

पाइपलाइनों की इम्प्रेस्ड करेन्ट कैथोडिक संरक्षण प्रणाली के लिए विनिर्देश

SPECIFICATION FOR IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM FOR PIPELINES

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Abbreviations:

AC	Alternating Current
BS	British Standards
BIS	Bureau of Indian Standards
CP	Cathodic Protection
CMRI	Central Mining Research Institute
CPPSM	Cathodic Protection Power Supply Module
CPTR	Cathodic Protection Transformer Rectifier
CTE	Coal tar enamel
DC	Direct Current
EHV	Extra High Voltage
FBE	Fusion Bonding Epoxy
HDD	Horizontal Directional Drilling
HV	High Voltage
HVDC	High Voltage Direct Current
IS	Indian Standards
μ A/mm ²	Micro-ampere per square millimeter
MMO	Mixed Metal Oxide
MOV	Motor Operated Valve
NACE	National Association of Corrosion Engineers
PE	Polyethylene
PVC	Polyvinyl Chloride
ROU	Right of Use
SV	Sectionalizing Valve

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1.0 SCOPE

- 1.1 This specification defines the requirements of system design, engineering, installation, testing and commissioning of an Impressed Current Cathodic Protection System for cross-country onshore underground pipelines/ structures including supplementing of corrosion survey, close interval potential logging survey, investigations for interaction/interference problems and mitigation of the same.
- 1.2 This specification provides the basic parameters to develop a suitable impressed current cathodic protection system for the pipelines/ structures requiring protection. All data required in this context shall be taken into consideration to develop an acceptable design and for proper engineering of the system.
- 1.3 Compliance with these specifications, and/or approval of any documents submitted by contractor shall in no case relieve the contractor of his contractual obligations.

2.0 APPLICABLE CODES AND STANDARDS

- 2.1 The system design, performance and materials to be supplied shall conform to the requirements of the latest revision of following standards as a minimum:

- | | | |
|--------------------------------|---|--|
| i) NACE Standard SP0169 | : | Control of External Corrosion on Underground or Submerged Metallic Piping Systems |
| ii) NACE Standard TM0497 | : | Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems |
| iii) NACE Standard SP0177 | : | Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems |
| iv) NACE Standard SP0286 | : | Electrical Isolation of Cathodically Protected Pipelines |
| v) NACE Publication No. 54276: | : | Cathodic Protection Monitoring for Buried Pipelines |
| vi) NACE Standard SP0572 | : | Design, Installation, Operation and Maintenance of Impressed Current Deep Ground beds |
| vii) IS 8062 | : | Recommended Practice- ICCP for Underground Piping |
| viii) BS 7361 Part I | : | Cathodic Protection- Code of Practice for Land and Marine Applications |
| ix) VDE 0150 | : | Protection against Corrosion due to Stray Current from DC Installations |
| x) IS 1554 Part I | : | PVC Insulated (Heavy Duty) Cables |
| xi) IS/ IEC: 60079 | : | Electrical Apparatus for Explosive Gas Atmosphere |

xii) IS/ IEC: 60529 : Classification of Degree of Protection Provided by Enclosures

2.2 In case of imported equipments standards of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

2.3 The equipment shall also conform to the provisions of Indian Electricity rules and other statutory regulations currently in force in the country.

2.4 In case of any contradiction between various referred standards/ specifications/ data sheet and statutory regulations the following order of priority shall govern:

- Statutory Regulations
- Data Sheets
- Job Specification
- This Specification
- Codes and Standards

3.0 SYSTEM IMPLEMENTATION

All work to be performed and supplies to be effected as a part of contract shall require specific review by Owner or his authorised representative. Major activities requiring review shall include but not be limited to the following:

- i) Corrosion survey data interpretation report and plot plans for land acquisition
- ii) Conceptual system design
- iii) Basic engineering package
- iv) Detailed engineering package
- v) Field testing and commissioning procedures
- vi) Procedures for interference testing and mitigation
- vii) Close interval potential logging survey procedure
- viii) As built documentation

4.0 CORROSION SURVEY

4.1 General

4.1.1 The details of corrosion survey including soil resistivity data along ROU and other data required for C.P design if available with the Owner shall be included as part of project specification/ data sheet. However, verification of its veracity and adequacy shall be the entire responsibility of the contractor. In addition, contractor shall have to generate/ collect additional data as per clause 4.4 below required for completeness of the job.

Contractor shall carry out soil resistivity survey at anode ground bed locations for design of ground bed. Where specified in the data sheet, Contractor shall carry out corrosion survey along the ROU of the pipeline conforming to the specifications included in the tender document.

- 4.1.2 To carry out soil resistivity measurement Wenner's 4-pin method or an equivalent method approved by Owner/ Owner's representative shall be used. Survey instruments shall have maximum AC and DC ground current rejection feature.

Care shall be taken to ensure that the resistivity observations are not influenced by the presence of foreign pipelines/ structures, and earth currents in the vicinity of EHV/ HV lines and installations using earth return in their power system etc.

4.2 Soil Resistivity Survey at Impressed Current Anode Ground Bed Plot

- 4.2.1 Each selected anode bed plot shall be sub-divided into sub-plots. Sizes of sub-plots shall depend upon the expected depth for soil resistivity investigations. Each of these sub-plots shall be investigated for resistivity data individually. Sufficient observations shall be taken at each of these sub-plots as required and desired by Owner/ Owner's representative to obtain sufficient information about sub-soil stratification and, wherever possible, to establish the depth of water table. The number of subplots at each ground bed plot shall be decided at site in consultation with Owner/ Owner's representative.
- 4.2.2 Number, location, demarcation and size of sub-plots and number of sets of resistivity observations required for each sub-plot shall be individually decided for each ground bed plot location.
- 4.2.3 One or more ground bed plots may be required to be selected and surveyed at each CP station to form a suitable ground bed.

4.3 Topographic Surveys

Cathodic protection stations consisting of anode ground bed, CP station etc. as applicable, along with all associated cabling up to pipeline and any other related equipment and accessories for CP station shall be demarcated on the ground. Ground plots so demarcated shall be surveyed for all other topographical and cadastral features and topo-sheets shall be developed by the CONTRACTOR, which shall be suitable for use in land acquisition etc.

4.4 Additional Data to be collected

The following data shall be collected to generate design data for evaluation of interaction/interference possibilities due to presence of other services in ROU or in its vicinity. OWNER shall provide assistance for liaison work to the extent possible.

- i) Route and types of foreign service/ pipeline in and around or crossing the right of use (including those existing and those which are likely to come up during contract execution).
- ii) Diameter, wall thickness, pressure, soil cover, and coating scheme used, type of cathodic protection system provided, if any, year of laying/ commissioning in case of foreign pipelines.
- iii) Details of the existing cathodic protection systems protecting the services i.e. type of protection, location, type, rating of anode beds, test station locations and their connection schemes. Present output current and voltage readings of the CP power supply units.
- iv) Remedial measures existing on foreign pipelines/ services to prevent interaction.
- v) Graphical representation of existing structure/ pipe-to-soil potential records.
- vi) Possibility of integration/ isolation of CP systems, which may involve negotiations with owners of other services.

- vii) Existing and proposed DC/AC power sources and systems using earth return path such as HVDC substations/ earthing stations, fabrication yards with electric welding etc. in the vicinity of the entire pipeline route.
- viii) Crossing and parallel running of electrified and non-electrified traction (alongwith information regarding, operating voltage, AC/DC type etc.) as well as abandoned tracks near ROU having electrical continuity with the tracks in use.
- ix) Crossing or parallel running of any existing or proposed EHV/HV AC/DC overhead power lines along with details of voltage, AC/DC type etc.
- x) Voltage rating, phases, sheathing details of underground power cables along ROU or in its vicinity.
- xi) Any other relevant information that may be needed in designing and implementing proper cathodic protection scheme for the proposed pipeline.

Contractor shall conduct necessary potential gradient surveys for any existing anode ground beds that may interfere with the CP system of the pipelines covered under this project.

4.5 Report

On completion of all field work, a report incorporating all the results generated from surveys and details of additional data collected shall be prepared. The report shall also contain detailed interpretation of survey results and resistivity data, probable interference prone areas, selected locations for anode ground beds etc., to form a design basis for the scheme of cathodic protection. This report shall also include various drawings prepared in connection with the above work. Soil resistivity values shall be plotted on semi-log graph sheets.

5.0 CATHODIC PROTECTION DESIGN PARAMETERS

A distinctly independent impressed current cathodic protection system shall be provided to protect the external surfaces of the complete pipeline/ structure installation as specified.

Unless otherwise stated in the data sheets, the following parameters shall be used for design of permanent cathodic protection system:

5.1 Protection Current Density Range

- i) Pipe lines having Coal Tar Enamel (CTE) coating with two/ three layers of reinforcement.

Minimum Protection Current Density*	
Temporary CP (μ A/m ²)	Permanent CP for 30-Year Design Life (μ A/m ²)
40	500

- ii) Pipe lines having Dual Layer Fusion Bonded Epoxy (DLFBE) coating or 3-Layer Polyethylene (3LPE) coating:

Minimum Protection Current Density*	
Temporary CP (μ A/m ²)	Permanent CP for 30-Year Design Life (μ A/m ²)
25	250

The above current density values for temporary CP system are applicable for CP system design life up to two years.

*Actual current density to be adopted shall be decided based upon soil and other environmental conditions, current drainage survey data, proximity of foreign pipelines/structures and other interference areas affecting the installation. Where considered necessary for satisfactory protection of pipeline the current density shall be suitably increased by contractor. Also refer to clause 7.1 (iv) below.

For all pipeline sections which are having intermediate HDD (Horizontal Directional Drilling) crossings, the nearby T/R units should have adequate provision of D.C. output current to cater to the extra protection current demand at the HDD crossings.

- 5.2** The pipe protection Current Density indicated in the clause 5.1 above shall be applicable where the temperature of the fluid transported by the pipeline/ the surface temperature of the buried portion of the pipeline does not exceed 30 °C. Where this temperature exceeds 30 °C, the protection Current Density shall be increased in minimum by 25% for every 10 °C rise in temperature over 30 °C.
- 5.3** Safety factor for current density : 1.3
- 5.4** Anode utilisation factor
(For High Silicon Cast Iron Anode) : 0.85 for centre connected anode
: 0.6 for end connected anode
- 5.5** Anode surface current density
(For High Silicon Cast Iron Anode continuous operation) : 15 Amp./sq.m for shallow anode for ground bed
: 10 Amp./sq.m for deep well anode ground bed
(For MMO Coated Titanium Anode for continuous operation) : 70 Amp./sq.m in coke backfill
: 30 Amp./sq.m in soil without coke backfill
- 5.6** Anode consumption rate
(For High Silicon Cast Iron Anode) : 0.2 kg./Amp-yr
(For MMO Coated Titanium Anode) : 2.0 mg./Amp-yr (In Coke Backfill)
- 5.7** Pipeline natural potential : (-) 0.45 V

- 5.8** Design life of CP system : 30 years, unless specified otherwise in the data sheet
- 5.9** Anode ground bed loop resistance : 1 Ohm (max.)
including anode to ground resistance,
anode and cathode cable resistances

(The output voltage rating of the CPTR unit/ CPPSM shall in minimum be adequate to drive the specified end of life cathodic protection current with safety factor, considering the total anode ground bed loop resistance as the sum of the resistance specified in this clause and pipe to earth resistance).

6.0 CATHODIC PROTECTION DESIGN CRITERIA

Cathodic protection system shall be designed to meet the following criteria:

- i) The pipe to soil potential measurements shall be between (-) 0.9V (OFF) and (-) 1.18V (OFF) with respect to a copper/copper sulphate reference electrode.
- ii) In rare circumstances, a minimum polarization shift of (-) 100 millivolts may be accepted as an adequate level of cathodic protection for the pipeline with the approval of Owner.
- iii) A positive potential swing of 100 millivolts or more shall be considered sufficient to indicate the presence of an interaction/ interference situation requiring investigation and incorporation of mitigation measures by the Contractor.

7.0 SYSTEM DETAILS

The system shall include the following major equipment/ sub-systems unless otherwise specified in project specifications:

- CP stations
- CPTR units/ cathodic protection power supply modules (CPPSM).
- Anode ground beds and anodes
- Anode junction box
- Cathode junction box
- Test stations
- Permanent reference cells
- Polarisation cell and surge diverter
- Polarisation coupons
- CP system at cased crossing
- Bond Stations
- Cables

All equipment shall be new and procured from EIL approved manufacturers. Equipment offered shall be field proven. Equipment requiring specialized maintenance or operation shall be avoided as far as possible. Prototype equipment shall not be accepted.

All equipment/ materials shall conform to the relevant specifications included in the tender document.

All equipment including CPTR unit, CPPSM, test stations, anode lead junction boxes etc. shall be located in safe non-hazardous areas.

Where it is essential to install electrical and electronic instrument enclosures and its accessories in hazardous area, such equipment shall be flame proof type and shall meet the requirements as per IS/ IEC: 60079 and shall be weather proof to IP-65 also as per IS/IEC:60529.

A copy of approval from local statutory authority, as applicable such as Petroleum & Explosives Safety Organization (PESO)/ Chief Controller of Explosives (CCE), Nagpur or Director General of Mines Safety (DGMS) in India, for the electronic instruments installed in electrically hazardous area along with:

- i) Test certificate from recognized test house like Central Institute of Mining and Fuel Research (CIMFR)/ Electronics Regional Testing Laboratory (ERTL) etc. for flameproof enclosure/ intrinsic safety, as specified in the data sheet, as per relevant standard for all Indian manufactured equipments or for items requiring Director General of Mines Safety (DGMS) approval.
- ii) Certificate of conformity from agencies like Laboratoire Central Des Industries Electriques (LCIE), British Approval Service for Electrical Equipment in Flammable Atmospheres (BASEEFA), Factory Mutual (FM), Physikalisch-Technische Bundesanstalt (PTB), Canadian Standards Association (CSA), Underwriters Laboratories (UL) etc. for compliance to ATEX directives or other equivalent standards for all equipments manufactured outside India.

7.1 Cathodic Protection Stations

The number and exact locations of CP stations shall be worked out based on the corrosion survey data collected. In addition, the following guidelines shall be followed for selecting the locations:

- i) Number of CP stations and their selected locations shall ensure that these remain valid and are adequate for the full design life of the system after considering all foreseeable factors.
- ii) As far as possible, the availability of nearby low resistivity areas for location of associated ground beds must be ensured while selecting the locations of CP stations.
- iii) As far as possible, locations of intermediate CP stations shall coincide with the locations of SV stations.
- iv) The proposed locations of CP stations and anode ground bed current ratings are detailed in project specifications/ data sheets. The same shall be verified for adequacy by the contractor. The requisite current drainage tests/ survey shall be conducted by the contractor to establish the adequacy of CP current requirement indicated in clause 5.0 above and adequacy of number, ratings of CP stations for permanent CP system indicated in the data sheet. The minimum end of life pipe protection current requirement shall be considered as the current requirement indicated in the clause 5.0 above or 3 times the current density value measured by the current drainage survey for polyethylene coated pipeline and 4 times the current density value measured by the current drainage survey for fusion bonded epoxy, coal tar enamel with reinforcement coated pipeline, whichever is maximum.

7.2 CP Transformer Rectifier Unit/ CPPSM

If specified in project specifications/ data sheet, the supply, installation, testing and commissioning of cathodic protection power supply module (CPPSM)/ indoor type Cathodic Protection Transformer Rectifier Unit (CPTR unit)/ outdoor type CPTR unit installed in kiosk along with kiosk shall be included in contractor's scope. The CP TR units shall be provided at CP stations where reliable AC power supply is available. CPPSM shall be provided at other CP stations where reliable DC power supply instead of reliable AC power supply is available. The CPTR unit/ CPPSM shall be installed in non-hazardous (safe) area as specified in data sheets.

7.3 Anode Ground Beds

- i) Each CP station shall have an independent anode ground bed, which may be of shallow or deep well construction depending upon the data collected by the contractor. Deep well ground beds may also be used in the congested locations where availability of suitable land for spread out ground beds is restricted.
- ii) Ground bed shall be located electrically remote from the pipeline and foreign pipeline/ other buried metallic structures. Nearest part of the anode bed shall at least be 100 meters away from the pipeline and foreign pipeline/ other buried metallic structures. The anodes installed in the ground shall be located in perennially moist strata, wherever possible. Horizontal ground beds shall be at right angles to the pipeline, as far as possible.

The location of ground bed shall be checked and ensured for remoteness from the pipeline and other buried foreign pipelines/ structures, building foundations, switchyards, electrical earthing systems, etc.

- iii) Unless otherwise agreed, anodes shall be of high silicon cast iron type or mixed metal oxide coated titanium anodes.
- iv) Sheet steel anode canisters of adequate size shall be provided for each anode. Anode canisters shall be filled with petroleum coke breeze. In case of deep well ground beds non-canistered anodes with petroleum coke breeze in the well surrounding the anodes shall be provided.
- v) Each shallow anode-bed shall contain anodes with canisters positioned horizontally or vertically in the soil with suitable backfill. The depth of anodes (depth of top of anode in case of vertically laid anodes) shall not be less than 2 meter from grade level.
- vi) Layout of anode installation in anode bed shall be detailed out in drawings showing anode installation details, anode grouping, anode wiring, anode cable routing, etc. The deep well anode ground bed details shall include the details of anodes, deep well casing, anode positioning, anode cable supporting, deep well gas venting, active, passive portions of the ground bed etc.
- vii) Anodes shall be supplied complete with tail cables, which shall be long enough for termination on their associated anode lead junction boxes without intermediate joints. Exact lengths and termination details shall be indicated in construction drawings.
- viii) Potential gradient around the anode bed shall be within safety requirements with regard to interference on foreign structures and its effective boundary shall be defined.
- ix) In case of two parallel pipelines running in the same ROU, the anode ground beds of the respective pipelines shall be located on the respective sides of the pipelines.

7.4 Anode Junction Box

Depending on the size and configuration of anode ground beds, one or more anode junction boxes shall be provided at each ground bed. All cable tails from individual anodes shall be terminated onto the respective anode junction boxes, which shall be further connected to the main anode junction box (where applicable). The main anode junction box shall be connected to the cable coming from CP power source. Each outgoing circuit in main junction box (where applicable) and each anode circuit in junction shall have provision for measurement and control of individual circuit/anode current.

7.5 Cathode Junction Box

Where output of the CP power supply unit is connected to multiple pipelines a cathode junction box shall be provided near the pipelines at the location of connection of the negative drainage cable to the pipelines.

The negative of the CP power source shall be connected to the incoming circuit of the cathode junction box. The junction box shall have separate out going circuit one for each pipeline to collect the negative drainage currents from each of the parallel pipelines.

The incoming circuit shall have a current measurement facility. Each out going circuits shall have provision for measurement and control of current.

7.6 Test Stations

7.6.1 Test stations shall be provided along the pipeline ROU for monitoring the performance of the cathodic protection system at the following locations. Test stations shall be provided at additional locations, if required, so that distance between any two adjacent test stations does not exceed 1000 meters in inhabited areas and 2000 meters in uninhabited areas like forest/deserts:

- i) At all insulating joints
- ii) At both sides of metal road crossings
- iii) At vulnerable locations with drastic changes in soil resistivity
- iv) At locations of surge diverters, pipeline grounding through polarisation cells, Zinc and Magnesium anodes
- v) At EHV/HV AC/DC overhead line crossings and selected locations where EHV/HV overhead line is in the vicinity of the pipeline
- vi) At railway line crossings and at selected locations along lines running parallel to the pipeline
- vii) At both sides of major river crossings
- viii) At EHV/HV cable crossings or along routes where EHV/HV cables are running in parallel
- ix) In the vicinity of DC networks or grounding systems and HVDC grounding systems where interference problems are suspected

- x) At crossings of other pipelines/ structures
- xi) At the locations of reference cell and polarization coupon installation
- xii) At both sides of cased crossings
- xiii) Locations where interference is expected
- xiv) At locations of sectionalizing valve (SV) stations
- xv) At any other locations considered necessary by Owner/ Owner's representative

7.6.2 Test stations for bonding shall be provided with shunt and resistor as a means to monitor and control current flow between the pipeline and foreign pipelines or structures that may exist in common ROU.

7.6.3 Test stations with current measuring facility shall be provided at each CP station drainage point (to measure pipeline current on any one side of pipeline from drainage point at intermediate CP station and towards protected side of the pipeline at starting, end point CP stations), at interference prone areas, on both sides of major river crossings, near marshy areas and minimum one for every 10 km max. along the pipeline.

7.6.4 Test stations shall be installed with the face of the test station facing the pipeline. The nameplate of test stations shall carry the following minimum information:

- Chainage in km.
- Test station connection scheme
- Distance from pipeline in meter.
- Direction of product flow.

7.6.5 Number of terminals and different schemes of wiring shall be as per the test station connection scheme. Minimum twenty percent spare terminals shall be provided in each test station.

7.6.6 Minimum two cables from the pipeline shall be provided at any test station.

7.6.7 The location of all the test stations shall be marked with their connection schemes and other relevant information on alignment sheets. A detailed test-station schedule shall be prepared.

7.7 Permanent Reference Cells

7.7.1 High purity copper/copper sulphate reference cells with proven high reliability shall be provided for stable pipe to soil potential measurement at CP stations and polarization coupons along ROU.

7.7.2 Silver/Silver Chloride reference cells in place of copper/copper sulphate cells shall be provided at marshy area locations, where water table is high and chloride concentration is more than 300 ppm. For marshy area in saline soil, high purity Zinc may be considered as an alternative to silver/silver chloride. The test station connection scheme shall clearly indicate the type of the reference electrode (Cu CuSO₄/Ag AgCl) at these locations.

7.7.3 The life of the reference cells shall be minimum 8 years under the installed conditions.

- 7.7.4 The cable from reference cells shall be provided up to CP power source at CP stations and up to test stations at the locations of polarization coupons. The cable up to CP power source shall be routed through test stations near pipeline.

7.8 Polarisation Cell and Surge Diverter

7.8.1 Polarisation Cell

- i) Wherever the pipeline is either crossing or running in parallel with overhead EHV/HV transmission lines of voltage grade 66kV and above, it is mandatory that the pipeline shall be grounded to discharge any accumulated potential/ surge that may appear in case of transmission line faults, as per below:
- The pipeline shall be grounded through polarization cell with Zinc galvanic anodes of either block anode or ribbon type. Sizing and quantity of anode shall be decided so as to achieve maximum total earth resistance of 5 Ohm for each location where pipeline crosses EHV/HV transmission lines.
 - The pipeline shall be grounded at regular intervals of maximum 1km where EHV/HV transmission lines run parallel within 25m of the pipeline. Also, where EHV/HV transmission lines run parallel beyond 25 m of the pipeline and it is expected from calculations/ software simulations that surge would appear in case of transmission line faults or any abnormal operating conditions.
- ii) Locations along pipeline where continuous induced over-voltage due to other overhead transmission lines/ underground cables of voltage grade below 66kV is expected or observed during commissioning, the pipeline shall be grounded through polarisation cell to the earth system of the EHV/HV tower causing the voltage induction or to a separate earthing system of Zinc anodes through polarisation cell.
- iii) Polarisation cell shall be installed inside test station of suitable size.
- iv) Type of polarization cell shall be as specified in data sheet.

7.8.2 Surge Diverter

Explosion proof spark gap surge diverter shall be provided across each insulating joint to protect it from high voltage surges. Surge diverters shall be suitable for installation in classified areas.

- 7.8.2 The total system including cables, cable termination, anodes/ surge diverters, polarisation cell shall be suitable for the anticipated fault current at the location of installation.
- 7.8.3 The surge diverter and polarisation cell system shall be suitable for the design life of permanent CP system. The grounding system shall have minimum resistance to earth to restrict the pipeline voltage as per NACE/VDE criteria but shall not exceed 5 Ohms.
- 7.8.4 The anodes shall be pre packed with special backfill adequately so that the performance of the anode is not affected by the carbonates, bicarbonates, nitrates, etc, present in the soil. In any case, the thickness of back fill shall not be less than 50mm on all the sides of the anode.
- 7.9 Motor operated valves where located on the cathodically protected portion of the pipeline shall be grounded by a Zinc anode of 20 kg. net Magnesium anodes grounding, if any, provided during temporary CP system shall be disconnected. The MOV power supply cable armour shall

be insulated (by cutting and taping with insulation tape) at MOV end to avoid armour carrying CP current.

- 7.10** The above ground cathodically unprotected pipeline at terminals, intermediate SV stations, pigging stations etc. shall be earthed with GI earth electrodes. The resistance to earth of grounding shall be limited to 5 Ohms (Max.).

7.11 Polarisation Coupons

Where specified in the project specification/data sheet steel coupons of pipeline material shall be provided along the pipeline to monitor the adequacy of the CP system to polarize/ protect coating holidays. Coupon shall be installed at CP station drainage points, predicted cathodic protection mid points along the pipeline, at locations where the pipeline is bonded to foreign pipeline/ structures, interference prone areas, marshy areas and at other locations as specified in the project specification/ data sheet, along the pipe line.

Coupons shall be installed at bottom 1/3rd portion of the pipeline and 250 mm away from the pipe surface.

The coupons shall be constructed from the pipeline material and shall have one side uncoated surface of 100 mm x 100 mm exposed to soil. Two cables one for connection to pipeline for protection and other for potential measurement shall be provided for each coupon. The protection cable shall be connected through a magnetic reed switch inside the test station to enable measurement of coupon 'OFF' potential.

A permanent reference electrode shall be installed adjacent to the coupon in a manner so as to measure the representative potential of the coupon.

Magnets for operation of reed switch shall be provided as specified in the project specification/data sheet.

7.12 CP at Cased Crossing

- 7.12.1** At cased crossings where casing will have coating on its external surface, it shall be protected by sacrificial anode installations provided at both ends of casing. The anode installation shall be sized based on the permanent CP design parameters and design life of permanent CP system.

- 7.12.2** The carrier pipe inside the externally coated casing shall be protected by Zinc ribbon anodes piggy backed longitudinally on the carrier pipe between 4 and 8 O'clock position. Anode shall be tied with carrier pipe using Nylon rope at close intervals and weld connected at the ends. The quantity/ no. of ribbon anodes shall be based on the permanent CP design parameters for marshy area and design life of permanent CP system.

7.13 Reference Cell Access Points

Reference cell access points shall be provided near insulating joint locations and at SV stations, where the ground is paved, for measurement of pipe to soil potentials. A perforated PVC pipe filled with native soil and buried at the location shall be provided for the purpose. The length of the PVC pipe shall be adequate to reach the native soil below the paving.

7.14 Cables

- 7.14.1** Cables shall be with annealed high conductivity stranded copper conductor, PVC insulated, 650/1100 V grade, armoured, PVC sheathed conforming to IS 1554 part-I, except for the cables

for anode tail, reference cells and pipeline for potential measurements. The size of the copper conductor shall be minimum 35 sq. mm. for anode and cathode cables, 6 sq.mm. for current measurement, 10 sq.mm. for anode tail cables and polarization coupon protection cables. The size of cable for bonding, polarization cell, grounding anodes and surge diverter connections shall be suitable for the maximum fault current subject to minimum 25 sq mm.

- 7.14.2 The anode tail cables shall be PE insulated, 650V grade, unarmoured, PVC sheathed and length shall be sufficient for termination on anode lead junction box without any joint in between.
- 7.14.3 The cables for reference cells, coupon and pipeline potential measurements shall be of 4 sq.mm copper conductor, PVC insulated, Aluminium backed by mylar/ polyester tape shielded, PVC sheathed, armoured, PVC over all sheathed type.
- 7.14.4 The CPTR unit incomer cable shall be minimum 4 sq.mm. Copper conductor, 650/1100 V grade, PVC insulated, armoured, PVC sheathed. The cable shall be of 3 core type for single phase CPTR units and of 4 core type for 3 phase CPTR units.
- 7.14.5 The cables for connecting various transducers from CPTR unit/CPPSM to telemetry interface junction box shall be twisted pair with individual pair shielded and overall shielded with aluminium backed by mylar/ polyester tape, PVC sheathed, armoured, PVC over all sheathed type.

8.0 INSTALLATION

8.1 Cable Laying

- i) Cables shall be laid in accordance with layout drawings to be prepared by the contractor. No straight through joint shall be permitted. Cable route shall be carefully measured and cables cut to required length. Minimum half metre cable slack shall be provided near anodes, anode junction box, pipeline and test stations to account for any settling.
- ii) All cables inside station/plant area shall be laid at a depth of 0.75 metre. Cables outside station/ plant area shall be laid at a depth of minimum 1.5 metres. Cables shall be laid in sand under brick cover and back filled with normal soil. For cables laid outside the station/plant area, polyethylene warning mats shall be placed at a depth of 0.9 metre from the finished grade, to mark the route.
- iii) In case of above ground cables, all unarmoured CP cables shall be laid in GI conduits of sufficiently large size, up to accessible height for protecting against the mechanical damage.
- iv) All underground unarmoured cables including anode tail cables shall run through PE sleeves. Distant measurement cables and permanent reference cell cables routed along the pipeline shall be carried at the top of the carrier pipe by securely strapping it at intervals with adhesive tape or equivalent as required.
- v) PVC pipes of proper size shall be provided for all underground cables for road crossings.
- vi) Cables shall be neatly arranged in trenches in such a manner that crisscrossing is avoided and final take-off to equipment is facilitated.
- vii) The cables for reference cells and pipeline potential measurement shall be routed in a separate trench other than the trench provided for the rest of the CP system cables, AC cables for CPTR Units etc.

- viii) The armour of the cables from CP station to test station (potential measurement, reference cell & drainage cables etc.), CP station to ground bed (anode cable) and test station to pipeline shall be earthed only at CP station end and test station end respectively of the cables. The cable armour shall be insulated (by taping with insulation tape) to avoid armour carrying CP current.

8.2 Permanent Reference Cells

The permanent reference cells shall be installed in natural soil conditions as per the recommendations of the cell manufacturer. Installations in highly acidic/ alkaline soil and soil contaminated by hydrocarbons shall be avoided.

8.3 Cable to Pipe Connections

All cable connections of other than cathode drainage cables to the new pipeline shall be made by an approved exothermic process or by pin brazing. However, cable connection to charged pipelines shall be made by pin brazing. Exothermic welding shall be adopted for water pipelines. The resistance of the cable to pipe at the pin brazing connection point shall not exceed 0.1 Ohm.

The cathode drainage cable shall be connected to a bolt welded to a metal plate, which is weld connected to the pipeline. The material of the plate shall be same as that of the material of the pipeline.

Pipe coating shall be repaired after connection of cable to pipeline. At cathode drainage point the cable joint including the bolt, metal plate and the exposed portion of the pipeline shall be covered by the coating repair material against ingress of water/moisture. The coating repair material shall be compatible with the original coating and shall prevent ingress of water along the cable surface and at the interface of coating repair with the original pipe coating.

8.4 Ground Bed Fencing

Where specified in project specifications/data sheet chain link fencing shall be provided around the location of each ground bed/anode lead junction box.

9.0 FIELD TESTING AND COMMISSIONING

9.1 System Testing at Site

Field tests as per the reviewed field testing and commissioning procedures prepared by the Contractor shall be carried out on the equipment/ systems before these are put into service. Acceptance of the complete installation shall be contingent upon inspection and test results. Field testing shall include but not be limited to the following:

- i) Contractor shall carry out pre-commissioning operations after completion of installation of the system including all pre-commissioning checks, setting of all equipment, control and protective devices. All site tests, reliability and performance tests shall be carried out by Contractor.
- ii) Before the electrical facilities are put into operation, necessary tests shall be carried out to establish that all equipment and devices have been correctly installed, connected and are in good working condition as required for the intended operation. Owner/Owners representative may witness all tests. At least one week's intimation notice shall be given before commencing the tests.

- iii) All tools, equipment and instruments required for testing shall be provided by Contractor.
- iv) Generally, the following minimum tests must be carried out and results shall be recorded:
- Visual Inspection : Comparison with drawings, specifications, detailed physical inspection and, if necessary, by taking apart the component parts.
 - Testing : Simulation tests of equipment to determine its operational fitness.

a) Cables

- Cable No.
- Voltage grade.
- Conductor cross section
- Continuity check
- Voltage test.
- Insulation resistance values between each core & earth, between cores (between core and earth for single core cable). All cables shall be tested by 500 V megger.

b) Reference Cell

- Location
- Type of cell
- Potential reading
- Installed on top/ bottom level of pipeline

c) Insulating Joint

- Location
- Pipe to soil potential of both protected and non-protected sides of the insulating joint before and after energisation of CP system

d) Surge Diverter

- Location/ Identification Number
- Rating
- Type
- Check for healthiness.

e) Polarisation Cell

- Location/ Identification Number
- Rating
- Check for wiring
- Check standby current drain after CP system energisation (Current drain with respect to voltage across the cell shall be recorded)

- Details of grounding provided for the polarisation cell.

f) Anode Ground Bed

- Location/ Station
- Check for actual layout and compliance with drawings
- Resistance of each individual anode
- Current dissipation by each individual anode
- Total resistance of complete anode bed
- Mutual interference

g) Polarisation Coupons

- Location
- Exposed area/ size of coupon
- Coupon to soil 'ON' and 'OFF' potentials
- Type of reference cell
- Magnetic reed switch rating
- Operation of magnetic reed switch with magnet

9.2 CP Commissioning Procedure

A model commissioning procedure for a three stations CP system of a pipeline is given below for general guidance. Contractor shall develop detailed commissioning procedure as per this guideline.

- On completion of installation of anode beds and other systems as envisaged in this specification, they shall be individually checked, tested and compared against the agreed specifications and procedure.
- Electrical continuity of the entire pipeline shall be verified in conformity with design.
- Input resistance of the pipeline at all the drainage points shall be checked and recorded.
- All current measuring test stations shall be calibrated and recorded using portable battery, variable resistances, voltmeters, ammeters, etc. as required.
- Temporary protection facilities provided (if any) which do not form part of permanent CP shall be disconnected from the system & removed unless agreed otherwise.
- Anodes provided for grounding at the MOVs on cathodically protected portion of the pipeline shall be disconnected. Sacrificial anode where provided for the protection of the casing pipe at cased crossings shall be disconnected.
- The pipeline shall be allowed to depolarize for at least 72 hours after switching 'OFF' the protection (if any) of all other pipelines in the common ROU.
- Before the pipelines are put on charge by switching 'ON' any of the CP stations, natural pipeline to soil, casing pipe to soil and coupon to soil potential values at all the test stations of

the system (coupon to soil potential at the locations of the coupon installations) shall be measured with respect to Copper/Copper Sulphate half cell.

- ix) CP station no.1 shall be energised with out put potential adjusted to achieve a maximum pipe to soil potential (PSP) as specified, at the test station nearest to the drainage point. Observations on either spread of protected portion of pipeline and coupons under this CP station shall be taken for PSP 'ON' and PSP 'OFF' values at each of the installed test stations (coupon to soil potential at the locations of the coupon installations). The typical switching cycle of current interrupter shall be 12 seconds 'ON' and 3 seconds 'OFF'. The pipeline current values across the cross section of the pipeline shall also be determined at all the intended test stations influenced by this station.
- x) CP station no.1 shall now be switched 'OFF', CP station no. 3 shall be switched 'ON' and measurement procedure as detailed in clause ix) above shall be repeated.
- xi) Similarly CP station no. 1 and 3 shall now be switched 'OFF', CP station no.2 shall be switched 'ON' and measurement procedure as detailed in clause ix) above shall be repeated.
- xii) All the CP stations of the system shall be switched 'OFF' and the pipelines shall be allowed to depolarize. All the three CP stations in the system shall then be simultaneously switched 'ON' and PSP values at the drainage points of pipeline shall be brought to a value of maximum PSP as specified and a complete set of observations shall be taken.

Another complete set of pipe to soil and coupon to soil observations shall be taken after lines have stayed on charge for 48 hours. If there are appreciable differences in these observations as compared to those of earlier set, a third set of observations shall be taken after 72 hours. Maximum drainage point protective potentials shall not be allowed to go beyond the maximum PSP values as specified, in any case.

Coupon to soil 'OFF' potential shall be measured at all locations of coupon installations by operation of magnetic reed switch in the test station. The PSP of the coupons shall be within the PSP range specified in clause 6 of this document.

The output of all CP stations shall then be so adjusted that the sites of occurrence of least negative protective potentials are not less negative than (-) 0.95V (OFF) and sites of occurrence of the most negative protective potential are not more negative than (-) 1.18V (OFF). A full set of pipe to soil, coupon to soil observations shall again be taken 72 hours after the adjustment of potentials and the protection system shall be left in this state of operation.

- xiii) Care shall be exercised to ensure that power supply remains uninterrupted during the period of commissioning. In case of an interruption, the test in progress shall be repeated after allowing time for polarisation. More sets of observations shall be taken in any of the steps specified above, if advised by the Owner/Owner's representative.
- xiv) The Zinc anodes for grounding of MOVs at the locations of MOVs on cathodically protected portion of the pipeline shall be reconnected to the MOVs.
- xv) At cased crossings where casing is protected, sacrificial anodes provided for the casing shall be connected to the casing pipe. The casing to soil potential and anode out put current shall be measured and recorded. Where casing pipe protection is inadequate or the out put current of the anode is more than the designed current, then additional anodes shall be provided as required.

- xvi) PSP values at each of the test stations of the existing pipelines shall be measured, plotted, where existing pipelines run in parallel to the new pipeline, mutual interference situations between the pipelines shall be identified and necessary mitigation measures shall be provided. Interference situations shall also be identified and mitigated by comparing different sets of readings taken at same test stations at different intervals of time under identical conditions where positive potential swing is 100 mV or more.
- xvii) Current readings at all the current measuring test stations shall be measured and recorded.
- xviii) Final records of testing and commissioning including graphical representation of final pipe to soil potential readings shall be compiled with interpretation in consultation with Owner/Owner's representative and submitted.
- xix) If any deficiencies are found in the system, the same shall be rectified by the contractor, at no extra cost or time schedule impact, to the complete satisfaction of Owner/ Owner's representative. Such deficiencies shall include mitigation of stray current electrolysis and interference problems that may be found existing in the course of testing and commissioning. A set of PSP observations shall also be taken during the peak of the first dry season after commissioning the system into regular operation. Any deficiency found in the protection of the pipeline shall be rectified by the contractor at his own cost.
- xx) If it is found during commissioning that the sites of occurrence of least negative or most negative protective potentials are less negative than (-) 0.95V (OFF) or more negative than (-) 1.18V (OFF) respectively even after 72 hours of operation, then the drainage point potentials shall be adjusted depending upon anode ground bed currents in consultation with Owner/Owner's representative. In any case, the protective 'OFF' potential values of pipeline and polarization coupons shall not exceed the PSP value range specified in clause 6 of this document, at any location on the pipeline.
- xxi) The reference cell shall be calibrated minimum once in 24 hours during the commissioning.
- xxii) The current dissipated by individual anodes shall be measured from the anode lead junction box and corrected for equal dissipation to the extent possible keeping the total ground bed current same.

10.0 INTERFERENCE MITIGATION

- 10.1** Investigations shall be made for stray current electrolysis of the pipeline, mutual interference between the pipeline and foreign pipelines/ structures, interference on foreign pipelines/structures due to the CP of the pipeline and ground bed, interference on metallic structures which lie in between pipeline and ground bed or near to ground bed, AC induction on pipeline due to overhead EHV/HV lines, interference due to high voltage DC lines, HVDC earthing system, electric traction etc.
- 10.2** Measurements including pipe/ structure to soil potentials and pipe/ structure currents etc. on the pipeline/ structure being CP protected and on foreign pipelines/ structures, and ground potential gradient etc. shall be made to investigate the current discharge and pickup locations. In case of fluctuating stray currents, investigations shall be made continuously over a period of time and if required simultaneously at different locations to find out the stray current source(s). Recorders shall preferably be used for long time measurements.
- 10.3** Wherever foreign pipelines which may or may not be protected by an independent CP system run in parallel to the protected pipeline, either in the same trench or very near to the protected pipeline and are not bonded to it, investigations shall be performed for current discharge points on both the pipelines.

- 10.4** Mitigative measures shall be provided depending upon the type of stray current electrolysis/interference. These shall include installation of bond with variable resistor, diodes, installation of galvanic anodes for auxiliary drainage of current, adjustment/relocation (if possible) of offending interference source, provision of electrical shield etc. depending on the type of interference.
- 10.5** Bonding with foreign pipelines/ structures as a mitigation measure shall be provided where the owners of the foreign pipelines/ structures have no objection. Otherwise alternative mitigation measures shall be provided. Wherever bonding is provided for mitigation, the bonding resistor shall be adjusted for optimum value for minimum/ no interference. Galvanic anodes installed as a mitigation measure shall be adequately sized for the life specified for permanent CP system.
- 10.6** Where overhead EHV/HV transmission lines/underground electric cables cross the pipeline or run in parallel with in or more than 25m from the pipeline, A.C. Voltage measurements shall also be made on the pipeline to find out continuous induction of voltage. In case of the induced voltage being beyond the safe limits, the pipeline shall be grounded in line with clause no.7.8 above.

11.0 CLOSE INTERVAL POTENTIAL SURVEY

Where specified, contractor shall carry out a close interval 'ON'/'OFF' potential survey over the entire length of pipeline by computerised potential logging method and identify the under protected/ over protected area, any major coating damage on the pipeline, after the backfilling has been consolidated sufficiently and CP system has stabilized. Contractor shall provide required mitigation measures and rectify the under/ over protected zones, identify if any, the major pipeline coating defects, required to be repaired. During the survey the reference cell shall be calibrated minimum once in 24 hours. Detailed procedures for running this survey shall be submitted for review.

Additional tests for detailed identification of coating defects shall be conducted by the contractor, if specified in the project specification/ data sheets.