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Indian Standard

CODE OF PRACTICE FOR CATHODIC PROTECTION OF STEEL STRUCTURES

PART II UNDERGROUND PIPELINES

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PART II UNDERGROUND PIPELINES

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PART II UNDERGROUND PIPELINES

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 30 April 1976, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard is being issued in parts. This part has been prepared to serve as a guide for the cathodic protection of underground pipelines. It should be read in conjunction with Part I which covers the general principles of cathodic protection.

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1. SCOPE

1.1 This standard (Part II) deals with the cathodic protection of underground pipelines.

2. GENERAL

2.1 Corrosion of a buried pipeline can be prevented to a major extent by avoiding direct contact between the pipe and the surrounding moist soil. This is done by coating the pipe with electrically insulated material. For the guidance of users some of the frequently used coatings are given in Appendix A.

2.2 To prevent further corrosion the coating and wrapping are supplemented by application of electric currents flowing to the pipe at the 'holiday' points so that the pipe is continuously maintained in the 'cathodic' state. Sufficient current should flow from soil to pipe to maintain a certain minimum pipe-to-soil potential.

3. UNDERGROUND PIPELINES

3.1 Classification of Pipes — Pipelines may be divided for the purpose of cathodic protection engineering into two classes: (a) short pipes in which their longitudinal electrical resistance is very small and to be considered an equipotential surface, and (b) long pipes or pipelines, where their longitudinal resistance is high and variation of resistance with length plays an important part in the design and engineering of the cathodic protection installation.

3.2 Pipe Material — Most of the pipelines are made of steel. There is also a considerable length of small diameter service pipes not made of steel. In the case of galvanized steel pipes after the galvanizing has been eaten away as shown by sample inspection, external cathodic protection may be worked out in the field.

3.3 Electrical Continuity — It is necessary to ensure that the pipeline to which cathodic protection is to be applied is electrically continuous and has a low and uniform longitudinal electrical resistance.

3.3.1 Steel pipelines having welded joints are intrinsically electrically continuous, whereas pipelines having certain types of rubber-sealed joints are discontinuous. Continuity may be effected by brazing or welding a metal strip or cable of adequate cross-sectional area to avoid any leakage of current from the pipe while ensuring that the protective potential is maintained on the other side of the pipe.

3.4 Protective Coatings — Cathodic protection being an added insurance against flaws in and against future damage to the protective coatings and in order that the cathodic protection is applied more efficiently, it is important to use a high efficiency coating having the same life expectancy as of the pipeline (*see* Appendix A).

3.4.1 *Test for Coating* — After the coating has cooled to ambient temperature, the coating should be tested for holidays with an electrical holiday detector capable of delivering test voltages between 10 and 40 kV at the point of contact between the electrode and outer surface of the pipe coating. The electrode should be of the coil spring or brush type completely encircling the pipe coating in its entire peripheral surface.

4. CATHODIC PROTECTION

4.1 Methods of Cathodic Protection — There are two methods of cathodic protection of underground pipelines, namely:

a) Sacrificial anode system, and

b) Impressed current system.

4.2 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.

4.3 Criteria for Cathodic Protection — The pipe-to-soil potential test has been established as a standard measurement technique in the evaluation of corrosion and cathodic protection of underground pipes for complete protection. In aerobic environment the minimum value of this potential is −0·85 volts with respect to a copper/copper sulphate half cell reference electrode placed over the pipeline as close to it as possible but not touching it. The value is −0·95 volts in anaerobic environment. In the presence of bacteria, the cathodic protection should be applied immediately.

4.3.1 Another criterion employed in cathodic protection is to produce a negative swing in the pipe-to-soil potentials of 0·30 volts from the initial or unprotected potentials. This criterion is more applicable to bare or poorly coated pipelines and is particularly recommended in soils of resistivity 5 000 ohm-cm or less in absence of stray currents.

4.3.2 There is also a safe upper limit up to which the potential should be depressed and that is considered as −2·5 volts when the pipes are coated with standard coal tar or asphalt coatings and are wrapped. (For other coatings the manufacturer's recommendations should be obtained.) A higher potential may cause evolution of hydrogen which may damage the coating.

4.4 Design — To design cathodic protection scheme of a buried pipeline, various factors should be known. The most important factors are as under:

a) Environment,
b) Soil resistivity of the area,
c) Condition of coating and wrapping,
d) Configuration of the pipeline with respect to other underground utilities, and
e) Past history of leaks on the same pipeline or other pipelines running in that area.

4.4.1 After this assessment, a current drainage test should be made. Current drainage test can be done for the existing pipelines. If a design has to be carried out for new line, which is still to be constructed, then proper assumptions for current requirement based on experience have to be made [*see* IS : 8062 (Part I)-1976*].

4.5 Locating Groundbed Sites — In selecting groundbed sites, the most important consideration from a design stand point is determination of effective soil resistivity.

4.5.1 In the case of uncoated or poorly coated pipelines the distance between the groundbeds and the pipeline will be relatively shorter and the distance between successive cathodic protection installations will also be

*Code of practice for cathodic protection of steel structures: Part I General principles of cathodic protection.

relatively shorter. When the coating on the pipeline is good, the distance between the pipeline and the groundbed could be made relatively longer and the distance between successive cathodic protection stations can be increased (*see* Fig. 1, 2 and 3).

4.6 Anodes — Following types of anodes are normally recommended:

a) Graphite anodes, properly treated.

b) Scrap mild steel or cast iron parts.

c) High silicon cast iron anodes.

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

4.6.2 While using scrap steel, it shall be ensured:

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

b) that the risers or necks on these scrap steels as well as interconnections between massive chunks of scrap should be carefully coated with asphalt or coal tar. This is to prevent necking out of the massive chunks.

4.6.3 The approximate quantities of graphite or steel may be worked out on the basis of information given in Table 2 of IS : 8062 (Part I)-1976*.

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

4.7 Backfills for Anodes — The backfills under these systems shall establish a good contact of the anode to the soil at all times. Under the impressed current systems, it should help to prevent gasblocking around the anode. Following compositions are recommended:

Coke-coal or graphite particles	Roughly 9·5 mm size
Maximum dust permissible	10 percent
Ratio of calcined lime to carbonaceous matter	1 to 6

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

4.7.1 *Location of Permanent Anodes* — Resistances of the groundbed to soil should be as low as possible in order to effect economies in power consumption and on material ratings. For this reason, following are recommended:

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

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*Code of practice for cathodic protection of steel structures: Part I General principles of cathodic protection.

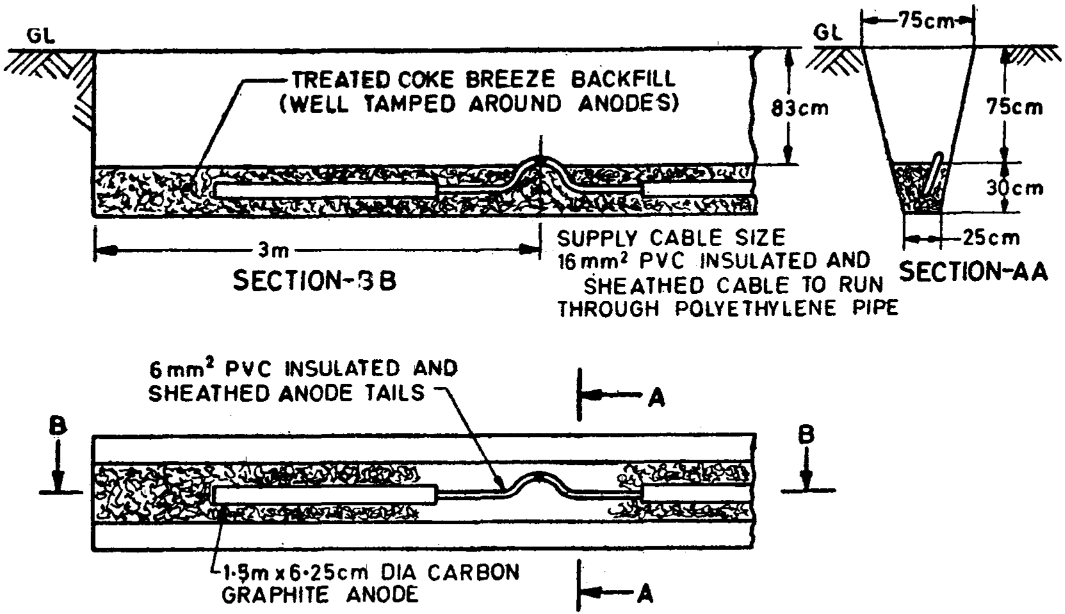
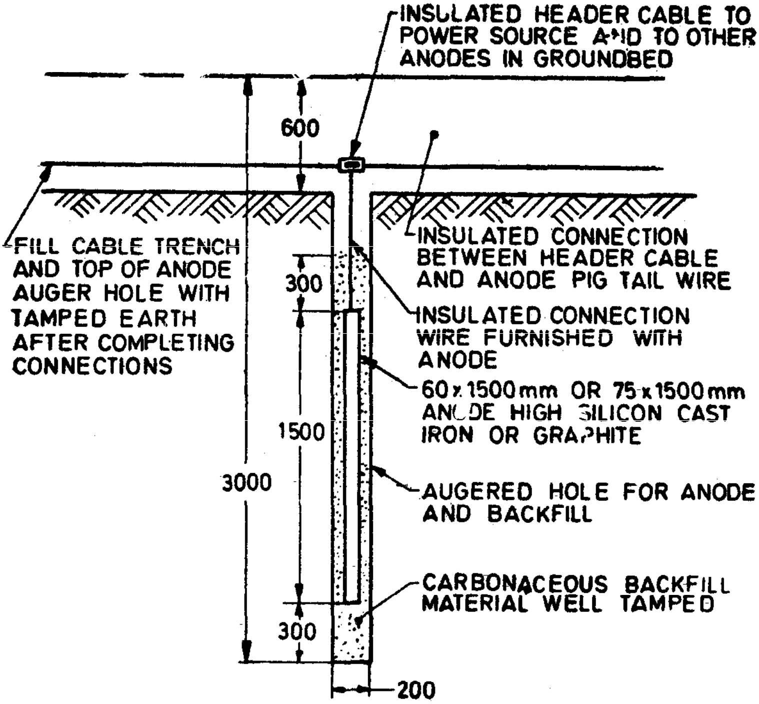


Fig. 1 Plan View of Groundbed



All dimensions in millimetres.

FIG. 2 TYPICAL VERTICAL ANODE INSTALLATION

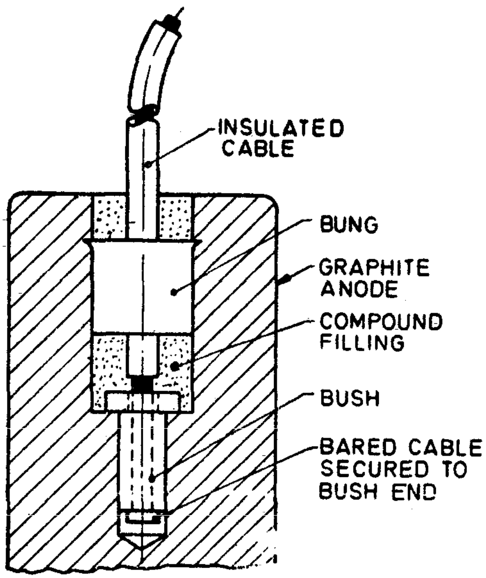


FIG. 3 SECTION THROUGH GRAPHITE ANODE CONNECTION

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 facilities.

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

Height from Anode Head cm	*Material*
0 to 30	Coarse coke breeze
30 „ 70	Gravel
70 „ 90 (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.

5. SPECIAL CONSIDERATIONS

5.1 Road and Rail Crossings — For pipelines crossing under railroad tracks, etc, an agreement would have to be made with the concerned authorities.

5.1.1 No long pipeline may 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 '. But the difficulty is that the 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. Therefore, one of the following alternative steps should be taken to secure protection of the carrier pipe inside the casing pipes:

a) The section of pipe inside the casing should be given a very good standard of coating and wrapping leaving least ' holiday ' possible. The carrier pipe should be insulated from casing pipe supported by plastic insulating supports fitted to it at regular intervals. Where possible the pipe inside the casing should be kept dry by use of suitable end-seals. If it is impossible to guarantee that no water will infiltrate within the casing, consideration may be given to the use of galvanic anodes in the form of magnesium or zinc strip attached to the carrier pipe. Alternatively, a pressure type sleeve end-seal may be used which overcomes the limitations of ordinary end-seals where it is virtually impossible to prevent ingress of moisture.

b) The outer and inner surfaces of the casing pipe should be coated to the same standard as the carrier pipe, if it is considered necessary that the casing is also provided cathodic protection. The casing pipe may then be bonded to the carrier pipe either by making a direct connection or by bringing leads to the surface and terminating them in a box. Alternatively, the casing pipe may be separately protected by means of sacrificial anodes in which case the casing pipe should be insulated from carrier pipe as in (a) above. It will be preferable to use concrete casing pipe wherever feasible.

c) In some cases it may be possible to seal the casing pipes to the carrier pipe by welding at each end and pressurizing the annular space with an inert gas, for example, nitrogen. Under these conditions it would not be necessary to coat the pipe inside the sleeve, but the sleeve coated externally to reduce the cathodic protection current demand. A pressure type sleeve as stated in (a) above is particularly suitable for this application. But it is recommended that the wrapping of the carrier pipe, where the seal will be fitted, is removed and an epoxy resin coating applied. This may be necessary due to the possibility of lack of adhesion of coating in this area which may lead to pressure loss underneath the wrapping.

5.2 Concrete Encased Pipe — Pipe encased in concrete, for example, as at river crossing, valve boxes, etc, may be cathodically protected, where it is passing through highly saline soil and the water table is high.

5.3 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 bridges.

5.3.1 For submerged crossings, care should be taken to give the 'submerged' section of the pipe a very good standard of coating and wrapping leaving least 'holidays' 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 put by railway authorities, pipelines over railway bridges are not always cathodically protected. In such a case, the pipe along the bridge is 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 the main line end.

5.4 Protecting Existing Pipelines — Cathodic protection, usually by impressed current, may often be applied to old pipelines, even though they are bare or have badly deteriorated coatings, in order to prolong their life. It is rarely economical to lift and recoat such pipelines except at selected points where interaction with neighbouring structures may be expected.

Bare pipelines with or without coating require high current density for their protection.

5.5 Insulating Flange — Pipeline may be sectionalized electrically to control current flows of either galvanic or external origin. Usually this is done by inserting ' insulating flanges ' (*see* Fig. 4).

NOTE — While deciding about the insulating flanges, due consideration should be given to fire hazards in the area.

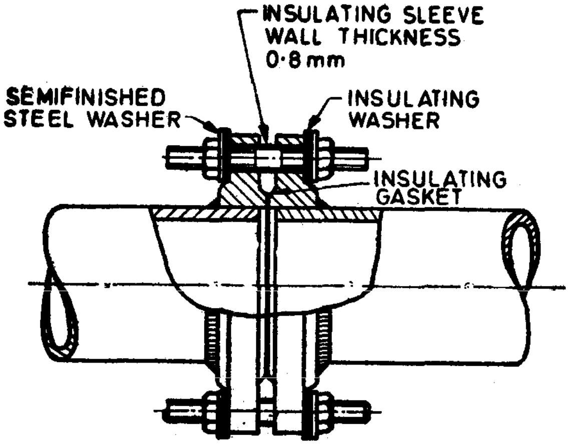


FIG. 4 TYPICAL INSULATING FLANGE

5.5.1 Pipe surfaces on each side of such insulating flanges 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 bitumen coating along the requisite length of pipe and also completely encase the insulating flange with the same coating. Insulating points should be painted with a distinct colour for easy identification. In zones highly susceptible to lightning, care should be taken that the insulation material is not damaged by electrical stresses set up by lightning strikes.

5.5.2 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.

6. STRAY CURRENT CORROSION AND CATHODIC PROTECTION

6.1 Causes — If a pipeline lies within a current return path resulting from electrical system, such as dc traction, welding or electrolytic plants, etc, there is an opportunity for the current to enter and leave the line, corroding the latter section of the pipeline at a much faster rate than that due to the galvanic effect. Because of the inherently accidental or unintentional nature of such current, they are usually known as 'stray currents' and the resulting corrosion as stray current corrosion.

6.2 Source — By far the greatest source of stray current is electric railway or tram car where the negative of the dc supply is usually connected to running rails. If the return path of the rail is not effective the return current is forced to pass into the ground.

6.3 Remedial Measures — This stray current corrosion may be prevented by: (a) a very good coating; (b) by ensuring that the continuity of the path of the traction is effective, in consultation with the traction authorities; and (c) by bending the pipeline to a return rail at the most negative position of the track, that is, near sub-station or where negative feeders are connected to the rails. The bending cable will then carry most of the return traction current back to the point of supply, thus ensuring that the structure receives partial or, sometimes, complete cathodic protection. To avoid accidental current reversals in this type of drainage bond, a unidirectional relay is usually provided in series with the cable providing the bond.

6.3.1 If the track voltage is likely to attain relatively high value, it is necessary to protect the unidirectional relay and bond against excessive currents by means of suitable series resistors and/or inductors and overload circuit-breakers and by providing more than one drainage connection.

7. OVERHEAD TRANSMISSION LINES

7.1 A minimum separation of 3 metres should be maintained between pipelines and transmission tower footings and ground cables. Regardless of separation, consideration should always be given to lightning and fault current protection of the pipelines.

7.2 It is desirable for the pipelines and transmission lines to cross at right angles.

8. INTERFERENCE IN CATHODIC PROTECTION

8.1 General — Cathodic protection interference is the undesirable current flow, between one or more cathodically protected/unprotected pipelines, cable sheaths, etc, and the pipeline in question.

8.1.1 Besides possibly accelerating corrosion on the line from which this current flow takes place, currents from cathodic protection systems could cause false operation of railway signalling equipment and could interfere with telecommunication circuits.

8.1.2 The interference effect may be minimized by exercising sufficient care during the design stage. This effect may be assessed by tests and criteria described in **8.4** and **8.5**, and corrected by measures as described in **8.9**.

8.2 Notifying Owners of Other Structures — It is essential that prior to the installation of cathodic protection system for any pipeline, all other organizations having buried metallic pipes, cables or other structures near the proposed installation, should be given due notices. The notices are intended to ensure that information becomes available to design the installations in such a manner that corrosion interference is kept to a minimum and that others may study the interference effect on their structures and take proper remedial measures.

8.3 Details of Notification — At an early stage during the planning of a cathodic protection scheme, a preliminary notification should be sent to each organization having buried metallic structures near the proposed installation which should include the following information:

a) Whether galvanic anodes or an impressed current system will be employed.

b) A sketch showing the route of the pipelines to be cathodically protected.

c) Position of groundbeds or anodes.

d) Approximate dates by which the system would be ready for an initial test and proposed date for putting into service.

NOTE — Compliance with this code does not confer immunity from relevant legal and statutory requirements, including regulations and bye-laws.

8.4 Interference Testing — After any initial tests of the system have been completed, notification should be sent to all organizations who have indicated that they have plant likely to be affected by the operation of the cathodic protection scheme. The following information should be given at least one month before the date proposed for interference test:

a) Suitably scaled plans for use during tests.

b) The current at which each rectifier or galvanic anode will be operated during the tests.

c) An indication of pipe/soil potential along the pipeline before and after the application of protection.

d) Dates for tests.

8.4.1 If after cathodic protection scheme has been brought into regular service, it is found necessary to alter the scheme substantially, details of the proposed amendments should also be notified.

8.4.2 Interference tests should be carried out within three months of switching on the cathodic protection. The structure/electrolyte potential changes due to interference will vary along the length of the surrounding structure. At some parts there will be negative changes while at some other positive changes. For most metals only positive potential changes are liable to accelerate corrosion.

8.5 Criteria for Corrosion Interference — Since positive potential changes are liable to accelerate corrosion, the structure/electrolyte potential changes are used as the basis for permitted degree of interference. The maximum positive potential changes at any part of a secondary structure, resulting from interference, should not exceed 20 mV.

8.6 Design of Cathodic Protection Installation to Minimize Interference Corrosion — The magnitude of any positive changes of structure/electrolyte potential on neighbouring secondary structure will depend mainly on:

a) The quality of the coating on the pipeline — the better the coating, the lesser is the interference effect.

b) The spacing between the primary (pipeline) and secondary structures — the more the spacing, lesser the effect.

c) The distance between the groundbeds or anodes and the secondary structures — greater the distance, lesser the effect.

d) The soil conditions at the locations where the foreign structure passes close to the structure under protection, as also near the drainage point of the cathodic protection system. For identical pipe diameter and their distance, the interference effect will be more pronounced in soils of low resistivity as compared to this effect in soil of high resistivity.

8.7 Sacrificial Anode Installation — With the galvanic anode installation, if the total current available is less than 100 mA, interference testing may be omitted. Even if the current exceeds 100 mA, interference testing may be omitted if the anodes are placed at least 2 metres away from any secondary structure.

8.8 Impressed Current Installation — The following precautions should be taken with the impressed current installation:

a) Structure/electrolyte potentials on the primary structure (pipeline) kept to the minimum within the required protective level.

b) To provide a good coating on the primary structure.

c) To site the primary structure as far away as possible from the secondary structure and, at the crossings, the spacing should be maximum which conditions permit.

d) The longitudinal resistance of the structure to be cathodically protected made as low as possible by means of continuity bonds, welded joints, etc.

e) The groundbed sited as far away as possible from neighbouring structure.

f) Consideration be given to install anodes at a considerable depth depending upon the soil resistivity and the current requirement of the structure.

g) Total current to be applied should be distributed from a sufficient number of installations to ensure a reasonably uniform distribution of structure/electrolyte potential on the primary structure.

8.9 Measures to Reduce Corrosion Interference — In addition to the precautions stated in **6.3** and **6.3.1** one or more of the following methods should be considered by the parties concerned as a means of reducing corrosion interaction at the points on the secondary structure whose positive changes in excess of recommended maximum have been measured. The method adopted should aim at restoring the structure/soil potential of the secondary structure to original value or making it more negative.

a) Installing a joint cathodic protection scheme so that full protection is given to both structures.

b) Bonding the two structures by means of suitable resistors.

c) The use of a galvanic anode connected to the secondary structure if the positive changes are small and localized, provided this does not put an extra high drain on the primary protective system.

d) Increasing the resistance between the two structures, at a point where a positive change is measured, by applying locally an additional good-quality coating and wrapping to the primary structure.

e) Isolating a section of pipe adjacent to secondary structures by means of insulating joints.

8.10 Special Considerations

8.10.1 *Telecommunication System* — If a telecommunication cable is bonded to or close to a cathodic protection system energized from a source of alternating current through rectifiers, or if groundbed of the cathodic protection system is sited close to the earth electrode of a telecommunication system, there may be interference to telecommunication system. This is due to harmonic currents of the fundamental frequency of the ac supply feeding the rectifier unit inducing unwanted noise voltages into the telecommunication circuits.

8.10.2 With rectifier current outputs of the order of 5A or less, interference is unlikely. With larger currents, or if the interference occurs, consideration should be given to the provision of smoothing for the rectifier.

8.10.3 *Railway Signal and Protection Circuits* — It is imperative that the use of cathodic protection on or adjacent to railway property be so planned and operated as to ensure that it cannot cause false operation of railway signalling plant.

9. OPERATION AND MAINTENANCE

9.1 Measuring Points — Test points for measuring pipe/soil potentials should be located at intervals along the pipeline where they will be conveniently accessible to the corrosion engineer. It is perferable to locate the test points as under:

a) At every 1/2 km, if the pipeline is less than 100 km long.
b) At every 1 km, if the pipeline is above 100 km but less than 500 km.
c) At every 2 km, if the pipeline is 500 to 1 000 km.
d) At every 3 km, if the pipeline is above 1 000 km.
e) At all road/rail cased crossings, both upstream and downstream.
f) At crossing of two or more lines.
g) At insulating flanges (both sides).
h) At 100 m distance when the pipe passes through several corroding media, such as salty marshes, waterlogged soils, stray current zones, etc. For bare large diameter pipes it might be necessary to locate the test points as close together as possible.

9.1.1 The test points consist of insulated conductors welded or brazed to the pipeline and brought to measuring 1-km posts or surface terminal boxes. Where the 1-km posts are used as test point, care should be taken to properly insulate the 1-km posts up to at least 30 cm above ground and delineate the same by a distinct colour for identification.

9.1.2 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.

9.2 Routine for Measurements

9.2.1 The dc voltage and current outputs of the transformer/rectifier should be noted at least once a week. These figures give a check on the satisfactory operation of the transformer rectifiers themselves, the groundbeds, and the connecting cables.

9.2.2 Measurements of pipe-to-soil potential should be taken monthly at selected points where access is easy and 4 monthly at all points. There may be a seasonal variation in potential, which can be compensated for by increase/decrease of the appropriate transformer/rectifier settings.

9.2.3 Where stray current problem exists, more frequent checks are necessary.

9.3 Faults and Remedies

9.3.1 *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 groundbed with a voltmeter and two half cells and should be replaced.

9.3.2 *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.

9.3.3 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, such as might be caused by heavy vehicles running over the pipe track, or a wash-out with rolling boulders. The damaged coating should be located either by visual examination or by use of the Pearson holiday detector and made good.

c) When a casing is short-circuited to the pipe the protective coating potential on the pipe is below the minimum value accepted in or around the point of short and the current drawn from the rectifier system is suddenly increased. 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.

   2) To install magnesium anodes on both sides of the line at each end of the casing that will enable the main line protection unit to carry beyond the casing.

9.3.4 Inadequately bonded coating may be avoided because, if it is disjointed in course of time, there would not be any protection left. It is, therefore, desirable to check the pipeline with a holiday detector at regular intervals.

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

9.3.6 When two or more pipelines are running in parallel and in close vicinity, the effect of shielding should be avoided.

10. SAFETY PRECAUTIONS

10.1 General — As cathodic protection necessitates the use of electrical equipment, certain safety precautions should be taken in hazardous areas.

10.1.1 Safety precautions for rectifiers, switches and cables are the same as for any other electrical appliance. The lowered potential of cathodically protected steel structures with reference to the surroundings means that contact with another steel 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.

10.2 Danger of Electric Shocks — Voltages in excess of 50 V dc 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 installation while working on the 'hot' pipeline 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 groundbeds due to the voltage gradient at the surface of the soil. Following precautions are to be taken in this regard:

a) the dc output of the rectifier transformer should not exceed 50 V dc.

b) the anodes are buried at least 30 cm below ground level.

c) the leads are fully insulated and protected against mechanical damage.

10.3 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, specially 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.

10.3.1 Bonds between metal work, associated with an electricity power system (for example, cable sheath) and cathodically protected structures, 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 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 structures. 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.

10.4 Installations in Dangerous Atmospheres

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

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

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

10.4.3 *Remedies* — The following safety measures should be adopted where applicable:

a) Provide flameproof enclosure of all electrical equipment, namely, transformer/rectifier, resistive bonds, etc, in accordance with relevant standards.
b) Provide continuous bonding cables across any intended break, before it is made, in protected pipelines.
c) Installation of insulating joints, as far as possible, in 'safe' areas.
d) Jump over the insulated flanges with a high resistance metal bond, which gives electrical/metallic continuity for high voltages but is high enough to prevent cathodic protection currents from passing over [*see* **7.3.2** of IS : 8062 (Part I)-1976* (*see also* Fig. 4)].

*Code of practice for cathodic protection of steel structures: Part I General principles of cathodic protection.

APPENDIX A

(*Clauses* 2.1 *and* 3.4)

PROTECTIVE COATING SYSTEM FOR UNDERGROUND PIPELINES

A-1. GENERAL

A-1.1 Cathodic protection is generally applied to coated pipelines. The coating system may be either coal-tar based or asphalt based and consists of a coat of primer followed by either one or two layers of asphalt or coal-tar enamel in conjunction with one or more layers of reinforced protective wrappings. In case extra protection is required, additional layers or thicknesses of enamel and wrappings may be applied.

A-1.2 Preparation of the Pipe Surface — The pipe surface shall be cleaned by wire brushes or other means including sand blasting so that all rust and millscales are removed, before application of the coating. Where sand blasting is resorted to, due health hazard precautions shall be taken.

A-2. COAL-TAR ENAMEL-CUM-FIBREGLASS REINFORCED WRAP FOR PIPELINES

A-2.1 The coal-tar based coating system shall conform to only one of the following types:

a) *Single Coat/Single Wrap* — A flood coating of enamel is applied and simultaneously a wrap of innerwrap is pulled into it. The minimum thickness of this coating shall be 2·5 mm.

b) *Single Coat/Double Wrap* — A flood coating of enamel is applied and simultaneously a wrap of innerwrap is pulled into it. Immediately following the application of the innerwrap, a layer of outerwrap is applied to the external surface of the coating. The minimum thickness of this coating shall be 3·2 mm. This is adequate for all normal conditions.

c) *Double Coat/Double Wrap* — A flood coating of enamel is applied and simultaneously a wrap of innerwrap is pulled into it. Immediately following this, a second flood coating of enamel is applied and then a layer of outerwrap is applied to the external surface of the coating. The minimum thickness of this coating shall be 4 mm. This is recommended for pipes laid in very wet or aggressive soils.

d) *Double Coat/Triple Wrap* — A flood coating of enamel is applied and simultaneously a wrap of innerwrap is pulled into it. Immediately following this, a second flood coating of enamel is applied and a second wrap of innerwrap is pulled into it. Immediately following this, a layer of outerwrap is applied to the external surface of the coating. This is only necessary for submarine pipes.

A-2.2 The coal-tar primer shall be compatible with the enamel to be used and shall consist of processed coal-tar pitch and refined coal-tar oils, suitably blended to produce a liquid that may be applied cold by brushing or spraying and which will produce an effective bond between the metal and a subsequent coating of coal-tar enamel. The primer shall contain no benzyl or other toxic or highly volatile solvent and shall show no tendency to settle out in the container. The other characteristics of the primer shall be as given below:

i) Drying time (to touch) at 70 percent RH and 30°C	Less than one hour
ii) Maximum boiling point of solvent	215°C
iii) Penetration of residue at 25°C (100 g mass for 5 s)	7
iv) Flash point	37°C, *Min*

A-2.3 The coal-tar enamel shall be plasticized coal-tar enamel, composed of a specially processed coal-tar pitch combined with an inert mineral filler. The enamel shall contain no asphalt of either petroleum or natural base. The other characteristics of the enamel shall be as given below:

i) Specific gravity at 25°C	1·3 - 1·6
ii) Penetration at:	
25°C (100 g mass for 5 s)	7 *Min*
96°C (50 g mass for 5 s)	Under 20
iii) Mineral filler passing through 75-micron IS Sieve	90 %, *Min*
iv) Softening point	104°C, *Min*
v) Mineral filler (ash, percent by mass)	25 - 35
vi) High temperature, sag test at 71°C	1·6 mm, *Max*
vii) Peel test	No peeling

A-2.4 The innerwrap shall be fibreglass reinforced innerwrap and shall consist of a uniform porous mat of chemically resistant borosilicate glass, melted at a temperature of 1 200°C and bonded with phenolic-type resin compatible with hot coal-tar enamel.

A-2.5 The outerwrap shall be either a fibreglass based outerwrap impregnated with enamel, compatible with the enamel to be applied or a bituminized, bonded, double kraft paper of not over 75 g/m².

A-3. ASPHALT-BASED COATING SYSTEM

A-3.1 The coating system shall conform to any of the following types, depending upon the degree of protection required:

a) *Single Wrap System*

1 coat of asphalt primer

1 coat of hot asphalt enamel (2·5 mm minimum thickness)

1 wrap of asphalt-saturated glass wrap

b) *Double Wrap System*

1 coat of asphalt primer

1 coat of hot asphalt enamel (2·5 mm minimum thickness)

1 wrap of glass mat (embedded in enamel)

1 wrap of asphalt-saturated glass wrap, completely bonded to the enamel

c) *Double Coat/Double Wrap System*

1 coat of asphalt primer

1 coat of hot asphalt enamel (2·5 mm minimum thickness)

1 wrap of glass wrap, completely bonded to the enamel

1 coat of hot asphalt enamel (5 mm minimum thickness)

1 wrap of asphalt-saturated glass wrap completely bonded to the enamel

A-3.2 The asphalt primer shall consist of suitably blended petroleum asphalt and petroleum solvents. It should not contain any pigment or inert fillers, and shall be applied by brushing or spraying as liquid coat to the cleaned pipe surface, so as to produce a suitable bond between the metal and the asphalt enamel. The primer shall have good spraying, brushing and levelling properties and a minimum tendency to produce bubbles during application. It shall be homogeneous and free from water. The other characteristics of the primer shall be as given below:

i) Drying time (to touch) at 70 percent RH and 30°C	One hour
ii) Flash point (closed)	37°C, *Min*
iii) Penetration at 25°C (100 g mass for 5 s)	2-25
iv) Solubility in carbon tetrachloride	99 %, *Min*

A-3.3 The asphalt enamel shall consist of petroleum asphalt blended with inert, non-hygroscopic, properly graded and clean mineral fillers. It shall be homogeneous and free from water and shall have the characteristics as given below:

i) Specific gravity at 15°C	0·99-1·00
ii) Softening point (ring and ball)	110-121°C
iii) Penetration at:	
25°C (100 g mass for 5 s)	5-10
46°C (50 g mass for 5 s)	2-7
iv) High temperature, sag test at 71°C	1·58 mm, *Max*
v) Low temperature, crack test at 30°C	No cracking
vi) Peel test	No peeling
vii) Mineral filler ash, percent by mass	10 to 40 % Ash shall consist of mineral filler only
viii) Mineral filler passing through 75-micron IS Sieve	90% *Min*

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