IS : 8062 (Part I)-1976

(Reaffirmed 1997)

Indian Standard

CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART I GENERAL PRINCIPLES

UDC 620·197·5 : 624·014·2

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

[redacted] Gr 5 *November* 1976

Indian Standard

CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART I GENERAL PRINCIPLES

Corrosion Protection Sectional Committee, SMDC 29

Chairman	*Representing*
Shri C. P. De	Ministry of Defence (R & D), Bombay
Members	
Shri T. K. Grover (*Alternate* to Shri C. P. De)	
Dr A. S. Bhaduri	National Test House, Calcutta
Shri N. C. Bagchi (*Alternate*)	
Shri D. D. Bhuptani	The Indian Tube Co Ltd, Jamshedpur
Shri B. N. Das	Tube Products of India, Madras
Shri S. Panchapakesan (*Alternate*)	
Joint Director (M & C), RDSO, Lucknow	Ministry of Railways
Chemist & Metallurgist-II, RDSO, Lucknow (*Alternate*)	
Joint Director Standards (Carriage), RDSO, Lucknow	Ministry of Railways
Chemist & Metallurgist-I, RDSO, Lucknow (*Alternate*)	
Dr S. K. Kundra	Pyrene-Rai Metal Treatments Ltd, Bombay
Shri M. S. Pendharkar (*Alternate*)	
Dr A. K. Lahiri	Engineers India Ltd, New Delhi
Shri T. K. S. Mani	Indian Paint Association, Calcutta
Shri G. C. Mathur	National Buildings Organization, New Delhi
Shri S. H. Balachandani (*Alternate*)	
Shri H. J. Mistry	The Alkali & Chemical Corporation of India Ltd, P.O. Rishra, District Hooghly
Shri V. R. Krishnan (*Alternate*)	
Dr M. N. Parthasarathi	Indian Lead/Zinc Information Centre, New Delhi
Shri N. N. Shenoy (*Alternate*)	
Dr K. S. Rajagopalan	Central Electrochemical Research Institute (CSIR), Karaikudi
Dr N. Subramanyan (*Alternate*)	
Shri G. Ramamurthy	Tata Engineering & Locomotive Co Ltd, Jamshedpur

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
Dr N. P. Rao	Defence Institute of Stores Preservation & Packaging (DISPP), Ministry of Defence, New Delhi
Shri J. Banerjee (*Alternate*)	
Representative	Defence Research Laboratory (Materials), Ministry of Defence (R & D), Kanpur
Representative	National Metallurgical Laboratory (CSIR), Jamshedpur
Shri M. B. Satyanarayana	Addisons Paints & Chemicals Ltd, Madras
Shri H. R. Bapu Seetharam	Bharat Electronics Ltd, Bangalore
Shri P. S. K. Prasad (*Alternate*)	
Shri R. K. Sinha	The Fertilizer Corporation of India Ltd, Sindri
Shri H. Sreenivasaiah	Bharat Earth Movers Ltd, Bangalore
Shri S. R. Prabhakar (*Alternate*)	
Shri Y. C. Subramanya	Directorate General, Ordnance Factories, Calcutta
Shri S. N. Wazir	Hindustan Steel Ltd, Ranchi
Shri H. N. K. Nadig (*Alternate*)	
Shri C. R. Rama Rao, Director (Struc & Met)	Director General, ISI (*Ex-officio Member*)

Secretary

Shri B. Mukherji
Deputy Director (Metals), ISI

Panel for Code of Practice for Cathodic Protection, SMDC 29 : P 1

Shri S. L. Aranha	Burmah-Shell Refineries Ltd, Bombay
Shri N. B. Roychowdhury (*Alternate*)	
Shri M. N. Bhagat	Indian Cathodic Protection Co Pvt Ltd, Bombay
Shri R. Bhatt	X-Ray Engineering Co India Pvt Ltd, Bombay
Shri K. Damodaran	Oil and Natural Gas Commission, Dehra Dun
Shri R. K. Rana (*Alternate*)	
Shri C. P. De	Ministry of Defence (R & D)
Shri B. Srinivas Rao (*Alternate*)	
Shri D. Sen Gupta	Oil India Ltd, Noonmati
Dr V. M. Kelkar	Engineers India Ltd, New Delhi
Shri V. H. Khakhar	Caltex (India) Ltd, Bombay
Shri M. Balakrishna (*Alternate*)	
Shri V. G. Kulkarni	Tata Consulting Engineers, Bombay
Shri V. T. Purohit	Electro Corr Damp, Bombay
Shri D. C. Roy	Indian Oil Corporation Ltd, New Delhi
Shri R. Vaidyanathan (*Alternate*)	
Shri S. K. Sanyal	Ministry of Defence (R & D)
Shri V. M. Shidhaye	Bombay Municipal Corporation, Bombay
Dr N. Subramanyan	Central Electrochemical Research Institute (CSIR), Karaikudi
Shri K. Balakrishan (*Alternate*)	
Shri D. M. Tagare	Madhav Capacitors Pvt Ltd, Bombay

Indian Standard

CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART I GENERAL PRINCIPLES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 9 June 1976, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This code has been prepared to serve as a guide for the cathodic protection of steel structures. This part deals with the general principles of cathodic protection. Cathodic protection of the different types of structures, for example, underground pipelines, ships' hulls, dock gates and caissons jetties and piers, etc, would be covered under separate parts of this code.

0.3 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This code (Part I) deals with the general principles of cathodic protection.

2. TERMINOLOGY

2.0 For the purpose of this code the definitions given in IS : 3531-1966† and those defined below shall apply.

2.1 Backfill — The material which fills up the space between a buried anode and the surrounding soil. It should have low resistivity, moisture

---

*Rules for rounding off numerical values (*revised*).

†Glossary of terms relating to corrosion of metals.

retaining capacity and be capable of increasing the effective area of contact between the anode and the environment.

2.2 Bond — A metal piece having very little electrical resistance for connecting two points on the same or different structures.

2.2.1 *Drainage Bond* — A bond to effect drainage (*see* **2.9**).

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

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

2.4 Cathodic Protection — A method of protecting a metallic structure from corrosion by making it a cathode so that direct current flows into the structure from the electrolytic environments.

2.5 Cell — An electrolytic system consisting of anode, cathode and an electrolyte.

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

2.7 Crossing Point — A point where two or more buried or immersed structures cross in a plan.

2.8 Differential Aeration — Unequal/access of oxygen/air to a structure at its different points resulting in local cell action and a consequent corrosion of the less aerated points.

2.9 Drainage (Electric Drainage) — This is draining away or drawing away electric current from a cathodically protected structure back to the source of current through an external conductor.

2.10 Driving emf — Driving emf is the open circuit potential difference between a structure to be protected (a cathode) and the system of anodes which protects this.

The emf 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 emf in galvanic cells are fixed while those in an impressed current system are variable.

2.11 Earth

a) The conducting mass of earth or of any conductor in direct electrical connection therewith.

b) A connection, whether intentional or unintentional, between a conductor and the earth.

c) To connect any conductor with the general mass of earth.

NOTE — Ground is sometimes used in place of 'earth'. Both terms include expanses of natural water.

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

2.13 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.

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

2.15 Ground Bed — A system of buried or submerged electrodes connected to the positive terminal of an independent source of direct current, in order to lead to earth the current used for the cathodic protection of a buried or immersed metallic structure.

2.16 Holiday — A break or pinholes in an otherwise uniform protective coating.

2.17 Impressed Current — A dc current impressed on a structure from outside its material galvanic circuit. Usually this comes from a rectifier put in for cathodically protecting a structure. The circuit formed with an impressed current does not form a natural circuit.

2.18 Insulating Flanges — Flanges which permit mechanical continuity but break the electrical continuity on a pipe. The flange faces have insulating gaskets in between and the nuts and bolts are again insulated from the substantial flanged faces.

2.19 Interference — The effect due to a foreign structure interfering electrically with cathodic protection, applied intentionally to a structure.

2.19.1 The foreign structure picks up current from the electrolyte at the point and then sends it into the electrolyte at a different location. Due to interference, that surface of the foreign structure which discharges current suffers accelerated corrosion whereas that surface which receives currents is under partial protection.

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

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

2.22 Protective Potential — The potential of a structure with reference to a specified standard reference half cell at and below which the structure stops corroding due to any electrolytic action.

2.23 Rectifier — An electrical appliance for converting ac from supply mains into dc.

2.24 Reference Electrode — An electrode whose potential is reproducible and which can be used for reference in the measurement of other electrode potentials.

2.24.1 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 in Table 1.

TABLE 1 POTENTIALS OF REFERENCE ELECTRODES WITH REFERENCE TO STANDARD HYDROGEN ELECTRODE AT 25°C

SL No.	ELECTRODE	POTENTIALS (VOLTS)
(1)	(2)	(3)
i)	Saturated calomel	+ 0·242
ii)	Silver/silver chloride/saturated KCl	+ 0·222
iii)	Copper/copper sulphate	+ 0·316
iv)	Zinc/sea water	— 0·78 (approx)

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

2.26 Stray Current — Current flowing in the soil or water environment of a structure and arising mainly from electric power or traction installations. Such stray current can pass from environment into the structure and vice versa. Stray alternating current is not considered in the code.

2.27 Structure — A buried or submerged construction (including such constructions as pipe lines, tanks, bridges and piers).

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

2.29 Tanks — Storage reservoirs of metallic nature (majority being of mild steel) which are completely or partly underground, kept on the ground or raised on supports above ground. The tanks could be of various shapes, and sizes and may have any number of external pipe or other structural connections.

3. GENERAL PRINCIPLES

3.1 Electrolytic Corrosion — When a metal corrodes in contact with an electrolyte, metallic atoms pass into the electrolyte as positive ions, leaving behind the electrons. Thus iron will corrode as:

$$Fe = Fe^{++} + 2\,\bar{e} \ldots\ldots (1)$$

The process is called oxidation and the metals thus corroding are called the anodes.

3.1.1 Anodic and cathodic areas may be present in the same structure. When both anode and cathode are in electrical contact, and the electrolyte is acidic, hydrogen evolution can take place according to eq (2):

$$2H^{+} + 2\bar{e} = H_2 \ldots\ldots (2)$$

The hydrogen ions have consumed the electrons. This is an example of cathodic reaction. The process is called reduction.

3.1.2 Cathodic reactions can take place in other ways. Oxygen may be reduced at the cathode in a neutral or basic solution according to eq (3)

$$O_2 + 2H_2O + 4\bar{e} = 4O\bar{H} \ldots\ldots (3)$$

This shows that a molecule of oxygen has consumed the electrons and in combination with water has produced hydroxyl ions or in other words it has produced a more alkaline solution around the cathode. The formation of hydroxyl ion is another example of cathodic reduction.

3.1.2.1 Though various reactions occur at the cathode, corrosion of metal does not generally occur at the cathode. However increased alkalinity due to formation of hydroxyl ion may attack metals like aluminium and lead high alkalinity may also cause deterioration of paints.

3.1.3 The metallic ions produced by anodic reaction may react with negative ions present in the electrolyte to give insoluble corrosion products. If the product forms on the surface of the corroding anode, it may stifle the anodic reaction.

3.1.3.1 In a neutral solution containing sodium chloride, the ferrous ion forms ferrous hydroxide which can precipitate from the solution. But it can be oxidized to ferric hydroxide by the oxygen present in the solution as shown in eq (5).

By adding equations (1) and (3)

$$2\,Fe + O_2 + 2H_2O = 2\,Fe\,(OH)_2 \ldots\ldots (4)$$

$$2\,Fe\,(OH)_2 + H_2O + \tfrac{1}{2}O_2 = 2\,Fe\,(OH)_3 \ldots\ldots (5)$$

Ferric hydroxide is the final product of the corrosion of iron and is popularly known as rust.

4. CATHODIC PROTECTION

4.1 Cathodic protection signifies protection of a metal structure from corrosion in an electrolyte by making it the cathode in a galvanic cell. The protection implies that the structure is to be supplied with direct current. The current may be provided by a sacrificial anode as in a galvanic cell or derived from an external power supply.

4.1.1 Thus there are two methods of cathodically protecting a metal structure from corrosion, namely:

a) galvanic method, and
b) impressed current method.

4.1.1.1 In the galvanic method sacrificial anodes based on magnesium, zinc or aluminium are used. The structures remain in electrical contact with the anode in the electrolyte. The performance of any anode depends on composition and operating conditions [Table 2, item (a)].

4.1.1.2 In the impressed current method, current is impressed upon the anode under a suitable dc voltage. The anode may be of inert type or consumable one at low rate. The lead and platinized titanium anodes are suitable for sea water while others may be used for soil, sea water and fresh water [Table 2, item (b)].

4.1.1.3 A typical consumption rate of sacrificial anodes and impressed current anodes for cathodic protection are provided in Table 2.

TABLE 2 COMPARISON OF SACRIFICIAL AND IMPRESSED CURRENT ANODES FOR CATHODIC PROTECTION

Sacrificial Anodes

MATERIAL	TYPICAL CONSUMPTION kg/A-yr
Magnesium	8·2
Zinc	11·8
Aluminium	7·3 to 9·0

Impressed Current Anodes

MATERIAL	TYPICAL LOSS kg/A-yr
Scrap steel	9·0
Graphite	0·12-2·3
High silicon iron	0·12-0·5
Lead	0·04-0·12
Platinized titanium	Nil

4.2 Criteria for Cathodic Protection — In order that a structure may be cathodically protected, it should receive direct current at suitable current density so that the structure is polarized to the protective potential. The potentials are measured with respect to reference electrodes. Full cathodic protection is obtained if the structure to electrolyte potential is kept at or below the values mentioned in Table 3.

TABLE 3 POTENTIALS FOR CATHODIC PROTECTION (VOLTS)

SL No.	METAL OR ALLOY	REFERENCE ELECTRODES		
		Copper/ Copper Sulphate	Silver/ Silver Chloride/ sat KCl	Zinc/Sea-Water
(1)	(2)	(3)	(4)	(5)
i)	Iron and steel:			
	a) Aerobic environment	−0·85	−0·75	+0·25
	b) Anaerobic environment	−0·95	−0·85	+0·15
ii)	Lead	−0·6	−0·5	+0·5
iii)	Copper-based alloys	−0·5 to −0·65	−0·4 to −0·55	+ 0·6 to +0·45

NOTE — It should be recognized that the potentials given above may not be obtained immediately on application of current and these refer to steady state values.

4.3 Polarization — Polarization is defined as the change of potential of an electrode resulting from current flow through the electrolyte. It varies with the density and direction of any current crossing the interface of the electrode and electrolyte.

4.3.1 When the potential and current values are plotted, a typical polarization curve may be obtained (*see* Fig. 1). The portion, *Z-A* of the curve indicates corrosion. As the potential becomes more positive, the rate of corrosion *O-A* increases. Conversely when the potential becomes less, the rate of corrosion is reduced. By altering the potential of the corroding electrode to an appropriate negative value, the corrosion may be entirely prevented.

4.3.2 In practice it is difficult to draw firm conclusions as to the corrosion rate from the measurement of the potential difference between the metal and the solution or soil because both the shape of the curve as well as the potential corresponding to zero current flow varies according to the properties of the surrounding electrolyte. The potential difference should be measured using a suitable reference electrode.

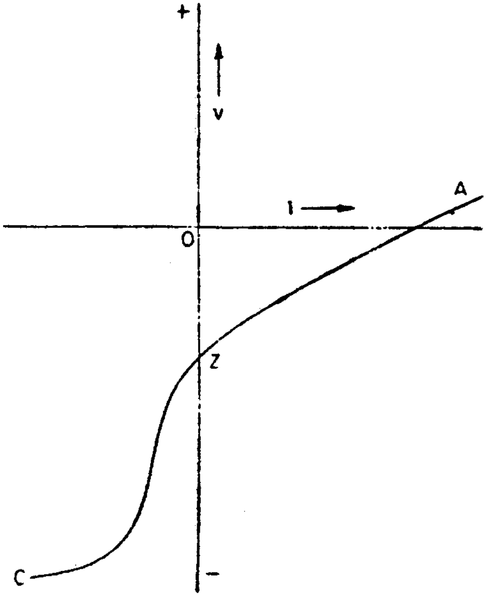

FIG. 1 POLARIZATION CURVE

5. PRELIMINARIES TO CATHODIC PROTECTION

5.1 Coating

5.1.1 Cathodic protection of underground structures is essentially supplementary to a good system of coatings. The coatings insulate the steel surface electrically and chemically from the corrosive action of the soil electrolyte. The recommended coating materials are either of the bituminous base or coal tar base. These coatings should also be checked for leaks and holidays with a high voltage leak-detector.

5.1.2 The soil surrounding the underground structure which has been properly coated is also of importance. The backfill should be of dry loose sand type. It should not cause cracks or punctures in the coating. It should not form cakes with the coating and pull it apart as it becomes wet and dry alternatively.

5.1.3 It is possible that cathodic protection may be called in as an emergency measure or an economical measure on existing structures which are already underground and on which the quality of coatings is doubtful. It is worthwhile investigating whether coating and backfill could be improved before applying cathodic protection.

5.2 It is recommended to make suitable provisions for the following at the preliminary stage only:

a) Insulating flanges on the pipe connections;
b) Permanent test points, if and where required;
c) Replacement of earthing points; and
d) Bonding between various structures to ensure electrical continuity, if and where necessary.

5.3 Initial Electrolysis Surveys — These surveys are expected to give important information regarding soil conditions, existing galvanic activity and requirement of cathodic protection.

5.3.1 *Soil Resistivity* — Soil resistivity reading is one of the most important readings required in these surveys.

5.3.1.1 *Method of measuring soil resistivity* — Soil resistivity may be determined by the four pin method, also known as the Wenner method. Four steel rods are spaced equally, the inter-electrode distance being equal to a length of '*a*' metres. The electrode are driven into the soil to a depth of $\frac{1}{20}$th of the distance between the electrodes.

A current (I ampere) is passed between the outer electrodes and the voltage (V volts) developed between the two inner electrodes are measured. Soil resistivity (ρ) is obtained from the formula:

$$\rho = 2 \pi a R \text{ where } R = \frac{V}{I}$$

It should be ensured that the electrodes make good contact with the soil. This may be aided by adding small quantity of water to the soil, if necessary.

The Wenner method gives the average soil resistivity to depth equal to the electrode spacing that is '*a*' metres. A typical depth of a pipeline is about 1·75 m. The electrode spacing 'a' should therefore, be related to the depth of the structure.

5.3.1.2 A number of soil resistivity measurements should be carried out to locate places where the soil resistivity is low. The soil resistivity should be measured at different depths, for example, 1, 3, 5 and 7 metres by varying the spacing of the electrodes (*a*).

5.3.1.3 While taking soil resistivity readings with the four pin method, one should make sure that the pins make a good contact to soil; that the pins are not polarized while taking the readings. One should also make due allowance for the seasonal variations in the soil resistivity. If necessary, two or more readings at different times of the year may be recorded.

5.3.1.4 The depth at which the soil resistivity readings are obtained, is determined by the spacing between the pins. The depths, which are of importance to us, are: (a) the lowest depth to which the structures to be protected are buried, (b) the depth at which we expect to bury the anodes, and (c) the depth at which foreign structures cross or pass by close proximity of our structures.

5.3.2 *Structure to Soil Potentials* — These should be measured with reference to a standard Cu/$CuSO_4$ reference electrode.

5.3.2.1 The following precautions shall be taken with reference to the standard Cu/$CuSO_4$ reference electrode:

a) The solution inside the cell shall always be saturated.

b) The copper rod or tube inside the cell shall always be polished and cleaned.

c) The porous wooden plug making contact with the earth should be cleaned and not clogged up either with soil or with copper sulphate crystals.

d) The porous plug should make a good electrical contact to the soil. These may be ensured by pouring water after the plug is semi-buried. If the porous plug sits on asphalted soils or soils saturated with petroleum oils, the readings obtained are erroneous. Sometimes it might be necessary to put the reference electrode on concrete pavements. If the reference electrode is located on concrete structure which is wet and does not have any oily surface, proper readings are obtained.

e) The reference electrode should be located as close to the point on the structure at which we desire to take the potential reading as is practically permissible. It may be realized that the reference electrode looks at the structure in a conical fashion. As we go further away, the area covered by this cone gets extended and the reading we get is an average potential of this area rather than the potential of the point where we are making a contact to the structure.

f) In water logged soils, care should be taken to see that water does not enter the reference electrode from the top.

g) The contact to the structure should be made with a sharp point after removing mill scales, rust flakes, overlying paints or oil layers. The contact should be firm while the readings are taken.

5.3.2.2 In soil of high resistivity, the voltage drop in the soil is also included in the structure to soil potential reading. Generally, no allowance is made for this discrepancy inasmuch as the electrodes are located at the closest possible location and corrosion activities in soils of high resistivity are comparatively negligible.

5.3.3 *Circulating Currents* — Circulating currents of low magnitudes cannot be read with ammeters. Since pipelines have uniform cross sections, voltage drops along these pipelines are measured and interpreted for pipeline currents. We can detect the points of corrosion and the points of protection accurately with the help of the direction and magnitude of these currents. When these currents converge together and leave for the soil, heavy corrosion may be expected. When these currents fall gradually and go into the soil, corrosion over the entire length may be expected. Pipeline currents are taken essentially to get a complete picture of what is happening on the underground structure together as a system.

5.3.3.1 While taking the readings, firm contact should be made at both the points on the pipe. If one point is loose or makes a contact to soil, we might read pipe to soil potential instead of pipeline voltage drop.

5.3.3.2 Length of the pipeline should be selected in such a way that readable voltage drops on the milivoltmeter are obtained.

5.3.3.3 The sections on which milivolt readings are taken should be straight, should not contain flange joints, elbows, etc.

5.3.4 *Temporary Ground Bed Tests* — In a temporary ground bed test, we erect a temporary ground bed, make this an anode and make the underground structure a cathode. Direct current of sufficient magnitude is passed to this ground bed and picked up on the underground structure. It is passed sufficiently long so that the underground structure reaches polarization potentials. At this stage, a whole set of structure to soil potential readings are taken and total ground bed currents and voltages at which these currents are fed are measured.

5.3.4.1 Temporary polarization may be checked by momentarily disrupting the cathodic protection current. The ground to soil potential should not abruptly drop down. It should drop down gradually. It may take several hours to achieve this stage. This criteria need not be rigidly applied to soils of high resistivity.

5.3.4.2 While carrying out these tests due precautions may be taken in respect of the following:

a) Total current requirements for a permanent cathodic protection system, and

b) Interference with underground signalling system or other structures.

5.3.4.3 Temporary ground bed test data are evaluated for the following:

a) Total current and voltage requirements for a permanent cathodic protection system;

b) Condition of the existing coating on the underground structures; and

c) Necessity of incorporating insulating flanges, jumping bonds, etc, at various points.

5.3.5 *Stray Current Electrolysis Surveys* — Stray dc currents are quite often put into the ground by traction systems which operate on these. They are also generated by dc welding machines operating in the vicinity. These stray currents are picked up by the underground structures at one point and returned at another convenient point. They upset the normal readings in two ways:

a) The pointer is not stationary when ordinary readings are taken in accordance with **4.3**, and

b) The values of the readings taken, from time to time are varying.

5.3.5.1 Upon noticing such fluctuations, one must make sure that these are not due to faulty contacts or loose connections in the metering system. Then, we should ascertain the source of these stray dc currents.

5.3.5.2 These readings are best taken on recording milivoltmeters. A chart for full 24 hours period is taken for one particular spot. Then the chart is taken for the next particular spot. This is a long and tedious way of recording effects of stray current electrolysis.

5.3.5.3 It is recommended that only voltage drops due to pipeline current be recorded to ascertain: (a) where the currents are being picked up, and (b) where the currents are being grounded. After this has been done, it is recommended that proper bends be established between the underground structure and the traction system, so that the stray currents are returned to the traction system through a metallic path and nowhere through the soil itself.

5.3.5.4 Cathodic protection systems in stray current areas may be designed and worked out in the same fashion as in the non-stray current areas. However, the effectiveness can be checked only with the help of recording milivoltmeters. Since the reference electrode will be used continuously for 24 hours, it is recommended that a specially designed electrode with a wider area of contact to soil and wider rod or cylinder diameter in the solution, may be used.

5.3.5.5 The period of 24 hours may be shortened for practical considerations where applicable.

5.3.5.6 For preliminary surveys a moving coil meter may be used. Where a recording milivoltmeter is not available, survey engineer may use with discretion, measurements at short intervals with a moving coil meter.

6. CATHODIC PROTECTION SYSTEMS

6.1 Designs of Cathodic Protection Systems

6.1.1 *Sacrificial Anodes* — It is possible to design cathodic protection systems on the basis of a single reading, namely, the average soil resistivity around the buried structure. The following values are recommended to obtain full cathodic protection on bare steel surfaces:

Resistivity ohm-cm	*Current mA/M²*	*Corrosivity*
Up to 500	108	Very high
Above 500 up to 1 000	75	High
Above 1 000 up to 1 500	32	Above normal
Above 1 500 up to 5 000	11	Normal

6.1.1.1 A due allowance should be made for the effectiveness of the coating on the underground structure. This allowance may be calculated with the help of known current picked up on individual underground structures during the temporary ground bed test. This value has to be modified to allow for the unevenness of current picked up during the temporary ground bed test.

6.1.1.2 However, if no temporary ground bed test has been run, a few anodes calculated on the basis of past experience may be put around the underground structure and the performance may be watched. Excess anodes may be dug out or their current may be limited so as to get prolonged life. If the anodes are less, more anodes may be added.

6.1.1.3 The design for cathodic protection for buried structures may be carried out with magnesium sacrificial anodes using 50 percent efficiency of the theoretical value. By referring to Table 2, it may be seen that 8·2 kg of anode would provide one ampere current for one year at this efficiency. The number of magnesium anodes around the structure may be worked out for a period of 5-10 years for effective cathodic protection.

6.1.1.4 Magnesium anodes without control on the output may also be used to save time-consuming current output adjustments.

6.1.1.5 Following compositions are recommended for cathodic protection materials in the sacrificial anode systems:

a) *Cast magnesium alloy anode*

Al	5-7 percent
Zn	2-4 percent
Mn	0·15 percent, *Min*
Fe	0·003 percent, *Max*
Ni	0·002 percent, *Max*
Cu	0·02 percent, *Max*
Si	0·10 percent, *Max*
Mg	Remainder

b) *Backfill for magnesium anodes* — One of the recommended composition for the backfill is gypsum 75 percent, bentonite 20 percent and sodium sulphate 5 percent.

6.1.1.6 It is recommended to use effective backfills around the anodes so that anodes are not polarized throughout their service life and the contact to ground of the anodes is effectively maintained. For this reason, it is also recommended that the sacrificial anodes be installed at depths where permanent water tables are obtained or where the soil resistivity is permanently low.

6.1.2 *Impressed Current Systems* — Impressed current systems are generally preferred:

a) when the soil resistivities are high and the seasonal variations in the soil resistivities are also high;

b) where a large number of underground structures have to be protected and maintenance costs have to be minimized; and

c) where the coating on the underground has deteriorated considerably and it is not economical to use magnesium anodes. Furthermore, the effective protection of magnesium anodes on bare surfaces will not have any large covering area from the point of attachment of the sacrificial anode.

6.1.2.1 Impressed current systems are generally based on the finding of the temporary ground bed test. Alternatively, current requirements for cathodic protection may be worked out under the same assumptions as under **6.1.1** bearing in mind that the spread of the current is non-uniform.

6.1.2.2 *Rectifiers* — Selenium plate rectifiers or silicon diode rectifiers are generally recommended. The voltage should be arrived at in conjunction with the rectifier supplier, due allowance being made for deterioration in the insulating values of the coating. At the time of ordering, it is important to specify whether the rectifier will be used indoor or outdoor and the maximum ambient temperature at which it is likely to operate.

The rectifier should be housed in a well ventilated place to avoid build up of heat. Its controls should be easily accessible. The area in which it is installed should be free draining so that accumulation of water is avoided. There should be adequate arrangements for cables carrying dc to the structures, with an air choke on the output side of the rectifier.

The provisions for flame/gas proofing should also be considered.

Header cables from the anodes are joined to the connecting cables and the joints are encapsulated with epoxy resin castings. It is very essential that no part of the cable joint is exposed to the soil.

6.1.2.3 *Anodes* — Following types of anodes are normally recommended:

a) Graphite anodes, properly, treated;

b) Scrap mild steel or cast iron parts; and

c) High silicon cast iron anodes.

6.1.2.4 For water-logged soils or salty soils, graphite anodes impregnated with wax and sodium-treated or high silicon cast iron anodes are recommended. The manufacturers' recommendations in this respect should be sought.

6.1.2.5 While using scrap steel, it should be ensured:

a) the steel parts are not covered with insulating materials, such as paints, asphalts, oils and greases; and

b) the risers or necks on these scrap steels as well as inter-connections between massive chunks of scrap are carefully coated with asphalt or coal tar. This is to prevent necking out of the massive chunks.

6.1.2.6 The approximate quantities of graphite or steel may be worked out with reference to the figures given in Table 2.

6.1.2.7 High silicon cast iron gives longer trouble-free service when used as an anode under these systems.

6.1.2.8 *Backfills for anodes* — The backfills under these systems shall establish and maintain a good contact between the anode and the soil throughout the period of cathodic protection. Under the impressed current systems, it should help to prevent gas blocking around the anode. A typical composition is given below:

a) Coke or graphite	Roughly 9·5 mm size
b) Dust permissible, *Max*	10 percent
c) Ratio of calcined lime to carbonaceous matter	1 to 6

NOTE — No volatile matters to remain in the carbonaceous particles.

6.1.2.9 *Location of permanent anodes* — Resistances of the ground bed to soil should be as low as possible in order to effect economy in power consumption and on material ratings. For this reason, the following are recommended:

a) Graphite anodes should be buried deep at the level of permanent water level.

b) Spacing between graphite anodes should be between 3 and 5 m.

c) Geometrical pattern of the graphite anodes should be such that the current spreads in the form of a fan to cover the underground structure.

d) The space above the anode head will then be filled as detailed below:

Height from Anode Head	*Material*
0 to 30 cm	Coarse coke breeze
30 to 70 cm	Gravel
70 to 90 cm (ground level)	Soil

If the ground level is more than 90 cm from the anode head, more of coarse coke breeze should be added to bring the level to 60 cm below the ground surface.

6.2 Erection and Maintenance

6.2.1 *Sacrificial Anodes* — The sacrificial anodes are buried to the required depths and their leads are directly connected to the underground structure at a convenient point above the ground like a pipeline which is connected to the underground structure. Initially, the currents are not regulated and the structure is allowed to be quickly over-polarized, if possible.

6.2.1.1 A second electrolysis survey is run to check the efficiency of this protecting polarization. If this survey shows that the anodes are putting excess currents, which they normally do, it is desirable to introduce a regulating resistance in the lead of each sacrificial anode. The connections to this regulating resistance should be of non-rusting type. These resistances will have to be adjusted back and forth till the outputs on all the anodes are controlled and a uniform protecting potential is obtained all round the structures. It might be desirable to dig around and have access to some critical parts of the underground structure to take reading initially. Once the pattern of these readings is obtained, a test lead at one or two points may be established on the underground structure and brought above ground for taking future readings.

6.2.1.2 In order to take effective maintenance of cathodic protection with sacrificial anodes, it is necessary to run periodic surveys wherein structure to soil potentials and anode outputs may be measured. If necessary, the regulating resistance in the anode leads may be adjusted in periodic surveys.

6.2.1.3 A cathodically protected surface is likely to become a most active electrolytic surface as soon as there is a break in the cathodic protection. Once cathodic protection has been established, it is very necessary to see that it does not have prolonged breaks.

6.2.2 *Impressed Current Systems* — When the anodes for the ground bed have been installed, their connections to the connecting cables are made, the rectifier is installed and connected and insulating flanges have been placed at proper places, the cathodic protection is ready to be switched on. It is switched on and for the first few days, a heavy over-current is passed to obtain quick polarization. After this, another electrolysis survey is run and currents picked up by individual structures are adjusted with the help of regulating resistances across the insulating flanges. These insulating flanges are placed across each underground structure. A final survey is taken and the rectifier outputs are recorded.

6.2.2.1 For periodical maintenance, it will be sufficient to measure rectifier outputs regularly. If there is a gradual or sudden fall in rectifier outputs, the reasons for this should be investigated. Periodic surveys to check readings of structure to soil potential may be run on an yearly basis.

6.2.3 *Surface Potential Surveys* — Surface potential surveys are recommended to locate discontinuities in the anodic ground bed systems. Two Cu/$CuSO_4$ reference electrodes are spaced some 3 to 5 m apart. Their ends are connected to a sensitive dc milivoltmeter. The voltage drop in the soil is caused by the anodic or cathodic currents which are flowing through the soil. This voltage drop and its direction are read by the milivoltmeter. By plotting these drops over a system of anodic ground beds, the break in the ground bed may be readily checked. This break shall be immediately repaired and the joint should be covered with an epoxy resin or any other suitable coating.

7. EARTHING OF CATHODICALLY PROTECTED STRUCTURES

7.0 The earthing should follow general practices recommended in:

a) IS : 3043-1966*, and

b) Practices mentioned under Rules 102 and 103 in the Petroleum and Carbide of Calcium Manual issued by the Chief Inspector of Explosives in India (CIE. 2.66).

7.1 Copper plates or cast iron plates are normally used as earthing points on the electrical system. It is possible for the two different metals > copper and the mild steel of the protected structure, form bimetallic couples and result in natural galvanic corrosion on the underground structure. From this point of view, it is desirable to devise earthing of these structures to comply with the requirements of the above two references and yet either not to cause corrosion or to interfere with the cathodic protection systems.

7.2 Sacrificial Anode Cathodic Protection System — Under this system, a number of sacrificial anodes are used, which may act as good and effective earthing points complying with all the requirements of the above mentioned references.

---

*Code of practices for earthing.

7.2.1 Sacrificial anodes sometimes have regulating resistances introduced in their leads so as to prolong the life of the anodes. When this is done, it is necessary to make sure that all the electric contacts are of the non-rusting type and the total resistance to ground lies within the specified limits.

7.3 Impressed Current Cathodic Protection System — Here it is recommended to put two distinct earthing points by driving 25 mm dia × 1·75 m to 2 m long cast iron or high silicon cast iron rods into the ground and connecting them to underground structures. The resistance of these rods to earth are to be maintained within the specified limits.

7.3.1 It should be understood that the current picked up on the bare surfaces of these rods is wasted as far as the cathodic protection system is concerned. Therefore, the exposed area of these rods shall be small enough to minimize the pick-up of cathodic protection current and it shall be at the same time large enough to provide the necessary contact to ground.

7.3.2 Sometimes the insulating flanges are provided on the outlet of these structures. Considering the requirements of good earthing, it is recommended that these insulating flanges be jumped over by a high resistance metallic wire. The resistance is so chosen that no sparking will ever take place across the two faces from the insulating flanges, and it does not interfere with the cathodic protection system itself.

INDIAN STANDARDS

ON

CORROSION PROTECTION

IS:	
3531-1966	Glossary of terms relating to corrosion of metals
3618-1966	Phosphate treatment of iron and steel for protection against corrosion
4180-1967	Code of practice for corrosion protection of light gauge steel sections used in building
4777-1968	Performance tests for protective schemes used in protection of light gauge steel against corrosion
5555-1970	Code of procedure for conducting field studies on atmospheric corrosion of metals
6005-1970	Code of practice for phosphating of iron and steel
7808-1975	Code of procedure for conducting studies on underground and subsoil corrosion of metals
8108-1976	Code of practice for cathodic protection of steel structures
Part I	General principles
Part II	Underground pipelines

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephone : 27 01 31 (20 lines) **Telegrams : Manaksanstha**

Regional Offices:

			Telephone
Western	: Novelty Chambers, Grant Road	BOMBAY 400007	37 97 29
Eastern	: 5 Chowringhee Approach	CALCUTTA 700072	23-08 02
Southern	: C.I.T. Campus, Adyar	MADRAS 600020	41 24 42

Branch Offices:

'Pushpak', Nurmohamed Shaikh Marg, Khanpur	AHMADABAD 380001	2 03 91
'F' Block, Unity Bldg, Narasimharaja Square	BANGALORE 560002	2 76 49
Showhouse Bldg, Sachivalaya Marg	BHUBANESHWAR 751001	5 36 27
Ahimsa Bldg, SCO 82-83, Sector 17C	CHANDIGARH 160017	2 83 20
5-8-56/57 L. N. Gupta Marg	HYDERABAD 500001	22 10 83
D 227 Todarmal Marg, Banipark	JAIPUR 302006	7 63 16
117/418 B Sarvodaya Nagar	KANPUR 208005	82 72
B.C.I. Bldg (3rd Floor), Gandhi Maidan East	PATNA 800004	5 36 55
Hantex Bldg (2nd Floor), Rly Station Road	TRIVANDRUM 695001	32 27

Printed at Delhi Printers, Delhi, India