IS 8062-2 (2006): Code of Practice for Cathodic Protection of Steel Structures, Part II: Underground Pipelines [MTD 24: Corrosion Protection]

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भारतीय मानक

प्राकृतिक गैस, तेल और द्रव के परिवहन के लिए भूमिगत पाईपलाईन/संरचना की केथोडिक सुरक्षा — रीति संहिता

(पहला पुनरीक्षण)

Indian Standard

CATHODIC PROTECTION OF BURIED PIPELINE/ STRUCTURE FOR TRANSPORTATION OF NATURAL GAS, OIL AND LIQUIDS — CODE OF PRACTICE

(First Revision)

ICS 25.220.40; 75.200

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 2006 **Price Group 9**

Corrosion Protection and Finishes Sectional Committee, MTD 24

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Corrosion Protection and Finishes Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1976. This standard has been prepared to serve as a guide for establishing minimum requirements for the control of external corrosion and underground pipeline/structure.

In this revision, following modifications have been made:

a) Requirement of the following Indian Standards have been merged:
   1) IS 8062 (Part 1) : 1976 Code of practice for cathodic protection of steel structures: Part 1 General principles
   2) IS 8062 (Part 2) : 1976 Code of practice for cathodic protection of steel structures: Part 2 Underground pipeline
b) Scope of the standard has been modified by including cathodic protection for pipeline/structure for transportation of natural gas, oil and liquids keeping in view the present practices being followed in the country in laying of buried pipeline/structure;
c) New definitions have been included in the terminology clause; and
d) Cathodic protection design surveys and surveys during operation and maintenance have been included.

In the formulation of this standard, assistance has been derived from the following:

ISO 15589 — Part 1 : 2003	Petroleum and natural gas industries — Cathodic protection of pipeline/structure transportation systems — Part 1 : On-land pipeline/structure, issued by the International Organization for Standardization (ISO)
ASTM G 97 : 1997	Standard test method for laboratory evaluation of magnesium sacrificial anode test specimens for underground applications, issued by the American Society for Testing and Materials
NACE RP 0169 : 2002	Control of external corrosion on underground or submerged metallic piping systems, issued by the National Association of Corrosion Engineers (NACE), USA

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified valve in this standard.

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AMENDMENT NO. 1 AUGUST 2006
TO
IS 8062 : 2006 CATHODIC PROTECTION OF BURIED PIPELINE/STRUCTURE FOR TRANSPORTATION OF NATURAL GAS, OIL AND LIQUIDS — CODE OF PRACTICE

(First Revision)

General — Substitute 'IS 8062 (Part 2) : 2006' *for* 'IS 8062 : 2006' wherever it appears in the standard

(*First cover and page* 1, *Title*) — Substitute the following for the existing:

'CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURE

PART 2 BURRIED PIPELINE/STRUCTURES FOR TRANSPORTATION OF NATURAL GAS, OIL AND LIQUIDS

(First Revision)'

[*Second cover page, Foreword, para* 3(a)] — Substitute the following for the existing matter:

"a) Some of the requirements of 'IS 8062 (Part 1) : 1976 Code of practice for cathodic protection of steel structure : Part 1 General principles' have been incorporated in this revision".

(*Second cover page, Foreword, para* 3) — Add the following new para after '(d)':

'This standard has been issued in four parts. The other parts are:

IS 8062 (Part 1) : 1976 Code of practice for cathodic protection of steel structures : Part 1 General principles

IS 8062 (Part 3) : 1977 Code of practice for cathodic protection of steel structures : Part 3 Ship's hull

IS 8062 (Part 4) : 1979 Code of practice for cathodic protection of steel structures : Part 4 Galvanic protection of dockgates, caissons, piers and jetties.'

(MTD 24)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CATHODIC PROTECTION OF BURIED PIPELINE/ STRUCTURE FOR TRANSPORTATION OF NATURAL GAS, OIL AND LIQUIDS — CODE OF PRACTICE

(First Revision)

1 SCOPE

This standard deals with the general principles and requirements of cathodic protection system for prevention against corrosion of external underground buried surface of metallic high pressure hydrocarbon product pipeline/structure.

This standard is intended to serve as a guide for establishing minimum requirements for control of external corrosion on pipeline/structure system. Corrosion control by a coating supplemented with cathodic protection should be provided in the design and maintained during service life of pipeline/structure system. Consideration should be given to the construction of pipeline/structure in a manner that facilitates the use of in-line inspection tools.

2 REFERENCES

The following standards contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

Standard	*Title*
ASTM G 97 : 1997	Standard test method for laboratory evaluation of magnesium sacrificial anode test specimens for underground applications
IS 10221 : 1982	Code of practice for coating and wrapping of underground mild steel pipeline/structure
IS 15569	Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation of gas and liquid hydrocarbons:
(Part 1) : 2006	Polyolefin coatings (3-layer pe and 3-layer pp)
(Part 2) : 2006	Fusion bonded epoxy coatings

3 TERMINOLOGY

For the purpose of this Code the definitions given below shall apply.

3.1 Anode — The electrode of an electrochemical corrosion cell at which oxidation occurs. Electrons flow away from the anode in the external circuit, which is normally metallic. Corrosion usually occurs and metal ions enter the electrolyte at the anode.

3.2 Anodic Area — That part of metallic surface that acts as the anode of an electrochemical corrosion cell.

3.3 Anodic Polarization — The change of the electrode potential in the noble (positive) direction resulting from the flow of current between the electrode and electrolyte.

3.4 Backfill — The material which fills up the space between a buried anode and the surrounding soil. It should have low resistivity, moisture retaining capacity and be capable of increasing the effective area of contact between the anode and the environment.

3.5 Bond — A metal piece having very little electrical resistance for connecting two points on the same or different pipeline/structure.

3.6 Cable — One conductor or multiple conductors insulated from one another.

3.7 Cathode — The electrode of an electrochemical corrosion cell at which reduction occurs.

3.8 Cathodic Area — Area on which the cathodic (protection) current is picked up from an electrolyte.

3.9 Cathodic Disbondment — The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

3.10 Cathodic Polarization — The change of electrode potential in the electronegative direction resulting from the flow of current between the electrolyte and electrode.

3.11 Cathodic Protection — A method of protecting a metallic pipeline/structure from corrosion by making it a cathode so that direct current flows on to the pipeline/structure from the surrounding electrolytic environment.

3.12 Cell — An electrolytic system consisting of anode and cathode in electric contact with an intervening electrolyte.

3.13 Closed Hole Deep Ground Bed — An installation in which the anodes are surrounded by backfill.

3.14 Coating — Corrosion protective coating consist of various components/layers of a dielectric material and is applied to a pipeline/structure to isolate it from its immediate environment and to provide uniformly high electrical resistance to flow of current between pipeline/structure and surrounding electrolyte.

3.15 Coating Disbondment — The loss of adhesion between a coating and the pipe surface.

3.16 Coating System — A coating consists of various components which provide effective electrical insulation of the coated pipeline/structure from its immediate environment.

3.17 Conductor — A material suitable for carrying an electric current. It may be bare or insulated.

3.18 Continuity Bond — An intentional metallic connection that provides electrical continuity.

3.19 Corrosion — The degradation of a material, usually a metal or its properties, that results from an electrochemical reaction with its environment.

3.20 Corrosion Potential — The mixed potential of a freely corroding pipe/pipeline/structure surface with reference to an electrode in contact with the electrolyte surrounding the pipe/pipeline/structure.

3.21 Corrosion Products — Chemical compound produced by the reaction of a corroding metal with its environment.

3.22 Corrosion Rate — The rate at which corrosion proceeds. (It is usually expressed as either weight loss or penetration per unit time).

3.23 Coupling — The association of two or more circuits or systems in such a way that electric energy may be transferred from one to another.

3.24 Coupon — Representative metal sample of known surface area used to quantify the effect of corrosion or the effectiveness of cathodic protection.

3.25 Criterion — Standard for assessment of the effectiveness of a cathodic protection system.

3.26 Crossing Point — A point where two or more buried or immersed pipeline/structure cross in a plan.

3.27 Current Density — The current per unit area of an electrode surface.

3.28 Direct Current (d.c.) Decoupling Device — A device used in electric circuits which allows the flow of a.c. in both directions and stops or substantially reduces the flow of direct current. The conduction of current takes place when predetermined threshold voltage levels are exceeded.

3.29 Deep Ground Bed — One or more anodes installed a minimum of 15 m below earth's surface for supplying cathodic protection current to an underground/submerged pipeline/structure through soil/water.

3.30 Differential Aeration — Unequal access of oxygen/air to various parts of a pipeline/structure resulting in local cell action and a consequent corrosion of the less aerated parts.

3.31 Diode — A bipolar semi-conducting device having a low resistance in one direction and a high resistance in the other.

3.32 Drainage — Draining of electric current from a cathodically protected/affected pipeline/structure back to its source through an external conductor.

3.33 Drainage Bond — A bond to effect drainage of current.

3.34 Drainage Test — A test in which direct current is applied usually with temporary anodes and power sources to assess the magnitude of current needed to achieve permanent protection against electrochemical corrosion

3.35 Driving Voltage — Driving voltage is the open circuit potential difference between a pipeline/structure to be protected (a cathode) and the system of anodes which protects it. This voltage does not include the voltage drop in the soil or in the connecting load and is the total voltage available for establishing a protective circuit. The driving voltage in galvanic cells is fixed while that in an impressed current system is variable.

3.36 Earth

a) The conducting mass of earth or of any conductor in direct connection therewith;
b) A connection, whether intentional or unintentional, between a conductor and the earth; and
c) To connect any conductor with the general mass of earth.

3.37 Electrical Isolation — The condition of being electrically separated from other metallic pipeline/structure or the environment.

3.38 Electrical Survey — Any technique that involves coordinated electrical measurements taken to provide a basis for deduction concerning a particular electrochemical condition relating to corrosion or corrosion control.

3.39 Electrode — A conductor of the metallic class (including carbon) which carries current into or out of an electrolyte.

3.40 Electrolyte — A chemical substance containing ions that migrate in an electric field.

3.41 Foreign Pipeline/Structure — Any pipeline/ structure that is not intended to be a part of the system of interest.

3.42 Galvanic Anode — The electrode in a galvanic couple formed by two dissimilar metals (as applied to cathodic protection) in which the galvanic current is flowing from this electrode into the electrolyte. The galvanic anodes corrode and are designated as sacrificial anodes.

3.43 Galvanic Anode Cathodic Protection — A system in which current for cathodic protection of a pipeline/structure is supplied by galvanic anodes. As galvanic anodes get consumed in the system is also designated as Sacrificial Anode Cathodic Protection System.

3.44 Galvanic Cell — A cell consisting of two dissimilar metals in contact with each other in a common electrolyte.

3.45 Galvanic Current — A current passing into or out of a pipeline/structure due to a galvanic couple being established in which the pipeline/structure forms one of the electrodes. By using less noble metal artificial galvanic couples are formed in such a way, that the galvanic current protects a desired pipeline/ structure.

3.46 Galvanic Series — A list of metals and alloys arranged according to their corrosion potentials in a given environment.

3.47 Ground Bed — A system of buried or submerged galvanic or impressed current anodes for supplying cathodic protection current to a pipeline/structure through electrolyte.

3.48 Grounding Cell — A d.c. decoupling device containing two or more electrodes, commonly made of zinc, installed at a fixed spacing and resistively coupled through a prepared backfill mixture.

3.49 Holiday — A defect, including pinholes in an otherwise uniform protective coating that exposes the metal to the surrounding earth.

3.50 Impressed Current — A direct current impressed on a pipeline/structure from an external power source for providing cathodic protection to it.

3.51 Impressed Current Anode — An anode that provides current for cathodic protection by means of impressed current.

3.52 Impressed Current Cathodic Protection — A system in which current for cathodic protection is provided by an external source of d.c. power.

3.53 Impressed Current Station — A station containing d.c. power equipment, anode ground bed and other items to provide cathodic protection by means of impressed current.

3.54 In-Line Inspection — The inspection of a steel pipeline/structure using an electronic instrument or tool that travels along the interior of the pipeline/ structure.

3.55 Instant Off Potential — Pipeline/structure to electrolyte potential measured immediately after interruption of all sources of applied cathodic protection current.

3.56 Instant on Potential — Pipeline/structure to electrolyte potential measured immediately after switching on all sources of applied cathodic protection current.

3.57 Insulating Flanges — Flanges which permit mechanical continuity but break the electrical continuity.

3.58 Interference — Interference is effect of stray current on electric parameters including potential of a pipeline/structure.

3.59 Interference Bond — An intentional metallic connection designed to control the electrical current flowing between metallic systems.

3.60 IR Drop — Voltage difference caused between two points of soil/water electrolyte due to flow of current.

3.61 Isolating Joint — Electrically insulating component such as monoblock insulating joint, insulating flange, isolating coupling, etc, inserted between two lengths of pipeline/structure to prevent electrical continuity between them.

3.62 Line Current — The direct current flowing on a pipeline/structure.

3.63 Long-Line Corrosion Activity — Current flowing through the earth between an anodic and a cathodic area that returns along an underground metallic pipeline/structure.

3.64 Mixed Potential — A potential resulting from two or more electrochemical reactions occurring simultaneously on a metal surface.

3.65 Natural Potential — Pipeline/structure to electrolyte potential measured when pipeline/structure is completely depolarized: (i) before the application of cathodic protection, and (ii) after switching off cathodic protection system.

3.66 On Potential — Pipeline/structure to electrolyte potential measured while cathodic protection system is continuously operating.

3.67 Open Hole Deep Ground Bed — An installation in which the anodes are surrounded only by an aqueous electrolyte.

3.68 Packaged Anode — An anode that when supplied, is already surrounded by a selected conductive material backfill.

3.69 Pipe-to-Electrolyte Potential — The potential difference between the pipe metallic surface and electrolyte that is measured with reference to an electrode in contact with the electrolyte.

3.70 Pipeline/Structure to Electrolyte Potential — Potential of a pipeline/structure with reference to a standard reference electrode located as close to the pipeline/structure as is practically permissible in the electrolyte or soil.

3.71 Polarization — A shift in the potential of an electrode resulting from a flow of current between the electrode and the electrolyte surrounding it.

3.72 Polarization Cell — A d.c. decoupling device consisting of two or more pairs of inert metallic plates in an aqueous electrolyte.

3.73 Polarized Drainage — A form of electric drainage in which the connection between protected/affected pipeline/structure and source of stray currents usually d.c. operated traction system of railways includes a reverse current switch (usually a diode) for unidirectional flow of current.

3.74 Polarized Potential — The potential across the pipeline/structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

3.75 Primary Pipeline/Structure — The basic pipeline/structure to which cathodic protection is to be applied, as distinct from a secondary pipeline/structure, on which interference takes place.

3.76 Protective Current — It is the total current to be picked up on the pipeline/structure so that it reaches protective potential.

3.77 Protective Potential — The potential of a pipeline/structure with reference to a specified standard reference electrode at which the corrosion rate of the metal is insignificant.

3.78 Rectifier — An electrical equipment for converting a.c. from supply mains into d.c.

3.79 Remedial Bond — A bond between a primary and secondary pipeline/structure to eliminate or reduce corrosion interaction.

3.80 Remote Earth — That part of electrolyte in which no measurable voltages, caused by current flow, occur between any two points.

3.81 Resistance Bond — A bond either incorporating resistors or of adequate resistance in itself for the purpose of limiting current flow.

3.82 Resistivity — Resistance between opposite faces of a unit cube of a substance usually given for a one-centimeter cube.

3.83 Reverse-Current Switch — A device that prevents the reversal of direct current through a metallic conductor.

3.84 Safety Bond — A bond connecting metallic enclosure/framework of an electric equipment with earth to limit the rise of potential above earth in the event of a fault.

3.85 Secondary Pipeline/Structure — A pipeline/structure not in view when cathodic protection is originally planned, but enters the picture as a result of interference.

3.86 Shielding — Preventing or diverting the cathodic protection current from its intended path.

3.87 Shorted Pipeline/Structure Casing — A casing which is in direct metallic contact with the carrier pipe.

3.88 Soil Resistivity — A measure of the physical and chemical characteristics of soil to conduct electricity expressed in units of ohm-centimetres or ohm-metres.

3.89 Sound Engineering Practices — Reasoning exhibited or based on thorough knowledge and experience, logically valid and having technically correct premises that demonstrate good judgment or sense in the application of science.

3.90 Stray Current — Stray current is the current that is intended to flow in some other circuit and is referred to as stray current when it flows in an unintended circuit.

3.91 Stray-Current Corrosion — Corrosion resulting from stray current transfer between the pipe and electrolyte.

3.92 Telluric Current — Current in the earth as a result of geomagnetic fluctuations.

3.93 Test Stations — Stations where cables from pipeline/structure and other devices are terminated to facilitate tests/measurement with regard to corrosion activity, effect of cathodic protection and other current, performance of connected devices, etc.

3.94 Voltage — An electromotive force or a difference in electrode potentials expressed in volts.

3.95 Wire — A slender rod or filament of drawn metal. In practice, the term is also used for smaller gauge conductors.

4 ABBREVIATIONS

a.c.	–	Alternating current
CP	–	Cathodic protection
CSE	–	Copper — Copper sulphate reference electrode
d.c.	–	Direct current
ICCP	–	Impressed current cathodic protection
TS	–	Test station
V_{on}	–	Instant ON potential
V_{off}	–	Instant OFF potential

5 PIPELINE/STRUCTURE SYSTEM DESIGN

The following requirements should be considered, while designing the pipeline/structure system, so that cathodic protection system can be implemented successfully.

5.1 External Corrosion Control

External corrosion control must be a primary consideration during the design of the pipelines/ structure system. Material selection and coatings are the first line of defense against external corrosion. Cathodic protection is essential for a coated pipeline because perfect coatings are not feasible and all coatings are subject to deterioration with time. Further, coating is not an essential requisite for the application of cathodic protection. Finally cathodic protection can be applied at any stage during the design life of a pipeline.

5.1.1 Materials and construction practices that create electrical shielding should not be used on pipeline/ structure.

5.1.2 Pipeline/structure should be installed at a location where proximity to other pipeline/structure and surface formation will not cause shielding.

5.1.3 The depth of the pipeline/structure shall be adequate to have a uniform distribution of cathodic protection current.

5.1.4 When two or more pipelines/structures are running in parallel and in close vicinity, the effect of shielding should be avoided by relocating and spacing the pipeline/structure properly.

5.2 Electrical Isolation

Isolating devices should be installed within pipeline/ structure system where electrical isolation of portions of system is required to facilitate the application of external corrosion control. Isolating joints should be provided at: (a) both extreme ends of pipeline, and (b) all extreme ends of structure to be protected by a cathodic protection system and should also be considered at following locations:

a) At points where pipeline/structure changes ownership such as metering stations, well heads etc;
b) Between cathodic protected pipeline/ structure;
   1) Non-protected facilities such as compressor or pumping station,
   2) Other pipeline/structure with different external coating/cathodic protection system, and
   3) Electric operated MOV and other such installations connected with safety earthing system.
c) Junction of branch lines, dissimilar metals etc;
d) Between normal pipeline/structure section and other pipeline/structure section that is;
   1) Laid in different type of electrolyte, for example, river crossing, and
   2) Subject to interferences due to stray currents.
e) On both sides of pipeline/structure laid over above ground pipeline/structure such as bridges;
f) Isolating joints shall be protected by using electrical earthing or surge arresters at locations where pipeline/structure voltage due to electric power system or lightening is likely to exceed safe limits;
g) Internal surface of pipeline/structure on both sides of insulating joint shall be suitably coated for sufficient length to avoid interference current corrosion in case of pipeline/structure transporting conductive fluids;
h) Design, materials, dimensions and construction of isolating joints should be in accordance with specifications;
j) Design of cathodic protection system should include permanent facilities for: (a) testing effectiveness of isolating joints, and (b) bonding of pipeline/structure isolated sections as and where required;
k) Pipe surfaces on each side of such isolating joint should be protected from contact with

soil for a distance of at least 50 times pipe diameter in order to prevent concentrated flow of current from section to section around the insulation. This protection is obtained most effectively by placing the pipe above ground on suitable supports; however, where such a plan is impracticable, an effective alternative is to apply extra thick coating along the requisite length of pipe and also completely encase the isolating joints with the same coating. Insulating joints should be painted with a distinct colour for easy identification; and

m) Care should be taken to see that the insulated flanges are not short-circuited by chips of metal, dirt, etc. In certain cases this is ensured by mounting over the flanges, shrouding boxes and then filling these boxes with bitumen.

5.3 Electrical Continuity

Cathodic protected pipeline/structure should be electrically continuous for unimpeded flow of current. Necessary actions should be taken to ensure electrical continuity by providing permanent bonds across mechanical connectors, flange joints etc.

5.4 Test Stations

Test stations should be located at intervals along the pipeline/structure where they will be conveniently accessible to the corrosion engineer facilitate testing of cathodic protection parameters. Such locations may include, but are not limited to the following:

a) Test stations shall be provided on both sides of cased crossing, if width of cased crossing is more than 20 m;
b) Test station shall be provided on both sides of river/canal, etc, if;
    1) Isolating joints have been provided on both sides or;
    2) Width of river/canal is more than 50 m;
    3) Pipeline/structure laying conditions require the special monitoring of PSP on both sides of river/water crossing;
c) Crossing of two or more lines;
d) Only one test station shall be provided at Isolating joint with facilities for measurement of details for both sides of isolating joint;
e) Installation of a test station should also be considered at locations where pipeline passes through corrosive environment, such as:
    1) Stray current areas;
    2) Valve stations;
    3) Current drain point;
    4) Bridge crossings;
    5) At close vicinity of foreign pipeline anode ground bed; and
f) A test station should be provided at locations where the pipeline/structure is connected with:
    1) Earth electrodes for safety earthing and/or mitigation of a.c./d.c. interference,
    2) Galvanic anodes for cathodic protection, and
    3) Corrosion coupons.

5.4.1 From each test station at least two cables should be connected to pipeline/structures. All cables shall be identified by colour coding or tags.

5.4.2 Test leads from all pipeline/structure (including foreign pipeline/structure) should be terminated at all test stations in case of pipeline/structures are laid in common right of way.

5.4.3 Pipeline/structure running parallel in common right of way should not be bonded below the ground in the absence of any overriding consideration. Locations of underground bonding connections, if any should be properly identified.

5.4.4 Permanent test stations with cable connections to the pipeline/structure should be installed simultaneously with the pipeline/structure to facilitate monitoring of the performance of temporary cathodic protection.

5.4.5 The spacing between test stations should not exceed 1 500 m by considering the requirement of conducting close interval potential logging survey that uses continuous test wire between successive test station. In urban or industrial areas, interval should not be more than 1 000 m.

5.4.6 Brazed connections including thermit welding processes should not be made within 150 mm of the main butt or longitudinal weld in high tensile steel pipe. The connection should be tested for mechanical strength and electrical continuity.

5.5 Road and Rail Crossings

As far as possible, cased crossings should be avoided wherever they are not necessary. In India, it is mandatory to cross railway tracks by using casing. For pipeline/structure crossing under rail/road tracks, etc, an agreement would have to be made with the concerned authorities.

No long pipeline/structure ca n avoid crossing of roads and rails. Special precautions are necessary at such locations to safeguard the carrier pipe by passing it through an additional oversize pipe termed a 'Casing pipe'. The section of the pipe thus encased in the

'Casing pipe' is termed as a 'Carrier pipe'. Casing pipes may act as a shield to the flow of cathodic protection current to the carrier pipes thereby defeating their primary purpose of providing safety.

The section of carrier pipe inside the casing should have the best possible standard of coating with as few holidays as possible. The carrier pipe should be insulated from casing pipe supported by plastic insulating supports fitted to it at regular intervals. The carrier pipe inside the casing should be kept dry by use of suitable end-seals and by filling the annulus between carrier and casing pipe with a suitable insulating material such as wax, concrete slurry or petroleum jelly. This will prevent future ingress of water in the annulus. Proper construction practices for cased crossings and proper fixing of end seals (including use of pressure type end seals) must be ensured for preventing problems of electrical shorts between carriers and casing future ingress of water in the annulus may be prevented.

5.5.1 Effectiveness of electric isolation between casing and carrier pipes should be tested at the time of laying of pipeline/structure and remedial actions should be taken simultaneously.

5.5.2 Corrosion protective coating on external and internal surface of casing pipe can reduce magnitude of current flow between casing and carrier pipes through soil/water inside the casing.

5.6 River Crossings

There are three alternate methods of crossing of rivers and small streams:

a) Submerged crossings,
b) Suspended crossings, and
c) Use of existing road and rail pipe bridges.

For submerged crossings, care should be taken to give the submerged section of the pipe the best possible standard of coating with as few holidays as possible. For the other two methods, the pipe should be insulated from the metallic hangers, on which the pipes are supported, by using suitable insulating material such as neoprene sleeves. This is required only, if the pipe along the crossing is protected cathodically. On account of the restrictions imposed by railway authorities, pipeline/structure over railway bridges are isolated by installing insulating flanges at both ends of the bridge. It should be noted that the flange towards the bridge end should be insulated and not that at the main line end.

5.6.1 For proper cathodic protection of concrete encased/cement weight coated pipeline/structure, rebars of concrete should be electrically isolated from pipeline/structure.

6 PIPELINE/STRUCTURE EXTERNAL COATING

The function of external coating is to control corrosion by isolating the external surface of the underground or submerged pipeline/structure from the environment, to reduce cathodic protection current requirements, and to improve current distribution. External coatings must be properly selected and applied and coated pipe should be carefully handled and installed to fulfil these functions. The following types of coatings are normally used for high pressure cross-country underground pipeline/structure:

a) 3-layer polyethylene/polypropylene [*see* IS 15569 (Part 1)],
b) Fusion bonded epoxy [*see* IS 15569 (Part 2)], and
c) Coal tar enamel (*see* IS 10221).

7 CRITERIA FOR CATHODIC PROTECTION

External corrosion protection can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of specific data that demonstrates that adequate cathodic protection has been achieved one or more of the following conditions shall apply.

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

Consideration is understood to mean the application of sound engineering practice in determining the significance of voltage drops by methods, such as:

a) Measuring or calculating the voltage drop(s);
b) Reviewing the historical performance of the cathodic protection system;
c) Evaluating the physical and electrical characteristics of the pipe and its environment; and
d) Determining whether or not there is physical evidence of corrosion.

7.2 A negative polarized potential of at least 850 mV relative to a saturated copper/copper sulphate reference electrode.

7.3 A minimum of 100 mV of cathodic polarization between the pipeline/structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion. 100 mV Polarization potential criteria should be avoided under following conditions:

a) Higher operating temperature;
b) Electrolyte containing sulphate reducing bacteria;
c) Pipeline/structure affected by stray currents; and
d) Pipeline/structure connected to/consisting of components of different materials.

7.4 Special Conditions

7.4.1 On bare poorly coated pipeline/structure where long-line corrosion activity is of primary concern, the measurement of a net protective current at predetermined current discharge points from the electrolyte to the pipe surface, as measured by an earth current technique, may be sufficient.

7.4.2 In some situations, such as the presence of sulfides, anaerobic/aerobic bacteria, elevated temperatures, acid environments, and dissimilar metals, the above criteria may not be sufficient and (–) 950 mV is to be applied.

7.4.3 To prevent damage to the coating, the limiting critical potential should not be more negative than –1 200 mV referred to CSE, to avoid the detrimental effects of hydrogen production and/or a high *p*H at material surface.

7.5 Other Considerations

7.5.1 Methods for determining voltage drops should be selected and applied using sound engineering practice. Once determined, the voltage drops may be used for correcting future measurements at the same location, providing conditions such as pipe and cathodic protection system operating conditions, soil characteristics and external coating quality remains similar.

7.5.2 When it is impracticable or considered unnecessary to disconnect all current sources to correct for voltage drops in the pipeline/structure to electrolyte potential measurements, sound engineering practices should be used to ensure that adequate cathodic protection has been achieved.

7.5.3 Situations involving stray currents and stray electrical gradients may exist that require special analysis.

7.5.4 Where feasible and practicable, in-line inspection of pipeline/structure may be helpful in determining the presence or absence of pitting corrosion damage.

7.6 Reference Electrode

An electrode whose open circuit potential is constant under similar conditions of measurement used to measure the pipeline/structure to electrolyte potential.

7.6.1 The hydrogen electrode is taken to be the standard with reference to which other electrode potentials are determined. It is inconvenient in practice to use hydrogen electrode. Therefore, certain electrodes known as reference electrodes are used in potential measurements in the studies of corrosion and cathodic protection. Potentials of some useful reference electrodes are given below.

7.6.2 Potentials of reference electrodes with reference to standard hydrogen electrode at 25°C:

Sl No.	*Electrode*	*Potentials Volts*
(1)	(2)	(3)
i)	Saturated calomel	+0.24
ii)	Silver/silver chloride/saturated KCl	+0.22
iii)	Copper/copper sulphate	+0.32
iv)	Zinc/sea water	–0.78

8 CATHODIC PROTECTION SYSTEM DESIGN OBJECTIVES

8.1 Major objective of cathodic protection system design includes the following:

a) To provide sufficient current to the pipeline/structure so that selected criteria of cathodic protection system is effectively achieved;
b) To minimize interference current on primary and secondary/foreign pipeline/structure;
c) To provide a design life of anode system commensurate with the life of pipeline/structure;
d) To provide adequate allowance for anticipated change in cathodic protection current requirements with time; and
e) Adequate monitoring facilities to test and evaluate cathodic protection system performance.

8.2 Cathodic Protection Design Information

The following information is useful for designing proper cathodic protection system.

8.2.1 *Pipeline/Structure Design and Engineering Details*

Details of pipeline/structure to be protected:

a) Material, length, diameter, wall thickness.
b) Design/Operating temperature and pressure and product to be transported.
c) Corrosion protective coating.
d) Design life of pipeline/structure and corrosion protective coating.
e) Pipeline/structure route layout drawings including but not limited to insolating joints.

f) Terminal and intermediate stations:
   1) Road, railway and water crossings,
   2) Cased crossings,
   3) a.c./d.c. power lines and installations that may cause electric interference,
   4) Possibility of telluric current activity,
   5) Foreign pipeline/structure running parallel to and/or crossing the pipeline/structure,
   6) ICCP stations of foreign pipeline/structure, and
   7) Availability of power supply at terminal and intermediate stations.

g) Required design life of (a) CP system for current capacity, and (b) anodes.

h) Type of soil/resistivity and environmental conditions.

8.2.2 *Field Surveys and Data Collection*

Details to be collected by field surveys as required for design of CP system:

a) Existing pipeline/structure — Current drain/Coating resistance test;
b) Soil chemical analysis for ionic and microbial/bacterial loading;
c) Electric resistivity of soil at locations of anodes; and
d) Specific details required for investigation and mitigation of interference problems.

8.2.3 *Current Requirement*

It is always better to use the protective current requirement data based on existing pipeline/structure which are being operated almost in the same type of environment. As a general guidance, protective current densities given in Table 1 for various coatings may be considered as a requirement for newly coated pipeline/structure.

8.3 Temporary cathodic protection (TCP) is recommended when construction period is more than 3 months and soil resistivity is less than 100 ohm-m. While designing TCP the current density should be at least 50 percent of the values given in Table 1.

Table 1 Protective Current Density for Newly Coated Pipeline/Structure

(*Clauses* 8.2.3 *and* 8.3)

Sl No.	Soil Resistivity ohm-m	[3 LPE] Coated Pipe µA/m²	[FBE] Coal Pipe µA/m²	Coal Tar Enamel µA/m²
(1)	(2)	(3)	(4)	(5)
i)	10-100	25	50	125
ii)	<10	50	70	150
iii)	>100	15	25	75

8.4 Types of Cathodic Protection

There are two methods of cathodic protection of underground pipeline/structure, namely:

a) Sacrificial anode system, and
b) Impressed current system.

8.4.1 *Sacrificial (Galvanic) Cathodic Protection System*

In the sacrificial anode system, sacrificial anodes based on soil resistivity should be used as given in Table 2. The pipeline/structure remain in electrical contact with the anode in the electrolyte. The performance of any anode depends on composition and operating conditions. Sacrificial anodes are limited in current output by the anode to pipe/pipeline/structure driving voltage and electrolyte resistivity (*see* Fig. 1).

8.4.1.1 System design shall include calculations for:

a) Current requirement,
b) Design life of anodes, and
c) Resistance and output current of anode(s).

8.4.1.2 Guideline for selection of galvanic anode cathodic protection system is given under **8.5.1**.

8.4.1.3 Guidelines for selection of type of galvanic anodes, depth and distance between galvanic anode and protected pipeline/structure are given in Table 2. Guidelines given in this table may not be followed if engineering evaluation or field tests confirm that design requirements can still be met by a different approach.

For galvanic anode systems, the following shall apply:

a) The resistivity of the soil or the anode backfill shall be sufficiently low for successful application galvanic anodes;
b) The selected type of anode shall be capable of continuously supplying the maximum current demand; and
c) The total mass of anode material shall be sufficient to supply the required current for the design life of the system.

Galvanic anodes shall be marked with the type of material (for example trade name), anode mass (without anode backfill) and melt number. Full documentation of number, types, mass, dimensions, chemical analysis and performance data of the anodes shall be provided. The environmental impact of galvanic anodes shall be considered.

Utilization factor for zinc and magnesium anode shall be considered as given below:

Utilization Factor	*Centre Connected*	*End Connected*
Zinc (Zn)	0.85	0.5
Magnesium (Mg)	0.88	0.6

Table 2 Sacrificial Anodes

(*Clauses* 8.4.1 *and* 8.4.1.3)

Sl No.	Anode	Soil Resistivity ohm-m	Distance from Pipe	Minimum Depth
(1)	(2)	(3)	(4)	(5)
i)	Zinc (Zn)	< 10	2	1.2
ii)	Magnesium	> 10-45	5	1.2
iii)	Ribbon (Mg)	> 45-100	0.5	1.2

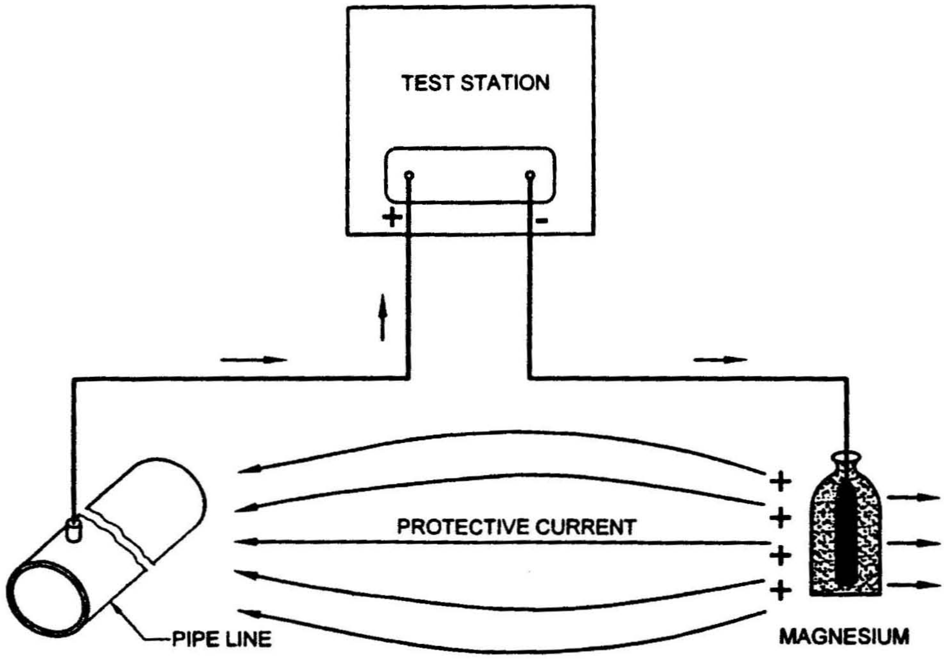

FIG. 1 GALVANIC/SACRIFICIAL ANODE SYSTEM

8.4.1.4 *Zinc anodes*

A typical composition of zinc anodes is given in Table 3.

Table 3 Typical Chemical Composition of the Alloy Used for Zinc Anodes

Sl No.	Element	Composition of Mass Fraction, Percent Min	Max
(1)	(2)	(3)	(4)
i)	Cu	—	0.005
ii)	Al	0.10	0.50
iii)	Fe	—	0.005
iv)	Cd	—	0.07
v)	Pb	—	0.006
vi)	Zn	Remainder	

NOTE — The maximum amount of other elements shall be 0.02 percent (mass fraction) each.

Other alloys may be used provided the performance in similar soils is reliable and documented.

8.4.1.5 *Magnesium anodes*

Magnesium anodes shall be performance-tested in accordance with ASTM G 97. The values obtained from the testing shall be the basis for the design of the system. A typical composition of magnesium anodes is given in the following Table 4.

Table 4 Typical Chemical Composition of the Standard Alloy Used for Magnesium Anodes

Sl No.	Element	Composition of Mass Fraction, Percent Min	Max
(1)	(2)	(3)	(4)
i)	Cu	—	0.02
ii)	Al	5.3	6.7
iii)	Si	—	0.1
iv)	Fe	—	0.003
v)	Mn	0.15	—
vi)	Ni	—	0.002
vii)	Zn	2.5	3.5
viii)	Mg	Remainder	

NOTE — The maximum amount of other elements shall be 0.005 percent (mass fraction) each.

Other alloys may be used provided the performance in similar soils is reliable and documented.

8.4.1.6 *Anode backfill*

Anode backfill for galvanic anodes should consist of a mixture of gypsum, bentonite clay and sodium sulphate. The specific composition of the anode backfill shall be determined by the need to minimize resistivity and maximize moisture retention.

The required composition of the anode backfill material shall be included in the anode specification.

8.4.2 *Impressed Current Cathodic Protection System*

A direct current impressed on a pipeline/structure from an external power source for providing cathodic protection to it. Impressed current system contains d.c. power equipments, anode ground bed and other related items. A typical illustration of an impressed current cathodic protection system is shown in Fig. 2.

8.4.2.1 Guidelines for selection of impressed current cathodic protection system are given under **8.5.2**. System design shall include calculation for:

a) Current requirement,
b) Zone of protection of ICCP Station,
c) Resistance and design life anode ground bed, and
d) d.c. output voltage and current rating of d.c. power equipment.

8.4.2.2 *Anode ground beds*

8.4.2.2.1 *General*

The anode ground beds of an impressed-current CP system for cross country pipeline should be either remote deep well or remote shallow type. These should be designed and located so as to satisfy the following:

a) Mass and material quality shall be suitable for the specified design life of the CP system,
b) Resistance to remote earth of each ground bed shall allow the maximum predicted current demand to be met at no more than 70 percent of the voltage capacity of the d.c. source during the design life of the CP system. The calculation shall be carried out for the unused anode bed at the end of life, and
c) Harmful interference on neighboring buried structures shall be avoided.

In selecting the location and type of ground beds to be installed, the following local conditions shall be taken into account:

a) Soil conditions and the variation in resistivity with depth,
b) Ground water levels,
c) Any evidence of extreme changes in soil conditions from season to season,
d) Nature of the terrain,
e) Shielding (especially for parallel pipelines), and
f) Likelihood of damage due to third party intervention.

The basic design shall include a calculation of the ground bed based upon the most accurate soil resistivity data available.

The current output from anodes should be independently adjustable.

8.4.2.2.2 *Deep-well ground beds*

Deep-well ground beds should be considered where:

a) Soil conditions at greater depth are far more suitable than at surface,
b) There is a risk of shielding by adjacent pipelines or other buried structures,
c) Available space for a shallow ground bed is limited, and
d) There is a risk of interference current being generated on adjacent installations.

The detailed design shall include a procedure for drilling the deep well, establishing the resistivity of the soil at various depths, completing the borehole and method of installing the anodes and conductive backfill.

The borehole design and construction shall be such that the undesirable transfer of water between different geological formations and the pollution of underlying strata is prevented.

Metallic casings should be used for stabilizing the borehole in the active section of the ground bed. The metallic casing shall be electrically isolated from any structures on the surface. Metallic casings only provide temporary borehole stabilization, as the metal will be consumed by the d.c. current flow.

If permanent stabilization is required, non-metallic, perforated casings should be used.

In the calculation of the ground bed resistance, the soil resistivity data corresponding to the depth at the mid-point of the active length shall be used and the possibility of multi-layered soils with significantly different soil resistivity considered.

Deep-well ground beds should be provided with adequate vent pipes to prevent gas blocking between anode and the conductive backfill. Vent pipe material shall be manufactured from the non-metallic chlorine-resistant material.

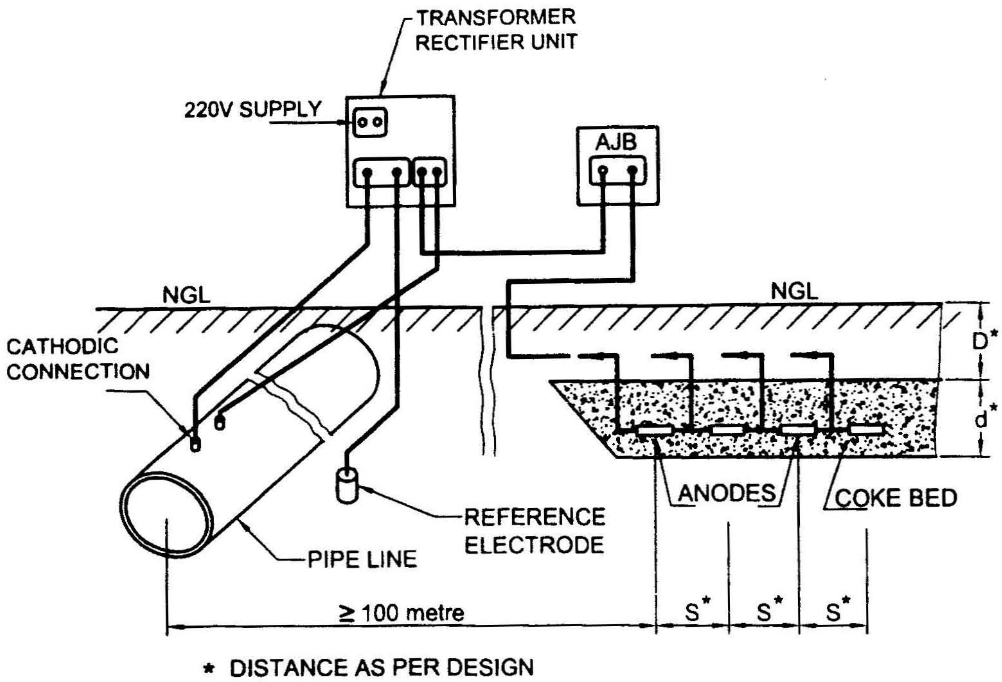

FIG. 2 IMPRESSED CURRENT ANODE SYSTEM

8.4.2.2.3 *Shallow ground beds*

Shallow ground beds should be considered where:

a) Soil resistivities near the surface are far more suitable than at the depths of a deep-well ground bed.
b) There is no risk of shielding by adjacent pipelines or other buried structures.
c) Space is available for a shallow ground bed.
d) There is no risk of interference current being generated on adjacent installations.

Shallow ground bed anodes shall be installed horizontally or vertically. In either case, the top of the conductive backfill shall be at least 1.5 m below ground level.

In the calculation of the ground bed resistance, the soil resistivity data corresponding to the centre-line (horizontal ground bed) or mid-point (vertical ground bed) of the anodes shall be used and with the possibility of multi-layered soils with significantly different soil resistivities considered.

The detailed design shall include a procedure for the construction of the ground bed and for the installation of the anodes and the conductive backfill.

8.4.3 *Impressed-Current Anodes and Conductive Backfill*

Anode materials should be selected from the following list:

a) High-silicon iron alloy, including chromium additions, in soils with high chloride content;
b) Magnetite;
c) Graphite;
d) Mixed-metal-oxide coated titanium;
e) Platinized titanium/niobium;
f) Conductive polymers; and
g) Steel.

Alternative materials may be used, if their performances relevant to the specific operating conditions are reliable and documented.

The specific material, dimensions and mass shall deliver 125 percent of the required anode current output required for meeting the specified design life of the CP System.

A carbonaceous or other conductive backfill material shall be used unless the soil conditions give a satisfactory ground bed resistance, the soil is homogeneous and uniform consumption of anodes is expected.

The environmental impact of the dissolution of anode materials and breakdown of the conductive backfill material shall be considered. Utilization factor for Mixed Metal Oxide and High Silicon Anodes are as given below:

Utilization Factor	*Centre Connected*	*End Connected*
Mixed metal oxide (MMO)	0.80	0.90
High silicon	0.80	0.6

Use of continuous conductive polymer anodes should be considered, particularly for very high resistivity soils surrounding the pipeline.

8.4.4 *Sources of Power*

A d.c. supply needed for cathodic protection is supplied using Transformer Rectifier Unit (TRU) or Cathodic Protection Power Supply Control Module (CPPSM).

The input source of power for Transformer Rectifier Unit (TRU) or Cathodic Protection Power Supply Control Module (CPPSM) is generally state grid. Where state grid power supply is not reliable or available, the following power sources are generally used:

a) Closed cycled vapour turbo alternator (CCVT),
b) Thermo electric generator (TEG),
c) Solar power,
d) Wind power,
e) Diesel generator, and
f) Any other reliable source of power.

While selecting the power source for cathodic protection system, following considerations should be taken into account:

a) Reliability,
b) Maintenance requirement,
c) System life,
d) Initial cost,
e) Type of fuel, and
f) Operating cost.

8.4.5 *Current Output Control and Distribution*

The impressed-current output should be controlled by the output voltage on TRU/CPPSM and corresponding potentials measured along the pipeline.

8.4.5.1 *Current distribution for multiple pipelines*

Where there is more than one pipeline to be cathodically protected, the current return from the pipelines should be independently adjustable. In such cases, the pipelines shall be isolated from each other and provided with a negative connection to the current source.

Resistors should be installed in the negative drains to balance the current to each of the adjacent pipelines individually. Each negative drain shall be provided with a shunt and diode preventing mutual influence of pipelines during on-potential and off-potential measurements.

All cables, diodes and current measurement facilities should be installed in a distribution box.

8.4.5.2 *Automatic potential control*

The d.c. voltage source can be provided with automatic potential control which shall be linked to a permanent reference electrode buried close the pipeline. Reference electrodes shall be regularly calibrated.

The potential measuring circuit shall have a maximum input resistance of 100 mμ. The electronic control system shall have an accuracy of ±10 mV and be provided with adjustable voltage and current-limiting circuits and alarms to protect the pipeline against polarization outside the established criteria in the event that reference electrode fails. A panel-mounted meter should be provided to enable the reading of pipe-to-soil potential

8.4.5.3 *Automatic current control*

The d.c. voltage source can be provided with current control to set output current to the pipeline or the anode system.

Automatic current control alone shall not be used for setting current flow where soil moisture or other variations near the pipeline can cause potential variations.

8.5 Choice of Method for Cathodic Protection

The choice between the two systems of cathodic protection, namely, sacrificial anode and impressed current depends on a detailed assessment of the technical and economic factors involved. Generally, sacrificial anode cathodic protection system is used for temporary protection of pipeline/structure till permanent cathodic protection system is commissioned and reliable power supply is arranged. However, the choice between the two systems depends on the following factors:

a) Magnitude of current required for cathodic protection,
b) Electrical resistivity of electrolyte,
c) Design life of cathodic protection system,
d) Availability and reliability of power availability of space for anode installation,
e) Requirements of CP system monitoring and control, and
f) Future developments.

8.5.1 *Galvanic Anode System*

a) Galvanic anode system is usually provided for:
   1) Small diameter pipeline/structure or well-coated pipeline/structure requiring small current in low resistivity soils, water, swamps/marshes, and
   2) Temporary cathodic protection of pipeline/structure until permanent impressed current system is commissioned and reliable power supply is arranged.

b) Application of galvanic anode system is considered where:
   1) No power for impressed current is available or available power is not reliable or maintenance of electrical system is not possible,
   2) Application of remote impressed current system can not be provided due to limitations of space or other considerations,
   3) Impressed current system is to be supplemented for localized (hot spot) protection, and
   4) Application of impressed current system may create unmanageable interference problems for other nearby pipeline/ structure.

8.5.2 *Impressed Current System*

a) Impressed current system should be preferably provided for cathodic protection of pipeline/structure unless application of galvanic anode system is required due to factors given under preceding sub-clauses and other overriding considerations; and
b) The following factors should also be taken into account for sites of impressed current systems:
   1) Availability and reliability of power supply and suitable location for installation of d.c. power equipment;
   2) Availability of proper site for installation of prospective anode ground bed, keeping in view effects of: (i) electrical resistivity of soil and surface and sub-soil conditions, and (ii) distance between pipeline/structure and remote ground bed on current distribution and performance of anode ground bed; and
   3) Effects of proposed system on existing and future pipeline/structure of the owner and others and other developments.

9 CONSTRUCTION AND INSTALLATION OF CATHODIC PROTECTION SYSTEM

9.1 General

All construction and installation works of cathodic protection systems should be performed in accordance with approved construction drawings, specifications and procedures under the surveillance of trained and competent personnel to verify that all installations are in strict accordance with approved documents and well-established practices.

9.2 The construction and installations works at site shall include but not limited following activities:

a) Physical inspection of all equipment/materials on receipt at site to confirm that all equipment/ materials are in accordance with despatch documents/specifications/drawings and have not got damaged during transport to site;
b) Proper storage of equipment to ensure that no damage is caused to equipment/materials during storage at site;
c) Pre-installation inspection/tests/measurements to confirm that all equipment/materials are in accordance with approved drawings/ specifications;
d) Inspection during/after installation to confirm that all equipment/materials are installed in accordance with approved drawings, specifications/procedures and well-accepted practices; and
e) Pre-commissioning inspection, test/ measurements to confirm that;
   1) All equipment/materials/installations all free from physical defects/damages,
   2) All accessories and devices have been properly installed and connected,
   3) All cables have been properly installed and terminated,
   4) Electric Resistance of all circuits and Insulation Resistance of all cables are as required, and
   5) Results of recommended pre-commissioning tests/measurements for all equipment/installations are in accordance with requirements for final commissioning of equipment/installation.
f) Equipment/Installation Commissioning Tests/ measurements in accordance with approved/ specified procedures, and
g) CP System commissioning tests/measurements in accordance with approved/specified procedures.

9.3 A comprehensive coverage of all activities and construction practices is not feasible within framework of this standard. Other sections of this standard also include some specific requirements/recommendations for installation, testing and commissioning.

10 ELECTRIC INTERFERENCES

10.1 General

Corrosion caused by interference current on buried metallic pipeline/structures differs from other causes of corrosion, in that the current which causes the corrosion has a source foreign to the affected pipeline/ structure. Usually, the interfering current is derived from a foreign source, not electrically continuous with the affected pipeline/structure, or is drained from the soil by the affected pipeline/structure. Detrimental effects of interference currents occur at locations where the currents are subsequently discharged from the affected pipeline/structure to the earth.

Sources of direct current interference are:

a) Constant current sources, such as from CP rectifiers, and
b) Fluctuating current sources, such as d.c. electrified railway systems and transit systems, coal mine haulage systems and pumps, welding machines and direct current power systems.

Types of a.c. interference are:

a) Short-term interference caused by faults in a.c. power systems and electrified railways,
b) Long-term interference, caused by inductive or conductive coupling between the pipeline/structure and high-voltage lines or electrified railways, and
c) Telluric currents interference.

10.2 Direct Current Interference

10.2.1 *Measurements*

In areas where d.c. interference currents are suspected, one or more of the following should be performed:

a) Measure pipe-to-soil potentials with recording or indicating instruments;
b) Measure current density on coupons;
c) Measure current flowing on the pipeline/structure with recording or indicating instruments; and
d) Measure variations in current output of the suspected source of interference current and correlate them with measurements obtained as above.

The measurements should be carried out for a period of 24 h, or a period which is typical for the suspected interference phenomenon being investigated, to assess the time dependence of the interference level.

Interference with other buried pipeline/structures or installations should be measured while the CP system is energized. Interference measurements should generally include following:

a) Measure both the foreign pipeline/structure and the interfered pipeline/structure pipe-to-soil potential while the relevant sources of CP current that can cause interference are simultaneously interrupted; and
b) Measure the pipe-to-soil potential at the other pipeline/structure or installation while the CP system is energized.

10.2.2 *Criteria for Corrosion Interference*

Positive potential changes are liable to accelerate corrosion. Negative potential changes provide cathodic protection but excessive negative potential is liable to adversely affect corrosion protective coating. Safety of equipment and personnel are endangered if change of potentials and/or current flow due to interferences results in higher than permissible limits for safety of equipment and personnel. Therefore necessary actions are required to be taken for investigation and mitigation of interferences in accordance with specified criteria and recommended practices.

a) *Pipeline/Structure to Electrolyte d.c. Potentials*

   Pipeline/structure is considered to be effectively protected by cathodic protection system if pipeline/structure to electrolyte potential is within limits specified under 7.
b) Notwithstanding pipeline/structure to electrolyte d.c. potentials being within limits for effective cathodic protection, interferences resulting in more than 50 mV change of d.c. pipeline/structure to soil potential. Potentials should be investigated by owner/s of affected pipeline/structure and remedial actions should be taken.

10.2.3 *Mitigation of d.c. Interference Corrosion Problems*

Common methods to be considered in resolving interference problems on pipeline/structures or other buried structures include:

a) Prevention of pick-up or limitation of flow of interfering current through a buried pipeline/structure,
b) A metallic conductor connected to the return (negative) side of the interfering current source,
c) Counteraction of the interfering current effect by means of increasing the level of CP, and
d) Removal or relocation of the interfering current source.

NOTE — Cooperation and exchange of information between owners of pipeline affected by interference is essential as d.c. interference between pipeline is constantly evolving phenomenon.

10.2.3.1 Specific methods to be considered, individually or in combination are as follows:

a) Design and installation of metallic bonds with a resistor in the metallic bond circuit between the affected pipeline or other structures.

The metallic bond electrically conducts interference current from an affected pipeline/structure to the interfering pipeline/structure and/or current source;

b) Application of uni-directional control devices, such as diodes or reverse current switches;
c) Coating the bare pipe where interference current enters the pipeline/structure;
d) Application of additional CP current to the affected pipeline/structure at those specific locations where the interfering current is being discharged;
e) Adjustment of the current output from mutually interfering CP rectifiers;
f) Reduction or elimination of the pick-up of interference current by relocation/redesign of the ground bed such that it is electrically remote;
g) Installing properly located isolating joints in the affected pipeline/structure. Testing at the isolating joint should be done to assure that an interference condition has not then been introduced;
h) Improvement in the protective coating on the interfering structure; and
j) Installation of isolating shields between the pipeline/structure and the interfering structure.

NOTE — While installing isolating joints will reduce the magnitude of the stray current, it also introduces another current pick-up and discharge location, hence the reason for testing at the isolating joint.

10.3 Alternating Current (a.c.) Interference

10.3.1 *General*

The magnitude of permanent or short-term interference on a pipeline/structure from high-voltage a.c. sources such as power lines and electrified railways mainly depends on:

a) Length of parallel routing,
b) Distance from the pipeline/structure,
c) a.c. line voltage level,
d) a.c. line current level,
e) Pipeline/structure coating quality, and
f) Soil resistivity.

a.c. interference effects on buried pipeline/structures can cause safety problems. Possible effects associated with a.c. interference to pipeline/structures include electric shocks, damage to coating, accelerated corrosion and damage to insulators.

10.3.2 *Assessment of a.c. Induction*

a.c. interference can be assessed by taking into consideration data from the affected pipeline/structure such as coating resistance, diameter, route, and locations of isolating joints or isolating flanges and high voltage a.c. system data. This assessment may be done by a suitable simulation of system conditions. If the isolating device is bonded across, such that the pipeline/structure is electrically continuous with a plant earthing grid, then either the resistance-to-earth of the grid shall be estimated or the grid itself shall be part of the study.

For a.c. traction systems, data to be considered are the interfering high voltage, operating current, location and layout of the high-voltage tower and position of the wires, route (including the position of the transformers), frequency and electrical characteristics for high-power lines.

Results of test measurements for existing pipeline in same corridor should be considered for realistic assessment of a.c. induction.

To determine the a.c. corrosion risk, coupons should be installed where the a.c. influence is expected. They should be buried at the pipeline/structure depth and have adequate equipment for current measurements. It should also be considered to install additional coupons which can later be removed for visual examination.

The a.c. current density within a coating defect is the primary determining factor in assessing the a.c. corrosion risk. In case of low soil resistivity, high a.c. current densities can be observed.

In sections where a.c. voltages are higher than 10 V, or where voltages along the pipeline/structure show variation to lower values, indicating possible a.c. discharge, additional measurements should be performed on site.

No single measuring technique or criterion for the evaluation of a.c. corrosion risk is recognized to assess a.c. corrosion.

More specific measurements include:

a) Pipe-to-soil potential,
b) Current density, and
c) Current density ratio (a.c. current density divided by d.c. current density).

NOTE — If the a.c. current density on a 100 mm^2 bare surface (for example an external test probe) is higher than 30 A/m^2 (or less, in certain conditions), there is a risk of corrosion. Risk of corrosion is mainly related to the level of a.c. current density compared to the level of CP current density. If the a.c. current density is too high, the a.c. corrosion cannot be prevented by CP.

10.3.3 *Limiting a.c. Interferences*

The maximum step and touch voltage shall be limited in accordance with local or national safety requirements and shall be adhered to at all locations where a person could touch the pipeline/structure.

Protection measures against a.c. corrosion should be achieved through the following measures:

a) Reduce the induced a.c. voltage; and
b) Increase the CP level so that the positive part of a.c. current can be neglected.

To reduce a.c. voltage, the following methods should be considered:

a) Install pipeline/structure earthing equipped with suitable devices in order to let d.c. but not a.c. flow. A simulation on a computer might be required to optimize the number, location and resistance-to-earth of the earthing systems.
b) Install active earthing-potential-controlled amplifiers to impress a current into the pipeline/structure, compensating or reducing the induced voltage. This method should be applied, if the required reduction of induced voltage cannot be achieved by simple earthing. The location of compensation devices shall be carefully considered.
c) Add earthing systems to provide potential equalization at local areas. These earthing systems can be constructed using a wide variety of electrodes (galvanized steel, zinc, magnesium, etc). Some earthing systems can have an adverse effect on the effectiveness of the CP. To avoid adverse effects on the CP, the earthing systems should be connected to the pipeline/structure via appropriate devices, (for example spark gaps, d.c. decoupling devices, etc).

Shifting the d.c. voltage level to reach more negative potential can reduce the a.c. corrosion rate. The pipe-to-soil potentials should not be more negative than those given in 7.

11 OPERATIONS AND MAINTENANCE

11.1 Routine for Measurements

11.1.1 The direct current voltage and current outputs of the transformer/rectifier and pipe/pipeline/structure to soil potential at drain points should be monitored at least once a fortnight. These measurements verify the satisfactory operation of the transformer rectifiers, the ground beds, and the connecting cables. The survey for monitoring of performance CP stations should also include at least the following:

a) Permanent reference electrodes to soil potentials;
b) Currents of anode circuits at anode junction box;
c) Pipeline/structure currents at cathode junction box;
d) Input/output/performance parameters of power supply devices CCVT/Banks/TEG/ Solar panel; and
e) Performance parameters of specific devices provided for monitoring power supply, remote monitoring/control, etc.

11.1.2 Measurements of pipe-to-soil potential should be taken monthly at vulnerable points where access is easy and on quarterly basis at all test points. There may be a seasonal variation in potential, which can be compensated for by increase/decrease of the appropriate transformer/rectifier settings. The survey of test stations should also include at least following typical tests/measurements at regular intervals:

a) Line current measurements;
b) Anode to soil potential and output current of galvanic anodes of temporary cathodic protection system;
c) V_{on}/V_{off} pipeline/structure to soil potentials;
d) Foreign pipeline/structure to soil potentials and current through bonding connection, if provided;
e) Coupon to soil potentials and coupon current; and
f) Earthing resistance of earth electrodes.

11.2 Where stray current problem exists, more frequent checks may be made. Results provided by remote monitoring system should be periodically checked against manually recorded data to ensure that remote monitoring system is functioning correctly.

11.3 Surveys During Operation and Maintenance

Various specialized survey techniques are available, without requiring any direct access to the pipeline/ structure metal surface, to assess the protective system adequacy, non-destructively. Usually, each of these provides different information although there is some overlap. The specific requirements of a pipeline/ structure need be considered while selecting survey techniques or a combination of surveys.

11.3.1 *Close-Interval Potential Survey (CIPS)*

CIPS can be used to determine the level of CP along the length of the pipeline/structure. It can also indicate areas affected by interference and coating defects. The pipe-to-soil potential is measured at close intervals (typically 1 m) using a high-resistance voltmeter/ microcomputer, a reference electrode and a trailing cable connected to the pipeline/structure at the nearest monitoring station. Measurements of potential are plotted versus distance from which features can be identified by changes in potential caused by local variations in CP current density. The survey may be carried out with the CP system energized continuously (an 'on-potential' survey) or with all transformer-rectifiers switching off and on simultaneously with the aid of synchronized interrupters.

Because a large amount of data is produced, a field computer or data logger is normally used and the information later downloaded to produce plots of pipeline/structure potential versus distance from the fixed reference point.

11.3.2 *Pearson Survey*

Pearson surveys locate defects in the protective coating of a buried pipeline/structure.

An a.c. voltage is applied between the pipeline/structure and remote earth, and the resulting potential difference between two contacts with the soil approximately 6 m apart is measured. Two operators walk along the route, making the necessary contacts with the soil, usually via cleated boots. They walk either in-line directly over the pipeline/structure or side-by-side with one operator over the pipeline/structure. An increase in the recorded potential difference can indicate a coating defect or a metallic object in close proximity to the pipe.

The in-line method is helpful in the initial location of possible coating defects, since any increase in potential difference (usually determined by an increase in an audio signal) is obtained as each operator passes over the defect. However, when there is a series of defects close together, and specific information on a particular defect is required, the side-by-side method is preferred. Interpretation of the results obtained is entirely dependent on the operator, unless recording techniques are used.

11.3.3 *Current Attenuation Survey (CAT)*

Current attenuation surveys can be used to locate defects in protective coatings of buried pipeline/structure. The method is similar to the Pearson Survey technique in that an a.c. voltage is applied to the pipe, but a search coil is used to measure the strength of the magnetic field around the pipe resulting from the a.c. signal.

Current attenuation surveys are based on the assumption that when an a.c. signal flows along a straight conductor (in this case the pipeline/structure), it will produce a symmetrical magnetic field around the pipe. The operator uses the electromagnetic induction to detect and measure the intensity of the signal using an array of sensing coils carried through the magnetic field to compute pipe current. Where the protective coating is in good condition, the current will attenuate at a constant rate, which depends upon coating properties. Any significant change in the current attenuation rate could indicate a coating defect or contact with another pipeline/structure.

11.3.4 *Direct Current Voltage Gradient Survey (DCVG)*

A DCVG survey can be used to locate and establish the relative size of defects in protective coatings on buried pipelines. By applying a direct current to the pipeline/structure in the same manner as CP, a voltage gradient is established in the soil due to the passage of current to the bare steel at coating defects. Generally, the larger the defect, the greater the current flow and voltage gradient.

A current interrupter should be installed at the nearest transformer rectifier or a temporary current source to achieve a significant potential change (approximately 500 mV) on the pipeline/structure.

Using a sensitive millivoltmeter, the potential difference is measured between two references electrodes (probes) placed at the surface level in the soil within the voltage gradient. Defects can be located by zero readings corresponding with the probes being symmetrical either side of the defect. In carrying out the survey, the operator walks the pipeline route taking measurements at typically 2 m intervals with the probes one in front of the other, 1 m to 2 m apart. The probes are normally held parallel to and directly above the pipeline, enabling the direction of current flow to the defect to be determined. Making transverse readings with one electrode locate at the epicenter of the coating defect, anodic and cathodic characteristics can be determined.

11.4 Faults and Remedies

11.4.1 Electrical faults may occur in the bodies of the anode material due to excessive current. Anode failure may also occur due to a faulty seal on the connection. The anode in question may be located by traversing along the ground bed with a voltmeter and two half cells and should be replaced.

11.4.2 Cable faults which may occur due to various reasons, namely, mechanical damage, deterioration of insulation which for positive cable will result in rapid deterioration of the conductor can be found by excavation and inspection. The cables should be jointed or replaced.

11.4.3 Sudden local changes in the pipe-to-soil potential readings may be due to many causes, the principal of which are:

a) *Local flooding* — Transformer/rectifier setting should be readjusted.
b) Severe local coating damage or deterioration. The damaged coating should be located either by visual examination or by use of the Pearson holiday detector/CAT survey/ DCVG survey and bore hole inspection made good; and
c) When a casing is short-circuited to the pipe the potential on the pipe is expected to be relatively less negative, and it could even be less negative than the accepted value in or around the point of short. The current drawn from the rectifier system is expected to suddenly increase. When this is noted the ends of the casing would then have to be excavated and the cause of the 'short' found and removed. Where tests indicate that the point of contact is well back from the end of the casing, the chances are that it cannot be cleared with any reasonable effort and expense by working from the casing ends. To safeguard the carrier pipe inside such 'non-clearable' casings, any of the following methods may be adopted:
   1) To fill the entire annular space between pipe and casing with a material that will stifle any corrosion tendency. Proprietary casing compounds (greases containing chemical inhibitors) or unrefined petroleum (low in sulphur content) may be used, and
   2) To install magnesium anodes on both sides of the line at each end of the casing.

12 SAFETY PRECAUTIONS

12.1 General

Safety precautions mentioned under this clause and all other safety precautions as required for cathodic protection works and installations in hazardous/non-hazardous areas shall be taken to ensure safety of equipment and manpower.

12.1.1 Safety precautions for rectifiers, switches and cables are the same as for any other electrical appliances.

12.1.2 The lowered potential of cathodically protected steel pipeline/structure with reference to the surroundings means that contact with another steel pipeline/structure which will normally be at zero potential may produce a spark. It is recommended, therefore, that every precaution should be taken to avoid such sparking.

12.2 Danger of Electric Shocks

Voltages in excess of 50 V d.c. are seldom used for cathodic protection, thus the danger from electrical shock is very unlikely. Safety procedures should be adopted to switch off the cathodic protection or installation of grid earthing while working on the pipeline/structure during cutting, tapping, etc. It is further advisable to put a temporary bond around the line before starting the work on the line and this bond allowed to remain till the job is finished. This bond should be no less in size than standard welding cable and provided with suitable clamps. Attention should also be paid to the danger of possible harm to life near the ground beds due to the voltage gradient at the surface of the soil. It should be ensured that:

a) d.c. output of the rectifier transformer should not exceed 50 V d.c., and
b) Leads are fully insulated and protected against mechanical damage.

12.3 Fault Conditions in Electricity Power Systems in Relation to Remedial and/or Unintentional Bonds

There is a possible risk in bonding a cathodic protection system to any metal work associated with the earthing system of an electricity supply network, especially in the vicinity of high voltage sub-stations. Therefore, such bonding should not be accepted as a general rule, any exception to it being made by the corrosion engineer himself, after competent tests.

12.3.1 Bonds between metal work, associated with an electricity power system (for example, cable sheath) and cathodically protected pipeline/structure, can contribute an element of danger when abnormal conditions occur on the power network. The principal danger arises from the possibility of current flow, through the bonds, to the protected pipeline/structure, due to either earth-fault conditions or out-of-balance load currents from the system. This current, together with the associated voltage rise, may result in electric shock, explosion, fire, overheating and also risk of electrical breakdown of coatings on buried pipeline/ structure. Such hazards should be recognized by the parties installing the bond and any necessary precautions taken to minimize the possible consequence. The rise in temperature of conductors, joints and accessories is proportional to $I^2 t$, where I is the fault current and t its duration. Bonds should be robust enough so that they may withstand, without distress, the highest value of $I^2 t$, expected under fault conditions. For extreme conditions, duplicate bonding is recommended.

12.4 Installations in Hazardous Areas

12.4.1 Cathodic protection can introduce hazards in areas in which an inflammable mixture of gas, vapour or dust (that is hazardous atmosphere) may be present which could be ignited by an electric arc or spark. In a cathodic protection system, a spark may be caused by one or more of the following reasons:

a) Disconnection of bonds across pipeline/structure joints;
b) Short-circuit of isolating joints, for example, by tools lying across a joint or breakdown due to voltage surges on the pipeline/structure induced by lightning or electrical switching surges;
c) Disconnection or breakage of cable carrying cathodic protection current; and
d) Connection or disconnection of instruments employed for measuring and testing of cathodic protection system.

12.4.2 In locations where any of the above hazards may arise, the operating personnel should be given suitable instructions and warning notices should be displayed.

12.4.3 It should be noted that likelihood of sparking is greater with impressed current system than with sacrificial anode system.

12.4.4 *Remedies*

As cathodic protection necessitates the use of electrical equipment, the following safety precautions should be taken in hazardous areas:

a) Provide flameproof enclosure of all electrical equipment, such as junction boxes and test stations in accordance with relevant standards. Provide continuous bonding cables across any intended break, before it is made, in protected pipeline/structure.
b) Installation of insulating joints, as far as possible, in safe areas.
c) Jump over the insulated flanges with a surge diverter, which gives electrical/metallic continuity for high voltages but is high enough to prevent cathodic protection currents from passing over.

13 DOCUMENTATION

13.1 Design Documentation

13.1.1 *General*

The basic design documentation shall include:

a) Results of any site surveys and soil investigations that have been carried out;
b) Results of any current drainage tests that have been carried out for the retrofitting of CP on existing pipeline/structure;
c) Any requirements for modifications with respect to existing pipeline/structure systems such as minimum electrical separation or coating repairs;
d) Calculations of current requirements, potential attenuation, electrical resistance and current output of ground beds;
e) Description of system including a schematic diagram of the proposed CP system;
f) A list of the estimated number and test stations;
g) Any sensitivities in the CP system that require special attention;
h) A schedule of materials;
j) A set of design drawings; and
k) A set of installation procedures.

13.1.2 *Construction Details and Installation Procedures*

Full construction details and installation procedures of the CP system should be documented to ensure that the system will be installed in accordance with this standard.

These should include:

a) Procedures for the installation of d.c. voltage sources, ground beds, cables, test facilities, cable connections to the pipeline/structure;
b) Procedures for all tests required to demonstrate that the quality of the installation meets the requirements;
c) Construction drawings including but not limited to plot plans, locations of CP systems and test facilities, cable routing, single-line schematics, wiring diagrams and ground bed construction and civil works; and
d) Procedures to ensure safe systems of work during the installation and operation of the CP system.

13.2 Commissioning Documentation

After the successful commissioning of the CP system, the following shall be compiled in a commissioning report:

a) As-built layout drawings of the pipeline/structure including neighbouring pipeline/structure or systems that are relevant to the effective CP of the pipeline/structure,
b) As-built drawings, reports and other details pertaining to the CP of the pipeline/structure,
c) Records of the interference tests (if any) carried out on neighbouring pipeline/structure,

d) The voltage and current at which CP system was initially set and the voltage and current levels necessitated by the results of the interference tests. The location and type of interference-current sources (if any), and

e) Records of the pipe-to-soil potentials at all test stations before and after the application of CP.

13.3 Inspection and Monitoring Documentation

The results of all inspection and monitoring checks shall be recorded and evaluated. They shall be retained for use as a baseline for future verifications of CP effectiveness.

13.4 Operating and Maintenance Documentation

An operating and maintenance manual shall be prepared to ensure that the CP system is well documented and that operating and maintenance procedures are available for operators. This document shall consist of:

a) A description of the system and system components,

b) Commissioning report,

c) As-built drawings,

d) Manufacturer's documentation,

e) A schedule of all monitoring facilities,

f) Potential criteria for the system,

g) Monitoring plan,

h) Monitoring schedules and requirements for test stations,

j) Monitoring procedures for each of the types of monitoring facilities installed on the pipeline structure, and

k) Guidelines for the safe operation of the CP system.

13.5 Maintenance Records

For maintenance of the CP facilities, the following information shall be recorded.

a) Repair of rectifiers and other d.c. power sources;

b) Repair or replacement of anodes, connections and cables,

c) Maintenance, repair and replacement of coating, isolating devices, test leads and other test facilities, and

d) Drainage stations, casing and remote monitoring equipment.

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

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Panel on Cathodic Protection of Pipe Line, MTD 24/P-1

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