

DEP SPECIFICATION

**CATHODIC PROTECTION DESIGN, INSTALLATION, AND
COMMISSIONING (AMENDMENTS AND SUPPLEMENTS
TO ISO 15589 1:2003)**

DEP 30.10.73.10-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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PART I INTRODUCTION

1 INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the control of corrosion of immersed, submerged or buried metal structures by cathodic protection (CP). This DEP is applied when selecting, designing, installing, and commissioning CP installations. This DEP applies to both new CP systems and to the upgrade or rehabilitation of existing systems.

This DEP has been combined with DEP 33.10.73.31-Gen. and DEP 33.10.73.33-Gen., and is comprised of the following Parts:

Part I Introduction

Part II General Requirements - The majority of the content in this part comes from previous versions of DEP 30.10.73.10-Gen., though some content previously was present in DEP 33.10.73.31-Gen. and DEP 33.10.73.33-Gen.

Part III Design of onshore CP systems - The majority of the content in this part comes from DEP 30.10.73.31-Gen., though some content previously was present in DEP 33.10.73.10-Gen. and DEP 33.10.73.33-Gen. Part III amends and supplements ISO 15589-1:2003.

Part IV Installation and commissioning of onshore CP systems - The content in this DEP previously was present in DEP 30.10.73.33-Gen.

Part V References

This DEP does not apply to offshore pipelines and platforms.

This is a revision of the DEP of the same number dated February 2013; see (Part I, 1.5) regarding the changes.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in oil and gas production facilities, oil refineries, chemical plants, gas plants and supply/marketing installations. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Cathodic Protection	Process of reducing or preventing corrosion of metal structures in contact with an electrolyte by the flow of direct current from the electrolyte into the structure surface.
Coke Breeze	Calcined petroleum coke with the properties defined in Table 1 of Part IV of this DEP.
Complex System	Structures which are to be cathodically protected, but cannot be electrically isolated, whether for technical or safety reasons, from foreign metallic structures situated in the same electrolyte as the structure to be protected.
Corrosion Potential	Theoretical potential of the surface, in absence of net (external) electric current flowing to or from the steel surface (see also "natural potential").
Current Density	Amount of current per unit area of the steel surface, coated or uncoated, in contact with the electrolyte.
Drain Point	Point on the pipeline or structure where the connection of the negative terminal of the cathodic protection voltage source is made to conduct [drain] the returning current from the pipeline to the voltage source.
Electrolyte	Conductive liquid or material such as soil or water in which an electric current can flow.
Foreign Structures/Pipelines	Metal structures or pipelines other than the structure or pipeline under consideration, in contact with the same electrolyte, and which are or may fall under the influence of the cathodic protection system; they may be owned by the Principal or other companies and may or may not be equipped with cathodic protection.
Groundbed	System of buried or submerged electrodes, to conduct the protecting current through the electrolyte to the steel surface to be protected.

Term	Definition
IR Drop	The voltage across a resistance when the current is applied in accordance with Ohm's Law.
Isolating Flange	Set of two flanges assembled with an insulating gasket and insulating sleeves and washers, for the purpose of electrically isolating two metallic pipe sections.
Isolating Joint	Factory assembled pipe fitting provided with insulating gaskets and resins, to be welded into a pipeline or piping for the purpose of electrically isolating two metallic pipe sections.
Natural Potential	Pipe-to-soil potential measured when no cathodic protection is applied and polarisation caused by cathodic protection is absent.
"OFF" Potential	Pipe-to-soil potential measured immediately after the cathodic protection system is switched off and the applied electrical current stops flowing to the pipeline surface, but before polarisation of the pipeline has decreased.
"ON" Potential	Pipe-to-soil potential measured while the cathodic protection system is continuously operating.
Pipe-To-Soil Potential	Difference in electrochemical potential between a pipeline or foreign structure/pipeline and a specified reference electrode in contact with the electrolyte. Similar terms such as structure-to-soil potential, pipe-to-electrolyte potential and pipe-to-[sea]water potential are sometimes used as applicable in the given context.
Pipeline	Pipeline and associated equipment as defined in the scope of the cathodic protection design contract.
Piping Section	Any part of the piping system, which is judged to constitute an electrically isolated entity. This may require the section to be electrically isolated at all of its extremities. A piping section may include any number of branches.
Piping System	The totality of the buried on-plot piping for which CP is to be provided.
Polarisation Cell	Device inserted in the earth connection of a structure that isolates for DC in the cathodic protection range.
Polarisation	Change of the pipe-to-soil potential caused by the flow of DC current between an electrolyte and a steel surface.
Reference Electrode	Non-polarising electrode of which the electrochemical potential is accurately reproducible and which serves as a reference for pipe-to-soil potential measurements.
Stray Currents	Electrical currents running through the electrolyte, originating from a foreign DC source and causing interaction with the corrosion and cathodic protection processes of the structure or pipeline. Stray currents may also originate from the pipeline's cathodic protection system and act upon foreign structures/pipelines.

Term	Definition
Structure	Structure and associated equipment as defined in the scope of the cathodic protection design contract.

1.3.3 Abbreviations

Term	Definition
AC	Alternating Current
AWG	American Wire Gauge
CIS	Close Interval Survey
CP	Cathodic Protection
Cu/CuSO₄	Copper/Copper Sulphate type of reference electrode.
DC	Direct Current
ECTFE	Ethylenechlorotrifluoroethylene
GPS	Global Positioning System
HDPE	High Density Polyethylene
HMWPE	High Molecular Weight Polyethylene
HVAC / HVDC	High Voltage Alternating Current / High Voltage Direct Current
IEC	International Electric Code
IR	'I' represents current (amps) and 'R' stands for the amount of resistance (Ohms), IR stands for Current (I) x Resistance (R)
MMO	Mixed Metal Oxide
NACE	National Association of Corrosion Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
PCR	Polarization Cell Replacement
PVC	Polyvinyl Chloride
SSD	Solid State Decoupler
THHN	Thermoplastic High Heat Nylon insulated wire
TW/THW/THWN	Thermoplastic Heat and Water Resistant insulated Wire

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (Part V).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
overall	This DEP combines DEP 30.10.73.10-Gen., DEP 30.10.73.31-Gen., and DEP 30.10.73.33-Gen., eliminating redundant statements and removing informative content.
overall	Integrated content specific to on-plot complex systems
(Part II, 2, Item 1)	Statement upgraded to DEM1
(Part IV, 2.1, Item 1)	Statement upgraded to DEM1
Datasheets	The previous appendices from DEP 33.10.73.33-Gen. have been converted into datasheets that are referenced in (Part V)

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://www.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

PART II GENERAL REQUIREMENTS

1 GENERAL

Part II gives general information for those responsible for CP systems to deal effectively with specialist consultants and Contractors normally used for CP work.

2 CATHODIC PROTECTION DESIGN

1. All tank configurations, all buried or submerged metallic piping, pipelines, vessels, and tanks SHALL [PS] be protected from corrosion using a cathodic protection system with the following exception:
 - a. Tank configurations where the tank foundation consists of at least 50 mm (2 in) of asphalt over an engineered foundation or at least 100 mm (4 in) concrete underlain by an engineered pier or pilings foundation.

Shell Group practice is to apply cathodic protection to all metallic buried onshore pipelines, buried plant piping, buried vessels and slugcatchers, subsea pipelines, offshore structures and jetties, seagoing vessels, mounded LPG storage vessels, and the soil side of above ground storage tank bottoms not resting on asphalt or concrete foundations.

2. Selection of foundations for ASTs shall be made with reference to DEP 34.11.00.11-Gen., and considering the site-specific geotechnical conditions at the location of the tank.
3. In addition to cathodic protection (Part II, 2, Item 1), coatings shall be used to protect buried or submerged metallic piping, pipelines, and tanks from corrosion.
4. Refer to Section 5.1 of ISO 15589-1 for general CP design requirements.
5. Refer to (Part III, 5.2) for the design information requirements for the CP system.
6. The basic CP design shall include the following as a minimum, as applicable:
 - a. the first seven bullet items in clause 13.1.1 of ISO 15589-1,
 - b. justification of the selected CP system and anode materials,
 - c. a summary of the used equations and standards,
 - d. historical performance of any existing CP systems or any other nearby CP systems in similar service that were used as the basis of the design.
 - e. evaluation of the following:
 - i. the overall cathodic current demand,
 - ii. whether or not any piping is part of a complex system (Part II, 8),
 - iii. the electrical isolation philosophy for the project, which leads to the designation of the piping sections,
 - iv. whether an integrated or discrete CP approach is to be adopted for the project,
 - v. the adoption of an impressed current or sacrificial anode CP system,
 - vi. the preferred generic anode groundbed configuration.
 - f. all significant factors that will impact on the detailed design; including the proximity of other electrical power sources and other ground-contacting metalwork.
7. The detailed design report shall include the following:
 - a. the last three bullet items in clause 13.1.1 of ISO 15589-1,

- b. commissioning procedures per (Part IV),
 - c. operation and maintenance instructions per clause 13.4 of ISO 15589-1,
 - d. calculation of all relevant groundbed dimensions, cable sizes, and power supply requirements.
 - e. any threats to the CP effectiveness identified in the basic design, e.g., the mitigation of stray current interference effects and safety issues,
 - f. details about the monitoring facilities required for the safe and effective operation of the CP system.
8. For the applicable data/requisition sheets, refer to Requisition DEP 30.10.73.93-Gen.

3 SURVEYS AND PRELIMINARY INVESTIGATIONS

3.1 GENERAL

3.1.1 General

The scope of pre-design surveys can include reviewing designs and monitoring data for any existing local CP systems, and carrying out site visits (if appropriate).

Pre-design surveys aimed at assessing the corrosivity of the terrain by means of resistivity measurements, redox potential measurements, microbiological sampling, and chemical analysis might not be required for Upstream onshore facilities.

1. The pre-design surveys shall identify any CP issues that will have to be addressed during the design.

Examples include, thermally insulated piping, hazardous areas, and piping that penetrates reinforced concrete.

3.1.2 Soil / water resistivity

1. Soil resistivity shall be classified as Table II-1 for all soil areas in contact with structures.

Table II-1 Relationship between soil resistivity and soil corrosivity

Soil resistivity, $\Omega \cdot \text{cm}$	Soil Corrosivity
Under 1500	Very corrosive
1500 to 5000	Moderately corrosive
Above 5000	Slightly corrosive

3.1.3 Soil composition and variations

1. The soil investigation should include analyses to determine levels of various salts and the pH values of samples taken at various points at the site or along the pipeline route.
2. Refer to (Part III, 5.4) for the requirements regarding soil variations.

3.1.4 Interference and stray currents

1. Refer to (Part III, 5.4) for the requirements regarding interference and stray currents.

3.2 EXISTING INSTALLATIONS

1. A current drainage test shall be performed to check the coating quality, the interference from foreign systems, and the influence of existing CP systems.
2. If repairs to existing systems are not possible, the CP system should be designed to minimise current loss to foreign structures (hot-spot systems or localised systems).

4 DESIGN OF CATHODIC PROTECTION SYSTEMS

4.1 GENERAL REQUIREMENTS

1. The CP system shall be capable of controlling corrosion on the structures while preventing adverse effects on the structure itself and on foreign structures/pipelines.
 - a. For modifications of, or extensions to, existing CP systems, the coding and identification of cables, piping sections and zones should be consistent with the coding system already in use.

4.2 DETERMINING THE SCOPE OF CATHODIC PROTECTION SYSTEMS

1. Prior to detailed design, all components (pipeline, vessels or structures) to be protected shall be identified, including the following:
 - a. materials of construction;
 - b. coating systems;
 - c. size and location of each component;
 - d. operating conditions;
 - e. insulation requirements;
 - f. operating environment.
2. For pipelines and piping that are to be cathodically protected, the protective current should not leak away to the adjacent installations connected by the pipeline or piping.
 - a. For piping systems, the Contractor shall review locations where the piping will contact concrete objects.
 - b. For piping systems, unless it can be guaranteed that the piping will not make contact with any reinforcing steel, the concrete object system shall be regarded as being part of a complex structure (Part II, 8).
3. If a buried vessel is to be cathodically protected inside a depot or complex, then the protective current should flow mainly to that vessel.
4. The scope of CP systems may be determined by one of the following:
 - a. the physical boundaries of installations;
 - b. the function;
 - c. type of construction;
 - d. owner/custodianship.
5. The installation may be divided into smaller units, for instance, if different coatings are used or if protection criteria are different (e.g., different construction materials).
 - a. Complex CP systems for on plot piping may be divided into piping sections which can be protected and monitored independently.
6. Scope boundaries should be electrically isolated to prevent interaction between systems.
 - a. If electrical isolation is not practicable, a localised CP system may be used; refer to (Part II, 8).

The scope boundaries include:

- *the installation of isolating joints or flanges in pipelines and piping (Part II, 7),*
- *electrical separation of earthing systems (Part II, 7.6)*
- *installation of separate CP current control if a combined current source is used*

4.3 CATHODIC PROTECTION CRITERIA

1. Polarisation limits shall be determined for each structure under cathodic protection.

Some alloys, notably high strength carbon steels, as well as duplex and martensitic stainless steels, have suffered hydrogen induced stress cracking (HISC) failures in conjunction with high levels of CP.

4.4 CATHODIC PROTECTION CURRENT REQUIREMENTS

1. Final current density shall be subject to approval of the Principal.
2. Refer to the following for specific current density for each application:
 - a. (Part III, 5.8) for onshore and in ground pipeline applications.
 - b. DEP 30.10.73.32-Gen. for offshore applications.

4.5 MONITORING FACILITIES

1. Monitoring facilities shall be installed to allow electrical contact with the pipeline or structure and to measure other parameters that could be useful to monitor performance.

5 PROTECTION BY GALVANIC SACRIFICIAL ANODES

5.1 GENERAL

1. Refer to (Part III, 7) for design requirements and (Part IV, 8) for installation and commissioning requirements.

5.2 ANODES

2.5.2.1 General

Anode leads shall be as follows:

- a. for installations with one or two anodes: minimum 4 mm² (12 AWG), single conductor, stranded copper wire with TW, THW, or HMWPE insulation.
- b. for installations with three or more anodes: minimum 10 mm² (8 AWG), single conductor, stranded copper cable with HMWPE insulation.

5.2.2 Magnesium alloy

1. Refer to (Part III, 7.3, Item 1) for compositional requirements for magnesium alloys.

5.2.3 Zinc alloy

1. Refer to (Part III, 7.2) for the compositional requirements for the zinc alloy.

5.2.4 Aluminium-Zinc-Indium alloy (Al-Zn-In alloy)

1. Al-Zn-In alloy, per Table II-2, should be used for pipeline/piping applications.
2. Al-Zn-In alloy, per Table II-2, shall be used for sea water applications.

Table II-2 Composition of Al-Zn-In anode alloys

Element	Indium Activated Alloy	High Performance Indium Activated Alloy
Cu	0.01 wt% max	0.003 wt% max
Si	0.10 wt% max	0.12 wt% max
Fe	0.13 wt% max	0.09 wt% max
Zn	0.5 to 5.0 wt%	2.5 to 5.75 wt%
In	0.005 to 0.05 wt%	0.016 to 0.040 wt%
Cd		0.002 wt% max
Others		0.02 wt% max
Al	Remainder	Remainder

3. For alloys in mud and temperatures over 30 °C (86 °F) refer to DEP 30.10.73.32-Gen.
4. Refer to the following for requirements for metallurgical testing and physical inspection:
 - a. NACE SP0492 for bracelet anodes.
 - b. NACE SP0387 for anodes other than bracelet anodes.
5. Refer to Part III, section 10.4 of DEP 30.10.73.32-Gen. for the requirements for prequalification of sacrificial anodes for application in seawater.

6 PROTECTION BY IMPRESSED CURRENT**6.1 GENERAL**

1. Refer to (Part III, 6) for design requirements and (Part IV, 2.3) for installation and commissioning requirements.
2. Refer to NEMA TC2 for the requirements for polyvinyl chloride (PVC) pipe and fittings.
3. Pipe joints shall have one end with male threads and one end with female threads with each threaded end manufactured so that made-up joints have a flush outside surface.

6.2 POWER SOURCES

1. Refer to (Part III, Annex E) for power source requirements.

6.3 GROUNDBEDS

1. Refer to (Part III, 6.2) for design requirements and (Part IV, 2.3) for installation and commissioning requirements.

6.4 ANODE AND PIPE MATERIALS

1. Anodes shall be as follows:
 - a. ASTM B 265, Grade I titanium wire that is 1.6 mm (0.062 in) diameter,
 - b. coated with iridium based TIR 2000 mixed metal oxide (MMO).

2. Refer to (Part IV, 2.3.5, item 3) for the coke breeze requirements.
3. The anode pipe shall be minimum Schedule 40 DN 100 (NPS 4) belled-end PVC pipe.
4. Slots on the pipe should conform to Standard Drawing S 41.032 for the anode pipe and S 41.067 for the monitoring tube.
5. The anode vent pipe shall be slotted PVC, Schedule 40, DN 20 (NPS ¾).
6. The monitoring tube from the anode to the test station shall be slotted PVC, Schedule 80, DN 65 (NPS 2½), with modified acme threaded joints.
7. Ends of anodes and monitoring tubes shall have PVC caps.
 - a. If specified for visual leak detection, the PVC caps on the monitoring tube shall have 6 mm (¼ in) diameter holes drilled at the 12 and 6 o'clock positions.

6.5 CABLES

1. The anode header cable (positive) shall be 10 mm² (8 AWG) stranded copper conductor with insulation or Principal-approved equivalent.

6.6 JUNCTION BOXES

1. Junction boxes shall comply with all of the following:
 - a. be made of aluminium, galvanised steel, or reinforced plastic;
 - b. IP 56 (NEMA 3) requirements;
 - c. have wire terminals to accommodate the following:
 - i. Lead wire for corrosion coupon or probe with CP.
 - ii. Lead wire for corrosion coupon or probe without CP.
 - iii. Reference electrodes lead wires and tank lead wire.
 - iv. Tank lead wire.
2. Lead cables shall be terminated on the numbered, insulated terminal block.
3. If a metallic junction box is used, a ground conductor shall be connected between a tank ground connection and the ground lug in the junction box.

6.7 STATIONARY REFERENCE ELECTRODES

1. Stationary reference electrodes shall be either zinc or copper/copper sulphate.
2. Zinc stationary reference electrodes shall be as follows:
 - a. 35 mm x 35 mm x 230 mm (1.4 in x 1.4 in x 9 in), pre-packaged in quick wetting backfill.
 - b. ASTM B418-80, Type II that is equipped with 2.5 mm² (14 AWG), standard copper lead wire with HMWPE insulation.
3. Copper/copper sulphate stationary reference electrodes shall be as follows:
 - a. Design life of 30 years and stability of ±5 millivolts under a 3.0 microamp load.
 - b. Equipped with an ion trap to prevent contamination.
 - c. 2.5 mm² (14 AWG) standard copper lead wire with HMWPE insulation.
 - d. Shipped in a cloth sack with moisture-retaining backfill.
4. Lead wires shall be of sufficient length to connect to the junction box without splicing.

6.8 IMPRESSED CURRENT GRID SYSTEMS FOR ON GRADE STORAGE TANK BOTTOMS

1. Refer to (Part IV, 7) for installation and commissioning requirements.
2. In addition to (Part II, 4), the CP system should be designed based on the following:
 - a. Current density of 21.52 mA/m^2 (2 mA/ft^2) for tanks at ambient temperature and at least 43.04 mA/m^2 (4 mA/ft^2) for tanks operated above 60°C (140°F).
 - b. Ribbon anode spacing for tanks, with or without secondary containment liner, of 1 m (3 ft) separation between adjacent anodes and 450 mm (1.5 ft) from the tank ringwall for anode-to-tank bottom distances of at least 230 mm (9 in).
 - c. Conductor bar spacing of no more than 4.6 m (15 ft) separation between adjacent conductor bars and a maximum of 2.3 m (7.5 ft) from the ringwall.
3. One of the following shall be selected for protection criteria instead of -0.85 volts DC applied "ON" potential (NACE RP0193):
 - a. -100 millivolts of polarisation;
 - b. IR free voltage of -0.85 volts DC versus a Cu/CuSO₄ reference electrode.
4. The anode ribbon shall be as follows:
 - a. titanium per ASTM B265, grade 1, coated with indium based TIR MMO;
 - b. at least 6 mm (0.25 in) in width by 0.6 m (0.025 in) thick.
5. The conductor bar shall be as follows:
 - a. titanium per ASTM B265, grade 1;
 - b. at least 12.7 mm (0.5 in) in width by 1 mm (0.04 in) thick.
6. The power feed cable shall be as follows:
 - a. Minimum 10 mm^2 (8 AWG) stranded copper with HMWPE insulation, or a Principal-approved equivalent if chlorides are present in the soil.
 - b. The copper cable conductor connected to a titanium rod which then is connected to a strip of 12.7 mm (0.5 in) wide by 1 mm (0.04 in) thick titanium conductor bar with a minimum length of 250 mm (10 in).
7. Junctions boxes shall meet the following:
 - a. All wiring from under the tank terminated in a junction box.
 - b. A non-explosion proof junction box, if used, located in non-hazardous area.
 - c. Non-explosion proof junction box enclosures, if used, to be IP 56 (NEMA 4X) stainless steel, galvanised steel, or fibreglass.
 - d. Equipped with an insulated (phenolic) terminal panel with the following:
 - i. A copper bus bar installed with properly sized shunts between the copper bus bar and each anode power feed cable.
 - ii. A shunt between the copper bus bar and common terminal provided for connection to the rectifier's positive terminal.
 - e. Separate individual brass bolts provided for terminating each reference electrode lead wire.
 - f. Terminations for the negative connection and rectifier negative terminal cable mounted on a common copper bus bar that is mounted on the terminal board.
 - g. All wiring connections clearly identified on the terminal board.
8. Ringwall penetrations for powerfeed cables and reference electrode lead wires should be located as near as possible to where the junction box is installed.

9. For junction boxes not installed at the tank ringwall, four 75 mm (3 in) diameter steel bollards shall be installed to protect the junction box.
10. Minimum 25 mm² (4 AWG) stranded insulated single conductor copper cable capable of carrying 125 % of rated current shall be used as DC power leads from the rectifier.
 - a. For direct burial service, the cable shall be HMWPE CP cable or, where chlorides are present in the soil, a Principal-approved equivalent.

7 ELECTRICAL SEPARATION

7.1 GENERAL

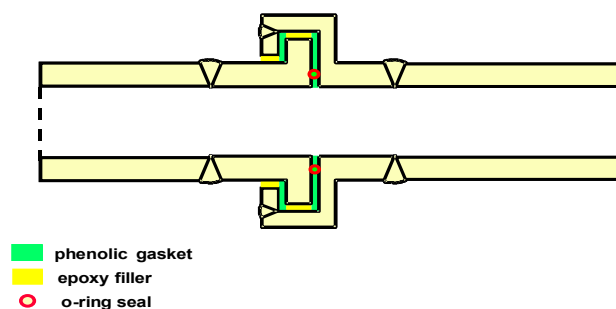
1. Refer to (Part III) for the design requirements and (Part IV) for installation and commissioning requirements for electrical separation.

7.2 ISOLATING JOINTS

Electrical isolation is achieved by installing monolithic isolating joints that are specially designed fittings including electrically isolating layers. An example is shown in Figure 1.

1. Refer to DEP 31.40.21.31-Gen. for the requirements for the construction of isolating joints and their mechanical and electrical properties.

Figure 1 Schematic diagram of a monolithic isolating joint

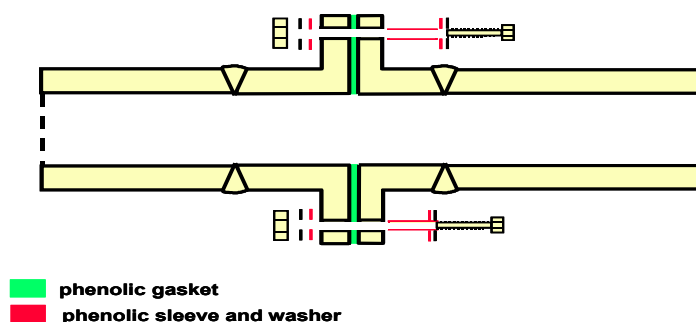


7.3 ISOLATED FLANGES

1. Where isolating joints are not feasible, isolated flanges may be used.

A schematic is shown in Figure 2. Refer to (Part IV, 13) for designation of gasket types.

Figure 2 Schematic diagram of an isolated flange



2. To test the isolating flange, a voltage of 1500 VDC shall be applied across the flange assembly for one minute without causing breakdown of the insulation or flash over.

7.4 ISOLATING SPOOLS

1. Refer to Section 3.2 of DEP 31.40.21.31-Gen. for design requirements.

7.5 ELECTRICAL EARTHING

1. Structures under cathodic protection should be electrically isolated from common or plant earthing systems to prevent a loss of current.
2. If electrical isolation cannot be achieved, earthing should be installed with decouplers.
3. If electrical safety earthing is required then refer to DEP 33.64.10.33-Gen. for requirements related to electromagnetic compatibility
4. For impressed current CP systems, each separate piping section shall have separate CP current return cables connected in a termination box to allow measurement of the CP return current.

7.6 SAFETY PRECAUTIONS

1. Refer to DEP 80.00.10.10-Gen. or DEP 80.00.10.13-Gen., whichever is applicable, for determination of area classification and associated requirements.
2. Refer to DEP 33.64.10.10-Gen. or DEP 33.64.20.10-Gen., whichever is applicable, for specific electrical requirements for CP equipment.
3. Transformer/rectifiers should be installed outside hazardous areas.
4. Current-carrying cables in hazardous areas shall be terminated so that they can only be dismantled with the use of special precautions.
5. Cable connections to equipment should be made by welding or direct brazing.
6. Before separating two parts of a CP system (e.g., at a flange) the system should have solid parallel current paths to conduct the CP current.
7. If a solid parallel current path cannot be verified, the breakpoint shall be bridged by a cable that is maintained until the parts are rejoined.
8. If work is carried out on impressed current CP installations, gas tests shall be conducted to ensure the absence of flammable mixtures.

7.7 ELECTRICAL STRIKE SYSTEMS FOR HORIZONTALLY BORED IMPRESSED CURRENT ANODE SYSTEMS UNDER EXISTING TANKS

1. The boring equipment frame shall be equipped with an electrical strike system capable of indicating an electrical strike through both current and voltage sensing devices.
 - a. The electrical strike system shall include warning strobes on the drill frame and power unit.
2. Grounding mats shall be supplied for both the operator and for the helper.
 - a. The grounding mat for the helper should be positioned so that stepping off the mat is not required while performing their duties.
3. The electrical strike system shall be connected to the trailer so that the trailer is at the same potential as the system.

8 DESIGN OF NON-DISCRETE CP SYSTEMS FOR ON-PLOT COMPLEX SYSTEMS

This section is applicable to structures which are to be cathodically protected, but cannot be electrically isolated, whether for technical or safety reasons, from foreign metallic structures situated in the same electrolyte as the structure to be protected. Such a structure is referred to as a "complex structure".

8.1 COMPLEX SYSTEMS

8.1.1 General

1. CP for complex systems, as defined in EN 14505, shall be designed in accordance to EN 14505, except as approved by the Principal.

EN 14505 also makes reference to EN 12954.

Pipeline network distribution systems are not considered to be complex structures.

8.1.2 Piping sections

8.1.2.1 Zones

1. Zones may be assigned on the basis of location or function, (e.g., product piping, service water, fire main, drains) or other factors (e.g., piping carrying hot fluid).

This sub-division into zones is simply for the convenience of the design. It is not implied that the zones are electrically separated from one another, or that different zones will necessarily require separate drain cables. A complex structure (according to EN 14505) is likely to involve more zones, because it might include earthing, piling, or reinforced concrete. However the zones are assigned solely as a step towards calculating the overall cathodic current demand. The allocation of zones has no bearing on the ultimate layout or operation of the CP system.

Zones can be helpful during CP surveys and when troubleshooting CP systems.

8.1.2.2 Cathodic Current Demand

1. The Contractor shall estimate the current requirement for each zone.

8.1.2.3 Groundbed Type

1. The Contractor shall evaluate the relative merits of the following:
 - a. an integrated CP design approach, polarising the entire site by means of remote anode groundbeds, or
 - b. a discrete approach, which will require the installation of either distributed or continuous anodes along the route(s) of the piping.

By the conventions adopted in the CP industry, the resulting polarisation of the piping can be obtained by raising the soil-side potential or installing an interruptible DC coupon.

This evaluation of groundbed options include the following:

- *the current requirements for each approach,*
- *the requirements for bonding (integrated approach),*
- *the practicalities of installing distributed or continuous anodes (discrete approach),*
- *the reliability and maintainability of electrical isolation (discrete approach),*
- *the risks of CP current being shielded by foreign structures (integrated approach),*

- the requirements for bonding to prevent stray current damage to foreign structures (integrated approach).

8.1.2.4 Sacrificial Anodes or Impressed Current Systems

1. Where an integrated CP approach is adopted an impressed current CP system shall be used.
2. Most discrete systems should be provided with impressed current CP.
 - a. Sacrificial anodes may be considered.

8.1.3 Criteria for CP

1. The potential measurement methods stated in Section 4 of EN 14505 should not be used on systems containing buried duplex stainless steel.

The potential measurement methods in Section 4 of EN 14505 are not relevant to the CP system design. However, in lower resistivity soils the -1200 mV (on) criterion could be more negative than -1100 mV (instant-off), which is the proposed standard limit for duplex stainless steels. This is not a design parameter, but is part of commissioning and monitoring.

8.1.4 Mixed metal oxide anodes

1. The requirements in Annex E.3.2 of EN 14505 shall apply.
2. The use of proprietary systems comprising MMO-coated titanium wires that are piggy-backed to a conductor cable and installed in flexible polymer “sausages” or “socks” filled with carbonaceous backfill shall be subject to the following:
 - a. A review of the Manufacturer’s/Supplier’s data regarding the dimensions of the conductor cable, and the interval between the factory-made connections to the titanium anode wire.
 - b. Demonstration (e.g., by calculation) by the Contractor that the voltage drops in such anode assemblies are acceptable.