currents induced on a steel pipeline were not capable of producing measurable corrosion. However, in recent years several papers have been published that report significant pipeline corrosion caused by alternating currents. This appears to result in part from improved coating quality, and increasing interaction between pipeline and power transmission infrastructure that results in high current densities at small coating defects.

Published guidance on acceptable voltage levels can be found in CIGRE TB 290 and in EN 15280.

The acceptable steady-state induced voltage limit stated in these documents is—

- (a) 4 V a.c. for soil resistivity $\leq 25 \Omega \cdot \text{m}$; and
- (b) 10 V a.c. for soils whose resistivity is $> 25 \Omega \cdot \text{m}$.

CIGRE TB 290 provides additional guidance on assessing the risk of a.c. corrosion. NACE IP 35110 also provides a state-of-the-art review of the corrosion rate, mechanisms and mitigation requirements for a.c. corrosion.

In situations where current densities can be determined, the propensity for a.c. corrosion may be an issue if the a.c. current density exceeds 10 A/m^2 and is greater than the d.c. current density. Furthermore, a.c. corrosion becomes highly likely if the a.c. current density exceeds 100 A/m^2 . (See EN 15280 for further information.)

NOTE: Considerable research is being undertaken on developing a better understanding of the a.c. corrosion phenomenon.

2.2.3 100 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 may not be applicable if the structure is affected by stray current or significant galvanic corrosion couples.

2.2.4 Alternative criteria

2.2.4.1 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 B.

2.2.4.2 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 in a year. Resistance probes shall be installed and used in accordance with the requirements of Appendix B.

2.2.4.3 Other criteria

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

2.3 OVERPROTECTION

Overprotection may cause accelerated disbondment of a coating and other deleterious effects and shall be minimized.

NOTES:

- 1 To determine the level of overprotection the potential corrected for soil voltage gradient error should be determined. This may be achieved by measuring the instantaneous off-potential as described in Appendix B. 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. In stray current areas, it may not be possible to prevent potentials going more negative than this value.
- 2 For testing to determine coating resistance to cathodic disbonding, refer to AS 4352.

SECTION 3 MEASURING TECHNIQUES AND EQUIPMENT

3.1 GENERAL

All instruments used for determining protection status shall be of an appropriate type and accuracy and shall have a valid calibration certificate or be calibrated against an instrument with 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.

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.

NOTE: For information on the calibration and maintenance of reference electrodes, refer to Appendix C.

3.2 POTENTIAL MEASUREMENT AND EQUIPMENT

3.2.1 General

The influence of stray current and telluric effects shall be established along the structure by data logging over a period as specified in Section 2 or by other means as required. In areas free of significant stray current or telluric effects, 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) AC 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.

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.
- 3 AC rejection should cover all frequencies of 50 Hz and above, since higher frequency components are often present.
- 4 Filtering may be required on data loggers to remove anodic transients up to 500 ms in duration because such brief transients are not considered a corrosion risk.

3.2.2 Positioning of monitoring electrodes

When measuring potential, reference electrodes should be placed at locations of minimum soil potential gradients, i.e. remote from anode beds and as close as practical to the structure. Potential gradients shall be taken into account when determining potential readings. These considerations shall similarly apply when establishing the potential of fixed electrodes. It may be necessary to water the ground immediately beneath the reference electrode to reduce the contact resistance with the soil.

Potential gradients may exist in the close proximity of earthing systems, particularly grading rings and copper mesh which may be connected to test points, valves and related infrastructure.

The extent of earthing systems shall be determined and the reference electrode located outside the zone of influence.

3.2.3 Off-potential measurements

Instantaneous off-potential measurements in areas that are not subject to the effects of stray currents or tellurics shall be carried out in accordance with Appendix B ensuring that all current sources are interrupted synchronously. These current sources include galvanic anodes, directly connected earthing systems, cross-bonds and polarization cells. For measurement techniques in areas affected by stray currents or telluric effects refer to Clause 2.2.2.6.

NOTE: Polarization cells may act as large capacitors and provide current when other sources are disconnected. This effect can be significant on well-coated pipelines that require little cathodic protection current. However, on pipelines with moderate or high CP current requirement the contribution from polarization cells during current interruption will generally be negligible.

There are inherent errors in using the pipeline off-potential technique. Refer to Paragraph B2.

3.3 CURRENT MEASUREMENT AND EQUIPMENT

Equipment used to measure current shall introduce sufficiently low resistance into the circuit being measured to cause errors of less than 1%. Commonly available digital multimeters typically introduce voltage drops of up to 200 mV at full scale reading. This is generally insignificant when taking measurements on impressed current circuits. However, 200 mV voltage drop in circuits with low driving voltage, such as encountered when measuring galvanic anode currents, will result in substantial errors. The error introduced may be reduced by selecting a current range on the instrument such that the leading numeral is zero (e.g. a reading of 020.0 mA rather than 200.0 mA). Errors can be virtually eliminated by taking measurements using a zero resistance ammeter circuit configuration, however, this is not generally suitable for time efficiency of measurement. An effective alternative is to use d.c. current clamps, which introduce no voltage drop in the measurement circuit.

NOTE: The ability of some d.c current clamps to measure low currents may be limited, and their resolution and accuracy needs to be evaluated for suitability to the measurement being taken.

SECTION 4 DESIGN OF STRUCTURES TO ACCOMMODATE CATHODIC PROTECTION

4.1 SCOPE AND GENERAL

4.1.1 Scope

This Section provides requirements for the design of pipes and cables, to accommodate cathodic protection.

For protection to be achieved, a structure shall be—

- (a) immersed or buried in an electrolyte;
- (b) electrically continuous; and
- (c) electrically isolated from structures or components that would otherwise compromise the cathodic protection.

4.1.2 General

Because many aspects of design and construction of pipes and cables can interfere with the corrosion prevention process, cathodic protection should 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 earliest possible time during the construction of the structure. It may be necessary to provide a temporary system prior to the installation and commissioning of a permanent system.
- 2 Additional information on structure design is given in Appendix D.

4.2 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 should 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.

Structures intended for transportation or storage of hydrocarbon products or hazardous fluids shall be provided with temporary cathodic protection unless the permanent system is commissioned within 3 months of structure installation.

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

4.3 COATED AND UNCOATED STRUCTURES

Most structures should 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 E.

4.4 ELECTRICAL HAZARDS AND DISTURBANCES

4.4.1 General

There are a number of mechanisms that can give rise to electrical hazards in buried or immersed structures. The mitigation of these electrical hazards shall be carried out in conjunction with the cathodic protection design in order to avoid an adverse interaction.

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

Three forms of stray current can affect the structure or its operation, as discussed in Clauses 4.4.2 to 4.4.4.

4.4.2 Direct current

Stray direct current can pose a corrosion hazard to a buried or submerged 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, telluric effects, other cathodic protection installations or electrical distribution systems.

While it may not be possible to fully quantify a stray current problem until the structure is installed and the environment has stabilised, an evaluation of the stray current risks shall be undertaken at the design stage and appropriate mitigation measures included in the design as far as can reasonably be determined. It may be possible to reduce or remove the problem at the design stage by locating the structure away from sources of such current.

Electrical transmission and distribution systems may also be a source of d.c. current, particularly by way of dissimilar metals interaction and partial rectification of out of balance a.c. currents (e.g. silica sand soils/copper oxides on earthing systems).

4.4.3 Surge current (short-term conditions)

Surge current (short-term conditions) can arise from several causes, as follows:

(a) *Lightning*

The results of lightning can include the following:

- (i) Direct lightning strikes to the pipeline or its ancillaries, including exposed valves and test points (see Paragraph F3.7).
- (ii) Magnetic induction from lightning strikes to ground near the pipeline.
- (iii) Conductive coupling to the pipeline in the earth by lightning current from adjacent structures, e.g. powerline towers.

(b) *Power transmission and distribution systems*

The results of surge current in power transmission and distribution systems can include the following:

- (i) Fault current on powerlines that run parallel to the pipeline and which causes induced longitudinal voltage on the pipeline at a hazardous level.
- (ii) Conductive coupling to the pipeline in the earth from power fault current to a nearby tower.
- (iii) Earth potential rise from fault current flowing to earth at towers, poles or high voltage installations (see Paragraph F3.4).

4.4.4 Continuous alternating current

Continuous alternating currents can be induced in the pipeline as a result of the following circumstances:

(a) *Long pipelines running parallel to a powerline*

For powerline/pipeline parallelisms (typically over 1 km), the load current in the powerline may induce, by transformer action, a continuous voltage in the pipeline (see Paragraph F3.2).

NOTES:

- 1 A special case is for single wire earth return (SWER) powerlines. Being an earth return circuit, efficient coupling occurs with the pipeline, however, currents are generally low and problems generally only arise with longer exposures or very high soil resistivities.
- 2 A similar condition arises with a.c. railways. Although the rail return parallels the earth return circuit, significant coupling arises with parallel pipelines and in some cases mitigation can be unachievable.

(b) *Capacitive coupling*

Electrically continuous pipes, or a section of a pipeline, that is above ground and isolated from ground under a power transmission line will intercept the electric field between the powerlines and earth, resulting in some voltages appearing on the pipeline (see Paragraph F3.5).

4.4.5 Mitigation measures for pipeline currents

In respect to the design of mitigative measures for pipeline currents generated as described in Clauses 4.4.3 and 4.4.4, the attention of a specialist is required.

Electrical hazards on pipelines shall be addressed by AS/NZS 4853.

4.5 TEST POINTS

4.5.1 General

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

4.5.2 Spacing

Typical maximum spacings for test points are as follows:

(a) Uncoated or poorly coated structures:

- | | |
|------------------------------------|---------|
| (i) Broad-rural..... | 1000 m. |
| (ii) Semi-rural | 500 m. |
| (iii) Suburban and high-rise | 500 m. |
| (iv) Low density dwelling | 500 m. |

(b) Well-coated structures:

- | | |
|-----------------------------------|---------|
| (i) Broad-rural..... | 5000 m. |
| (ii) Semi-rural | 2000 m. |
| (iii) Suburban and high-rise..... | 500 m. |
| (iv) Low density dwelling | 1000 m. |

4.5.3 Location

Test points should encompass critical areas where problems are likely to be encountered or where extra precautions are required.

Locations at which test points should be considered include the following:

- (a) At rail crossings, road crossings and at waterways.
- (b) At steel casings, on the casing and on the structure.
- (c) Adjacent to insulating joints and at structure terminations.
- (d) At highly corrosive soil locations.
- (e) At likely sources and discharge points of stray currents.
- (f) Adjacent to air/electrolyte interfaces.
- (g) At close proximity to foreign structures and at crossings with foreign structures.

Test points should be sited where they are accessible but are unlikely to be damaged after installation, e.g. at boundary fences. They should be located at sites selected to minimize hindrance to land usage and to avoid attracting vandalism.

Requirements for test point cabling are set out in Clauses 5.5 and 5.6.

All surface terminal boxes should be of durable construction and all test points should be suitably identified.

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

4.5.4 In situ reference electrodes

Consideration should 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 hard-standing area. Such reference electrodes should 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 should 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.

4.6 INSULATING JOINTS (ISOLATION JOINTS)

4.6.1 General

Insulating joints are used to electrically isolate parts of the structure to facilitate the use and control of cathodic protection systems and the effects of stray traction current. 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 and requiring cathodic protection on the external surface may exhibit internal corrosion at insulating joints or flanges. This may be minimized by coating the internal surfaces of the flanges and the pipe internally on the cathodically protected side with a non-conductive organic coating 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.

NOTE: A typical minimum length of internal coating for the purpose of reducing the internal conduction of CP current across an insulating joint is two pipe diameters for water with resistivity of 50 Ω .m. The actual requirement depends on water resistivity, with longer lengths required for lower resistivities.

Although not part of the scope of the cathodic protection designer, the electrical isolation joints shall be designed by the pipeline designer to take account of the operating conditions of the structure in terms of maximum design pressure, vibration, fatigue, cyclic conditions, temperature, thermal expansion and construction installation stresses. The materials selected should be resistant at the structure design temperature, to any fluids transported, including any corrosion inhibitors or flow modifiers that may be added to these fluids.

4.6.2 Location of insulation joints

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

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

- (a) At ownership changeover points.
- (b) At connection points to main line installations such as gathering or distribution laterals.
- (c) At inline measuring and 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) Where provision is made to minimize induced voltages.
- (i) At structure terminations.

4.6.3 Hazards and obstacles

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.

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

Insulating joints in enclosed or defined hazardous areas where combustible gases may be present shall be fitted with electrical surge protection. Surge protection devices in such areas shall be of a type that cannot cause an exposed arc.

Insulating joints shall be fitted with surge protection where pipelines are installed in areas subject to high voltage surges, such as near high voltage power transmission lines or areas subject to electrical storm activity. This protection is required to prevent breakdown of the insulation and safeguard personnel from electrical shock should they be in contact with both sides of the joint at the time of a surge. Such systems include polarization cells, insulating shrouds, properly rated surge protection devices and adequate insulation over a length of the structure to prevent personnel contact. Cable connections should be short, direct, and of a size suitable for carrying short-term high current loading. Rating of surge protection devices shall be selected to take into account the electrical hazard mitigation requirements of the pipeline and the breakdown voltage of the insulating device.

All insulating joints shall be electrically tested prior to installation and after tie-in to pipework (prior to backfilling for buried joints). Insulating joints in pipelines carrying conductive fluids (such as water) shall also be retested after filling. For buried joints this latter test shall be carried out prior to backfilling if practicable.

NOTE: Refer to Clause 7.7 and Appendix Q for test methods.

4.7 ROAD, RAIL AND OTHER CROSSINGS

From a cathodic protection viewpoint uncased crossings are preferred rather than cased crossings. Buried structures are sometimes cased for physical protection or other reasons under railway lines, major roads and other crossing locations and in these situations, for cathodic protection purposes, such casings shall be made of a conductive material, e.g. steel or concrete. Non-conductive casings are not compatible with cathodic protection.

NOTE: Requirements for structures installed within railway easement boundaries are as given in AS 4799.

Cathodic protection of the pipeline within the casing can only be achieved if the pipeline and casing are electrically isolated. Therefore, where steel casings are used they shall be electrically isolated from the structure by insulating spacers. Electrical isolation between the pipeline and casing shall be confirmed by testing prior to backfilling. Where a casing test point has been installed, testing for isolation shall also be made after backfilling.

The annular space shall be treated using one of the following options:

- (a) Filling the space with an electrolyte, e.g. bentonite clay or cement mortar.

The level of any filling shall be above the structure. This method allows cathodic protection of the structure within the casing, provided that the casing is uncoated. Cement mortar has the following advantages:

- (i) Providing mechanical support to the pipe so that it cannot settle and short circuit to the casing.
- (ii) Provides an alkaline environment so that bacterial activity is halted and exposed pipe steel is in a non-corrosive passive state.

The grout filling shall contain a flow modifier so that it flows readily around isolation devices and along the annular gap. It shall be pumped into the bottom of the low end of the casing and vented at the top of the high end of the casing.

Electrical isolation shall be confirmed after insertion of the carrier pipe but prior to filling with electrolyte, and further confirmed by retesting prior to backfilling.

- (b) Leaving void.

NOTES:

- 1 In practice it is difficult to prevent the ingress of moisture. End seals can be used, and for preference, casings should be sloped to allow drainage.
- 2 Any areas of the pipeline that are not immersed will not receive cathodic protection and may be subject to corrosion at coating defects in a humid environment.

Care shall be exercised to ensure that the coating on the structure is not damaged during installation.

Steel casings shall not be coated or lined, unless it is with a conductive material, e.g. cement, otherwise the structure within the casing may not be cathodically protected.

Steel casings shall not be cathodically protected because interference between the casing and the structure may cause corrosion of the structure inside the casing.

If isolation testing is required with steel casings, then a casing test point shall be installed.

NOTE: The coating condition of pipe installed by HDD or horizontal drilling should be evaluated prior to tying the pipe into the pipeline. This is because any coating defects on the pipe are unlikely to be readily repaired once the pipe is tied in. The procedure and proforma within Appendix M may be used for the testing.

4.8 ELECTRICAL ISOLATION

Buried structures shall be installed in a manner to ensure that they remain electrically isolated from all foreign buried metallic structures.

It is recommended that a separation of at least 300 mm be maintained between buried structures to prevent metallic contact shielding and to minimize interference. The annulus separation between a pipeline and casing will be determined by the installation procedure and size of the insulating spacers.

Specific items that require electrical isolation from a protected structure include the following:

- (a) Metallic reinforcement in weights, anchors and weight coatings.
- (b) Uncoated metal housings ancillary to a structure.
- (c) A metal casing, when it is intended to maintain electrical isolation between the casing and the structure.

NOTE: If the casing remains in electrical contact with the structure, a loss of cathodic protection on the structure will occur within the casing area.

- (d) Electrical supply earth systems.

NOTES:

- 1 Possible connections may occur in the earthing systems of compressors, pumps, telemetry installations, and valves or in any other electrically powered equipment that is earthed.
- 2 Isolation of electrical earthing may be achieved by the use of polarization cells, subject to the agreement of the electrical distributor.

- (e) Metal and metal reinforcing, together with associated earthing conductors and electrodes, on power transmission towers.
- (f) Areas where there is a likelihood that cathodic protection will be adversely affected by contact with other metallic structures such as bridgework, pipe stanchions, tunnel enclosures, piling and reinforcing in concrete.

NOTE: Where structures are attached to bridgework, it is permissible to forego electrical isolation, provided that insulated joints are used at each end of the bridge at the air/ground interface, i.e. where the pipe enters the ground.

4.9 ELECTRICAL CONTINUITY

For cathodic protection to be effective it is necessary to ensure that the structure, or each section of the structure, is electrically continuous. Bonds may be required to provide continuity of cathodic protection around sections isolated by insulating joints.

Care shall be taken to ensure electrical continuity in bolted structures. The electrical resistance of bolted connections can increase substantially when not protected from corrosion due to ingress of moisture.

The use of electrically-continuous welded or fusion joints is recommended. Joints of high electrical resistance, e.g. flanges with elastomeric rings, or spigot or socket couplings, shall be fitted with bonds.

The mechanical strength of a bond shall be adequate to withstand the effects of backfilling and maintenance, and the current-carrying capacity of a bond should be sufficient for it to remain undamaged after the passage of a heavy surge current from an external source (see Clause 4.4).

Continuity bonds shall be of a proven type that demonstrates their long-term electrical reliability. Welded connections, pin brazed studs or exothermic welds are strongly preferred. Continuity testing shall be carried out to confirm the effectiveness of all bonds prior to backfilling.

SECTION 5 DESIGN OF CATHODIC PROTECTION SYSTEMS

5.1 SCOPE AND GENERAL

5.1.1 Scope

This Section provides requirements for the design of systems for cathodic protection.

5.1.2 General

The design requirements for cathodic protection units shall comply with applicable regulatory requirements and the relevant requirements of AS/NZS 3000, AS/NZS 3008.1.1, AS/NZS 5000.1 (see Paragraph 5.5.4), AS 2374 and AS/NZS 3100.

NOTES:

- 1 The installation and operation of cathodic protection systems or traction drainage bonds may be subject to approval under legislation. In Australia, the control of stray currents from d.c. traction systems is coordinated by state electrolysis committees in some Australian states.
- 2 Further detailed information and guidance on the design of cathodic protection systems is given in Appendix G.

5.2 SAFETY HAZARDS

5.2.1 Electrical hazards

As a matter of personnel safety, the nominal voltage of a cathodic protection power supply shall not exceed 60 V ripple free d.c. (see Clause 5.2.2) unless appropriate safety precautions have been taken. In any case, the nominal voltage of a cathodic protection power supply shall not exceed extra-low voltage in accordance with the definitions of AS/NZS 3000. Requirements for pipelines in proximity to powerlines are given in AS/NZS 4853 and discussed in Appendix F. Consideration shall be given to the possibility of unintended high voltage occurring on the structure caused by the following.

- (a) Induced potentials from neighbouring high voltage lines.

NOTE: See Appendix F, Paragraph F3.

- (b) Surge effects due to power systems component failure including voltages developed across insulated joints.

- (c) Effects of lightning.

NOTE: See Appendix F, Paragraph F3.7.

In addition, the following aspects should be considered:

- (i) The effects of electric sparks on structures carrying products that are flammable and capable of forming explosive air/gas mixtures (see AS/NZS 60079.0). It is also necessary in such circumstances to ensure control of static electricity (see AS/NZS 1020).

NOTES:

- 1 AS/NZS 60079.0 defines the extent of hazardous zones in relation to various types of installations or items of equipment handling flammable liquids or gases. Protective devices should be installed to prevent build-up of static charge so that sparking does not occur.
- 2 Conduit or ducting proceeding from a cathodic protection installation into hazardous areas, e.g. test boxes and transformer rectifier enclosures, should be sealed to prevent the flow of flammable substances.

- (ii) Electrical gradients produced in water around fully and partially submerged anodes.

NOTE: Electric field strengths in water in excess of about 3 V/m when applied to the body at chest level can paralyse and cause respiratory failure. For design reasons, the field strength may sometimes be required to exceed this value. This will occur most frequently close to impressed current anodes, sometimes in seawater. In these situations, warnings should be given and access to such areas prevented by shielding or other means.

5.2.2 Wiring standards

Cathodic protection systems are direct current (d.c.) extra low voltage (ELV) installations and wiring shall comply with the requirements of Clause 7.5 of AS/NZS 3000:2007.

Extra low voltage is defined as voltages not exceeding 120 V ripple-free d.c. Ripple-free d.c. for sinusoidal ripple voltage is a ripple content not exceeding 10% r.m.s.

By definition, cathodic protection systems are protected extra-low voltage (PELV), as they are not electrically separated from earth because they are effectively earthed by the anodes in both galvanic and impressed current systems.

For PELV, basic protection from direct contact for all live parts shall be provided by barriers or insulation capable of withstanding a test voltage of 500 V a.c. for 1 min.

This shall be deemed unnecessary if the electrical equipment is within the zone of influence of equipotential bonding (e.g. inside an earthed cabinet) and the nominal voltage does not exceed 60 V ripple-free d.c. when the electrical equipment is normally used in a dry location only and large-area contact (greater than 8000 mm²) with the human body is not expected. In all other cases, basic protection is not required if the voltage is less than 15 V ripple-free d.c.

5.3 DESIGN REQUIREMENTS

The cathodic protection system for a structure shall be designed to provide full protection for the specified life of the system. In particular the system shall—

- (a) achieve a level of protection in accordance with the performance criteria and the protection criteria appropriate to the structure;
- (b) comply with all relevant regulatory requirements;
- (c) be compatible with the material of the structure;
- (d) not cause detrimental anodic or cathodic interference to any foreign structure;
- (e) not cause excessive negative potentials that may be harmful to the structure or to the coating of the structure (see Clause 2.3);
- (f) incorporate a testing facility to evaluate the levels of protection achieved;
- (g) not cause excessive electrical noise in telecommunication or information technology circuits;

NOTES:

- 1 For maximum allowable noise levels, refer to the relevant telecommunications act.
 - 2 Noise is minimized by correct filtering of transformer/rectifier units.
- (h) not cause malfunctioning of railway signalling equipment; and
 - (i) be capable of adjustment during commissioning for impressed current systems.

In areas subject to the effects of stray current from traction systems or other cathodic protection systems, the design shall allow for the mitigation of possible interaction on the structure.

The cathodic protection system shall be brought into operation as soon as possible following construction of the pipeline. If permanent cathodic protection cannot be commissioned within 3 months of installation of the pipeline, temporary cathodic protection shall be installed as the pipeline is laid before a biofilm forms. A temporary cathodic protection system will not necessarily give protection against stray current effects.

5.4 DESIGN DATA

5.4.1 General

Data for the design of a cathodic protection system shall be collected, documented and retained for the life of the system.

NOTE: Structure factors that have a significant bearing on the design of a cathodic protection system are given in Appendix D and an example of cathodic protection system design documentation is given in Appendix H.

5.4.2 Structure layout

Details of the structure shall be collected and documented. All features that may affect the successful implementation of a cathodic protection system shall be documented and considered in the design.

5.4.3 Cathodic protection current requirements

The current requirements for cathodic protection shall be determined by trial or by calculation. All assumptions in the derivation of the total current requirement shall be clearly documented. Sufficient capacity shall be provided to allow for structure coating deterioration over the life of the system.

NOTE: Mitigation of interference effects with any secondary structure may require additional current allowance.

5.4.4 Environment resistivity

The environment resistivity at the site of each cathodic protection installation shall be determined for the design of the groundbed system and the determination of interference. This is not required for temporary galvanic cathodic protection systems. Refer to Appendix O for resistivity measurement techniques, analysis and interpretation of the data.

5.4.5 Anode characteristics

The performance characteristics of the anodes to be used for the system shall be estimated and documented. In particular, the actual consumption rate of the anode in the operating environment shall be estimated and confirmation made that the anode array will achieve the system requirements in terms of current output and life.

5.5 MATERIALS

5.5.1 General

All materials specified in the design shall be suitable for installation in the proposed environment.

5.5.2 Cathodic protection units

Cathodic protection units shall comply with the requirements of the Clause 7.5.3 'Sources of supply by SELV and PELV' from AS/NZS 3000:2007.

Generally the source of supply shall be from a safety isolating transformer complying with AS/NZS 61558, however, any current source that has a degree of physical separation from higher voltage supply equivalent to the requirements of AS/NZS 61558 is acceptable.

A main switch or switches shall be installed to control the supply in all unearthed conductors of a cathodic protection unit unless the installation can be disconnected from supply on the higher voltage side.

Overcurrent protection shall be provided in all the unearthed conductors of the installation at the origin of supply, unless the installation meets the exceptions in Section 7 of AS/NZS 3000:2007.

5.5.3 DC cables

5.5.3.1 General

The current carrying capacity and temperature ratings of cables shall comply with the requirements of AS/NZS 3008.1.1. Cables shall be appropriately sized for the maximum design currents and shall be appropriately insulated. Joints in cables shall be avoided wherever possible, but where installed they shall be located so as to be accessible and their location clearly documented. Particular care shall be taken with the insulation of positive cables, as any damage to the insulation can result in premature failure of the cable.

Conductors shall be sized so that the voltage drop at any point in the installation does not exceed 10% of the nominal value when carrying the circuit-operating current unless the equipment is designed for operation with a voltage drop greater than 10%.

5.5.3.2 Insulation

Impressed current anode cables are particularly susceptible to failure from damage and insulation breakdown due to rapid anodic copper dissolution and the effects of chlorine gas.

Consideration should be given to sources of environmental attack on cable insulation such as termites and other agents.

Colours for cable insulation on any one installation should comply with a uniform colour code. Where a colour code is not specified, the following insulation colours are recommended:

- (a) Primary structure black.
- (b) Anode feeder cables..... red.
- (c) Reference electrodes yellow.
- (d) Earthing electrodes green or green-yellow.

Cable colours coded with green and green-yellow spirals shall be used exclusively for safety earthing applications.

5.5.3.3 Cable connections

Cable connections shall be electrically sound and sealed to prevent the ingress of moisture. Typical connection processes comprise welding (including thermit welding), brazing and bolting. Where bolted connections are used they shall be designed to prevent them increasing in electrical resistance due to corrosion, loosening, mechanical damage or any other cause.

NOTE: For details on thermit welding on hydrocarbon pipelines, refer to AS 2885.2.

5.5.4 Test cables

Test cables shall be made of copper, be of stranded construction, have a minimum conductor size of 4 mm² and comply with AS/NZS 5000.1. Double insulated cable is preferred.

5.5.5 Anodes

Anodes shall be fit for the intended purpose and conform to the relevant technical specifications. Sacrificial anodes shall comply with the requirements of AS 2239.

NOTE: The anode reactions of an impressed current cathodic protection installation in a saline environment result in the electrolytic formation of chlorine. Under stagnant conditions, the chlorine may be evolved as a gas, and could present a hazard to cable insulation and to inspection and maintenance personnel.

5.5.6 Electrical isolation joints

Electrical isolation joints shall be designed to provide electrical isolation for the pipeline (see Clause 4.6).

5.6 TEST POINTS

Provision shall be made for the measurement of the structure potential by the installation of test points at intervals along the structure to enable the effectiveness of the cathodic protection system to be verified.

All cable attachments shall be made in a manner appropriate to the structure, and during connection any damage to the coating shall be repaired with an approved material that is compatible with the structure coating and the cable insulation.

5.7 REFERENCE ELECTRODES

Where permanent references are installed they should be located close to the structure and at a similar depth to the structure.

The potential of a reference electrode shall be able to be verified to detect any variations.

Permanently installed reference electrodes shall either be designed to last the life of the system, or provision shall be made for their replacement (see Clause 3.2.2).

Advice on the calibration and maintenance of reference electrodes is given in Appendix C.

5.8 ELECTRICAL EARTHING

The earthing of pipelines can be a complex matter. In general, lightning earthing will be positioned at section ends, and low frequency induction earthing positioned at each end of parallel power transmission exposure.

5.9 NATURAL, INDIGENOUS AND HISTORIC HERITAGE

State and federal legislation exists to protect natural, indigenous and historic heritage.

Mechanisms shall be put in place that ensure disturbance or use of land shall be undertaken consistent with the legal requirements.