

DEP SPECIFICATION

INSTALLATION AND COMMISSIONING OF ONSHORE CATHODIC PROTECTION SYSTEMS

DEP 30.10.73.33-Gen.

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DESIGN AND ENGINEERING PRACTICE



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TABLE OF CONTENTS

1.	INTRODUCTION	6
1.1	SCOPE.....	6
1.2	DISTRIBUTION, INTENDED USE, AND REGULATORY CONSIDERATIONS	6
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	9
1.5	PROPRIETARY NAMES	9
1.6	SUMMARY OF MAIN CHANGES.....	9
1.7	COMMENTS ON THIS DEP	9
1.8	DUAL UNITS.....	9
2.	GENERAL.....	10
2.1	GENERAL GUIDELINES FOR CATHODIC PROTECTION.....	10
2.2	INSTALLATION AND COMMISSIONING OF GROUNDBEDS.....	10
3.	INSTALLATION OF DEEP ANODE BED SYSTEMS FOR CATHODIC PROTECTION.....	11
3.1	GENERAL REQUIREMENTS.....	11
3.2	MATERIALS.....	12
3.3	HYDROGEOLOGIC SURVEY	12
3.4	INSTALLATION OF CASING.....	13
3.5	ANODE HOLE.....	14
3.6	INSTALLATION OF ANODES	15
3.7	INSTALLATION OF CABLES	18
3.8	SYSTEM REQUIREMENTS AT GRADE.....	19
3.9	INSPECTION AND TESTING.....	20
3.10	ENERGIZING THE SYSTEM.....	21
3.11	SYSTEM DATA.....	22
4.	INSTALLATION OF IMPRESSED CURRENT SURFACE ANODE BED SYSTEMS.....	23
4.1	GENERAL REQUIREMENTS.....	23
4.2	MATERIALS.....	24
4.3	INSTALLATION OF ANODE BED	24
4.4	INSTALLATION OF ANODE SHUNT BOXES.....	28
4.5	INSTALLATION OF RECTIFIERS.....	28
4.6	INSPECTION AND TESTING.....	28
4.7	ENERGIZING THE SYSTEM.....	28
4.8	DATA AND DOCUMENTATION	30
5.	INSTALLATION OF HORIZONTAL IMPRESSED CURRENT ANODE SYSTEMS FOR NEW AND REPLACEMENT TANK BOTTOMS	31
5.1	GENERAL REQUIREMENTS.....	31
5.2	MATERIALS.....	32
5.3	INSTALLATION	33
5.4	INSPECTION	36
5.5	COMMISSIONING	36
6.	INSTALLATION OF HORIZONTALLY BORED IMPRESSED CURRENT ANODE SYSTEMS UNDER EXISTING TANKS.....	37
6.1	GENERAL REQUIREMENTS.....	37
6.2	MATERIALS.....	38
6.3	INSTALLATION EQUIPMENT	38
6.4	INSTALLATION	39
6.5	INSPECTION	41
6.6	COMMISSIONING	41
6.7	SUBMITTALS.....	42
7.	INSTALLATION OF IMPRESSED CURRENT GRID SYSTEMS FOR ON GRADE STORAGE TANK BOTTOMS.....	44
7.1	GENERAL REQUIREMENTS.....	44

7.2	MATERIALS.....	46
7.3	INSTALLATION	48
7.4	INSPECTION	51
7.5	TESTING AND COMMISSIONING.....	52
7.6	SUBMITTALS.....	53
7.7	WARRANTY REQUIREMENTS	53
7.8	DRAWINGS – TYPICAL DRAWING LIST	54
7.9	SAND PAD MATERIAL REQUIREMENTS	54
7.10	SAND PAD INSTALLATION REQUIREMENTS.....	55
7.11	PLATE INSTALLATION	55
7.12	MISCELLANEOUS	56
8.	INSTALLATION OF GALVANIC ANODE BED SYSTEMS.....	57
8.1	GENERAL REQUIREMENTS.....	57
8.2	INSTALLATION OF GALVANIC ANODE SYSTEMS IN SOIL	58
8.3	INSPECTION AND TESTING.....	59
8.4	COMMISSIONING	60
9.	DESIGN, MANUFACTURE, AND INSTALLATION OF AIR COOLED CATHODIC PROTECTION RECTIFIERS.....	61
9.1	GENERAL	61
9.2	DESIGN	62
9.3	MANUFACTURE	65
9.4	INSTALLATION	66
9.5	SOLAR POWERED GENERATOR STATIONS	68
9.6	COMMISSIONING	69
10.	DESIGN, MANUFACTURE, AND INSTALLATION OF OIL COOLED CATHODIC PROTECTION RECTIFIERS.....	71
10.1	GENERAL	71
10.2	DESIGN	71
10.3	MANUFACTURE	76
10.4	INSTALLATION	77
10.5	COMMISSIONING	79
11.	TEST STATIONS.....	81
11.1	GENERAL REQUIREMENTS.....	81
11.2	INSTALLATION GUIDELINES FOR ALL TEST STATION CONFIGURATIONS.....	82
11.3	CABLE-TO-STRUCTURE CONNECTIONS.....	84
11.4	PIPE-TO-SOIL POTENTIAL STATION CONFIGURATION	87
11.5	FOREIGN LINE CROSSING STATION CONFIGURATION	89
11.6	ELECTRICAL ISOLATION STATION CONFIGURATION	91
11.7	CASED CROSSING STATION CONFIGURATION	92
11.8	SACRIFICIAL ANODE STATION CONFIGURATION.....	93
11.9	COUPON TEST STATION CONFIGURATION	94
11.10	IR DROP STATION CONFIGURATION	96
11.11	IR FREE COUPON STATION CONFIGURATION	101
12.	INSTALLATION OF CATHODIC PROTECTION BONDS ON FOREIGN STRUCTURES	103
12.1	GENERAL	103
12.2	MATERIALS.....	104
12.3	INSTALLATION	105
12.4	INSPECTION	105
13.	INSTALLATION OF ELECTRICAL ISOLATION FOR CATHODIC PROTECTION.....	106
13.1	GENERAL	106
13.2	MATERIALS.....	107
13.3	INSTALLATION	109
13.4	SPECIAL INSULATING REQUIREMENTS	112
13.5	INSPECTION	112

14	INSTALLATION OF SYSTEMS FOR MITIGATING ALTERNATING CURRENT EFFECTS AND FAULT CURRENTS	113
14.1	GENERAL	113
14.2	SYSTEMS	114
14.3	UNPACKING AND MAKING READY	117
14.4	POTENTIAL GRADIENT CONTROL MATS AT ABOVE GROUND APPURTENANCES	117
14.5	POTENTIAL GRADIENT CONTROL MATS AT VALVES AND REMOTE BLOWDOWNS	119
14.6	ZINC GROUNDING CELL SYSTEMS	120
14.7	GROUNDING AND ISOLATING DEVICES	121
14.8	COUPON TEST STATIONS	121
14.9	INSPECTION	121
15.	PERFORMING CLOSE-INTERVAL PIPE-TO-SOIL POTENTIAL SURVEYS	122
15.1	GENERAL	122
15.2	EQUIPMENT AND MATERIALS	122
15.3	GENERAL REQUIREMENTS FOR SURVEYS	124
15.4	ON/OFF SURVEYS	126
15.5	RIVER CROSSING SURVEYS	129
15.6	NATIVE POTENTIAL SURVEYS	129
15.7	ON POTENTIAL SURVEYS	129
15.8	SURVEY DOCUMENTATION	129
15.9	SURVEY OPTIONS	131
16.	REFERENCES	134

APPENDICES

APPENDIX 1 – Partial List of Materials for Graphite / Silicon Iron Anode System	137
APPENDIX 2 – Partial List of Materials for MMO or LIDA® Anode System	138
APPENDIX 3 – Deep Anode Bed Drilling Log	139
APPENDIX 4 – Deep Well Anode Installation Log	141
APPENDIX 5 – Partial List of Materials for Surface Anode Bed System	142
APPENDIX 6 – Partial List of Materials for Galvanic Anode System	143
APPENDIX 7 – Installation Checklist for Rectifiers	144
APPENDIX 8 – Material Requirement Sheet for Air Cooled Rectifier Installation	145
APPENDIX 9 – Installation Checklist for Impressed Current Surface Ground Bed	146
APPENDIX 10 – Installation Checklist for Impressed Current Deep Well Ground Bed	147
APPENDIX 11 – Installation Checklist for Underground Sacrificial Anode Bed	148
APPENDIX 12 – Material Requirement Data Sheet for Isolation Fittings	149

1. INTRODUCTION

1.1 SCOPE

This DEP defines requirements and gives recommendations for the installation and commissioning of onshore cathodic protection systems. The installation and commissioning of cathodic protection systems for subsea pipelines and hardware is covered in DEP 30.10.73.32-Gen.

This is a revision of the DEP of the same number dated January 2000. See (1.6) for a summary of historical revisions to this document.

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 authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. Application in other similar facilities may also apply.

When DEPs are applied, a Management of Change (MOC) process should 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 may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are more stringent and which combination of requirements will be acceptable with regard 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 word should **indicates** a recommendation.

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.
Cathodic Protection Station	Combination of equipment installed to provide cathodic protection to the structure to be protected.
Current Density	Amount of current per unit area of the steel surface, coated or uncoated, in contact with the electrolyte.

Term	Definition
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 required current into and through the electrolyte to the steel surface to be protected.
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.
IR Drop	The voltage across a resistance in accordance with Ohm's law.
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.
Pipeline	Pipeline and associated equipment as defined in the scope of the cathodic protection design contract.
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 particular context.
Polarisation	Change of the pipe-to-soil potential caused by the flow of DC current between an electrolyte and a steel surface.
Polarisation Cell [Kirkcell]	Device inserted in the earth connection of a structure that isolates for DC in the cathodic protection range.
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.

Term	Definition
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.
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
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
CIS	Close Interval Survey
CP	Cathodic Protection
CPDM	Cathodic Protection Data Manager®
Cu/CuSO₄	Copper/Copper Sulphate as used for the Copper/Copper Sulphate type of reference electrode
DC	Direct Current
DOC	Depth of Cover
GPS	Global Positioning System
HDPE	High Density Polyethylene
HMWPE	High Molecular Weight Polyethylene (HMWPE) insulated cable is suitable for direct burial in cathodic protection applications for storage tanks, pipelines and other buried or submerged units.
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
MOVs	Metal Oxide Varistors
NACE	National Association of Corrosion Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NFPA	National Fire Protection Association
PCR	Polarization Cell Replacement
PVC	Poly Vinyl Chloride
SSD	Solid State Decoupler
TGIC	Triglycidyl Isocyanurate
THHN	Thermoplastic High Heat Nylon insulated wire

Term	Definition
TW/THW/THWN	Thermoplastic Heat and Water Resistant insulated Wire
UL	Underwriters Laboratories
VAC	Volts Alternating Current
XHHW	XLPE (cross-linked polyethylene) High Heat-resistant Water-resistant

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section is shown in brackets (). Other documents referenced by this DEP are listed in (16).

1.5 PROPRIETARY NAMES

The names "Wenner," "Kirkcell," and "Swain" are used in this DEP to indicate measuring techniques or equipment types, commonly understood by those names in cathodic protection engineering. They are not intended to indicate a requirement to apply equipment of that particular brand name.

1.6 SUMMARY OF MAIN CHANGES

This DEP is a major revision to the previous DEP dated January 2000, and represents a consolidation of subject matter from various Shell entities. The technical content of the previous DEP was preserved, however, references to offshore and marine cathodic protection has been removed and is now referenced in DEP 30.10.73.32-Gen. When the local standards from various Shell entities contained similar technical information, drawings, or forms, a comparison was performed and the most comprehensive and technically current content was adopted.

1.7 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form may be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.8 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.

2. GENERAL

2.1 GENERAL GUIDELINES FOR CATHODIC PROTECTION

General guidelines for cathodic protection are given in DEP 30.10.73.10-Gen.

It is Shell's policy to protect all buried or submerged metallic pipelines from corrosion using a combination of coatings and cathodic protection systems. The effects of corrosion and the design of corrosion protection shall be an integral component of all pipeline projects. In addition, local regulations may outline specific coating and cathodic protection requirements.

It is very important to plan for Cathodic Protection (CP) early in the design phase of the project. A qualified Corrosion Specialist shall be included in the design phase of all pipeline and tank projects. Early input from the Corrosion Specialist will help prevent unforeseen costs and ensure that corrosion mitigation issues are addressed in a timely and effective manner. Right of Way (ROW) issues, permits to drill deep wells or install distributed groundbeds, material delivery, and Contractor availability are items that require advanced scheduling.

CP shall be applied immediately after construction to protect all buried and submerged structures from corrosion.

Installation of cathodic protection systems will normally not be handled by the General Contractor responsible for laying the pipe. Corrosion Contractors specialize in cathodic protection installations and should be used to install cathodic protection systems.

Design, installation and commissioning of cathodic protection systems shall be carried out under the supervision of qualified and experienced NACE Cathodic Protection Specialists, preferably the design consultant's representative.

2.2 INSTALLATION AND COMMISSIONING OF GROUNDBEDS

The installation and commissioning of groundbeds and permanent monitoring facilities shall be closely supervised. A qualified corrosion control inspector shall be used to inspect the installation of CP systems to ensure all design and installation requirements are met. As-built drawings and data books shall be provided for all work performed. Upon completion of pipeline or tank construction, a baseline CP survey shall be conducted, recording native structure to soil potentials, AC potentials and current densities at all test leads, checking insulating devices and verifying that foreign crossings are not an interference concern. After energizing the new rectifiers, a second comprehensive survey shall be conducted to confirm there is adequate protection on the pipeline and again verify that AC or DC interference problems do not exist. All reports shall be submitted to the Principal representative.

3. INSTALLATION OF DEEP ANODE BED SYSTEMS FOR CATHODIC PROTECTION

3.1 GENERAL REQUIREMENTS

3.1.1 General installation requirements

1. Deep anode bed systems shall be installed in accordance with applicable government regulations, local requirements, and this DEP.
2. Electrical portion of the deep anode bed systems shall be installed in accordance with applicable local codes, the National Electrical Code, and API RP500.
3. Deepwell groundbeds shall be constructed in accordance with the design documents and drawings. Type, number, depth, and spacing of anodes shall be in accordance with (Appendix 1) and (Appendix 2).
4. Cable connections to protected structures shall conform to (11.3) of this DEP.
5. The installation checklist for deep well groundbeds (Appendix 10) shall be used by the inspector and included as part of the deliverable package to the Principal.

3.1.2 Contractor/personnel qualifications

1. Installation Contractor shall have a minimum of five years experience in the installation of deep anode beds for impressed current systems.
2. Installation of deep anode bed systems shall be carried out under the supervision of a NACE-certified cathodic protection or corrosion specialist.

3.1.3 Equipment and tools

1. Equipment and tools used to install anode beds shall be adequate for the job.
2. Equipment and tools shall be maintained in a manner that ensures safe use.
3. Safety equipment shall be used by installation personnel as required for the job.

3.1.4 Environmental considerations

Installation of deep anode beds shall conform to local environmental and groundwater requirements and to applicable government regulations.

3.1.5 Technical literature for materials

1. If the Installation Contractor also supplies the materials, Manufacturer's technical literature shall be provided for each item required by this DEP. Items required are those indicated in (Appendix 1) and (Appendix 2) of this DEP.
2. Technical literature shall include the Manufacturer's name and shall verify that the material meets the requirements of this DEP.
3. If more than one item or catalog number appears on a technical brochure, the proposed item shall be clearly identified.

3.1.6 Principal inspection

1. All equipment, materials, fabrications, and installations are subject to inspection, testing, and approval by the Principal.
2. Unless otherwise specified, a party designated by the Principal shall inspect installation work.

3.1.7 Permits

Installation Contractor shall obtain the required safety and work permits, including hot work permits, before proceeding with the installation work.

3.1.8 Safety

Installation Contractor shall be familiar with applicable government regulations and Shell safety guidelines and requirements and shall adhere to them.

Location of third party structure locations shall be performed before any excavation by making the required local contacts with One Call or equivalent service providers.

3.2 MATERIALS

3.2.1 Anodes

Type, size, and number of anodes shall be designated by the Principal and provided to Contractor in a Partial List of Material form (Appendix 1) and (Appendix 2).

3.2.2 Lead cable

1. Lead cable type, size, and length shall be designated by the Principal and provided to Contractor in a Partial List of Material form (Appendix 1) and (Appendix 2).
2. Lead cable shall be continuous from the anode to the shunt box without splices.

3.2.3 Positive header and negative cables

1. Positive header and negative cable shall be AWG stranded copper conductor with HMWPE, Kynar® or Halar® insulation (or Principal-approved equivalent) and of adequate size to carry the current from the entire anode bed.
2. Type, size, and length of cable shall be provided to Contractor in a Partial List of Material form (Appendix 1) and (Appendix 2).

3.2.4 Coke breeze

Type and quantity of coke breeze shall be and provided to Contractor in a Partial List of Material form (Appendix 1) and (Appendix 2).

3.3 HYDROGEOLOGIC SURVEY

3.3.1 Review of existing data

1. Unless otherwise specified, existing hydrogeological data, such as drilling logs of observation wells, previous deep anode bed installations, hydrogeology studies, and water well data shall be reviewed by the Principal before drilling starts.
2. Existing data shall be reviewed:
 - a. To determine if any conditions exist that could result in contamination due to the installation of the deep anode beds.
 - b. To determine if the deep anode bed needs to be relocated or extended casing and vent pipe lengths are required.
3. Results of review of existing data shall be furnished to the Installation Contractor.

3.3.2 Pilot hole

1. If required, a pilot hole shall be drilled to obtain hydrogeologic information.
2. Pilot hole shall be drilled with rotary type drilling equipment. Drilling mud (bentonite) shall be used to stabilize the hole.
3. Principal shall determine depth of pilot hole from review of the existing hydrogeological data.
4. Pilot hole shall be drilled to determine depth and thickness of the upper water table, confining bed intervals, and characteristics of additional aquifers.
5. Contractor shall produce a drill log of the pilot hole.
6. If the pilot hole is drilled deeper than the required depth and this results in penetration of a lower aquifer, the portion of the hole in the lower aquifer shall be cemented.
7. If the pilot hole is not used for an anode bed, its entire length shall be cemented.
8. If pilot hole is to be cemented, the cement grout specified in this DEP shall be used.

3.3.3 Hydrogeologic profile

1. A hydrogeologic profile shall be developed from the pilot hole-drilling log. Hydrogeologic profile shall include:
 - a. Identification of any subsurface hydrocarbon contamination.
 - b. Depth and thickness of aquifers.
 - c. Depth and thickness of subsurface soil strata.
 - d. Depth and thickness of impervious clay formations.
 - e. Evaluation and extent of contamination of aquifers.
2. The following characteristics of the anode bed shall be determined from the hydrogeologic profile:
 - a. Depth and thickness of clay stratum at which casing will be terminated. If the clay stratum has a thickness greater than 1.5 m (5 ft.), the casing shall penetrate 1 m (3 ft.) into the stratum.
 - b. Length of casing.
 - c. Location and distribution of anodes below the casing.

3.4 INSTALLATION OF CASING**3.4.1 Casing hole**

1. Casing hole shall:
 - a. Be drilled with rotary type drilling equipment.
 - b. Have drilling mud (bentonite) used to stabilize well bore.
 - c. Have a nominal diameter as designated in (Appendix 1) and (Appendix 2).
 - d. Be drilled to a depth 0.3 m (1 ft.) deeper than the casing length designated in (Appendix 1) and (Appendix 2).
 - e. Be drilled so that there is a uniform minimum 50 mm (2 in.) annulus between the casing and the hole wall.
2. Depth of hole shall be known at all times during drilling operation.

3.4.2 Mud/slurry pits

1. Unless otherwise specified, mud/slurry pits shall be above ground portable containers. Use of dug pits requires approval in writing by the Principal.
2. Dug pits shall be lined with a heavy-duty plastic liner.
3. Contractor shall be responsible for vacuum truck services and disposal of cuttings and fluids.
4. Removal and disposal of cuttings and fluids shall be done in a manner and at a location that complies with all applicable federal, state and local laws, rules and regulations.

3.4.3 Aquifers

Prior to the installation of a deepwell groundbed, the Contractor shall consider the environmental aspects since the groundbed may be installed through underground aquifers.

1. If the anode bed is installed in a zone with a single aquifer:
 - a. Casing shall extend to a depth of at least 6 m (20 ft.) below the lowest annual water table or as instructed by applicable government regulation.
 - b. Casing does not have to terminate in a clay zone.

2. If the anode bed is installed in a zone with multiple aquifers:
 - a. Casing hole shall be drilled using mud (bentonite) with a specific gravity higher than 1.06 to prevent cross contamination of aquifers.
 - b. Bottom of casing shall terminate in a confining zone (clay formation) or other area as determined by the hydrogeologic profile, or as instructed by applicable government regulation.
 - c. Entire length of the anode string shall be located in a single aquifer, if possible.

3.4.4 Insertion of casing

1. If specified, a casing shall be set in the bore hole. Normally a non-conductive (plastic) casing is used for the inactive length of the groundbed. Casing pipe and centralizers shall conform to (Appendix 1) and (Appendix 2).
2. Casing string shall be assembled one joint at a time while lowering the casing string with a drilling rig.
3. Centralizers shall be installed on the casing string at maximum intervals of 6 m (20 ft.). Casing string shall have a minimum of two centralizers.
4. Casing string shall be assembled until it rests at the bottom of the hole and then raised 0.3 m (1 ft.) to facilitate cementing of casing.
5. If bentonite grout is used, a 0.6 m (2 ft.) plug of bentonite gravel shall be poured into the hole prior to lowering the casing.
6. Casing pipe shall be nominal DN 250 (NPS 10) I.D. Schedule 40 PVC, glued bellied end, or as approved by the Principal.

3.4.5 Cementing of casing

1. Annulus between casing and hole shall be cemented after casing is inserted using either Portland cement grout or a high solids bentonite grout. Refer to DEP Standard Drawing 41.016.
2. Portland cement grout mix shall have 22.7 L (6 gal.) of water for every 42.6 kg (94 lbs.) of Portland cement and 4% by weight [2.6 kg (5.76 lbs.)] of sodium bentonite powder.
3. Bentonite grout mix shall have 53 L (14 gal.) of water for every 22.6 kg (50 lbs.) of bentonite (30% solids ratio). Mix shall have a specific gravity of 1.19 Kg/ LITER (9.9 lbs./gal.).
4. Grout shall be pumped through the annulus from the bottom up, until it fills the annulus between casing and hole up to grade. Method for pumping the grout in the annulus shall be approved by the Principal.
5. Portland cement grout shall be allowed to cure for 12 hours prior to drilling anode hole.
6. Anode hole may be drilled immediately if bentonite grout is used.
7. Quick setting Portland cement grout or grout additives shall not be used without prior approval by the Principal.

3.5 ANODE HOLE

3.5.1 Drilling hole

1. Depth of anode hole shall be determined from the hydrogeologic profile and shall not penetrate any lower confining zone.
2. An anode hole shall be drilled with rotary equipment at the diameter and depth as designated by the Principal. Data related to the drilling and installation of deepwell groundbeds shall be recorded in (Appendix 1) or (Appendix 2), based on designated anode material.

3. A drilling log shall be completed by the Contractor using the form provided in (Appendix 3). All underground strata shall be listed on the form. Drilling log shall be submitted to the Principal prior to installation of the anodes.
4. Air drilling without prior approval by the Principal is prohibited.
5. Adequate drilling aids, such as bentonite, shall be used to preclude “booting” or “ringing” and to provide a smooth, slick bore.
6. Water used in the drilling operation shall be clean and fresh.
7. The anode hole shall have a uniform wall from top to bottom. Wall cavities or excessive hole-enlargements are not acceptable.
8. Drill collars shall be of correct size to produce a smooth straight hole that offers minimum resistance to passage of the anodes.
9. All drill cuttings shall be disposed of as instructed by the Principal.

3.5.2 Testing hole

1. Anode hole shall be tested for presence of protrusions or irregularities with a rigid non-weighted cylinder lowered by wire cable.
2. Cylinder shall have a minimum length of 3 m (10 ft.) and a nominal diameter of 38 mm (1½ in.) smaller than diameter of the anode hole.
3. If the hole has irregularities that cannot be corrected, an additional hole shall be drilled at a location determined by the Principal. Cost of additional hole shall be borne by the Contractor.

3.5.3 Electrical log

1. Prior to cleaning the anode hole, an electrical log shall be performed by lowering a single anode into the hole.
2. Anode used for electrical log shall not be one of the anodes to be installed in the hole and it shall be furnished by the Contractor.
3. Current output and associated voltage shall be recorded at 1.5 m (5 ft.) intervals throughout the entire depth of the anode hole.
4. Electrical log data, as shown in (Appendix 3), shall be produced and submitted to the Principal prior to installation of the anodes. Test results may require modifications, e.g., anode depth, location etc., to the design.

3.6 INSTALLATION OF ANODES

3.6.1 General

1. A roller or sheave shall be used to control the cables during the anode lowering operation.
2. Details of anode string shall conform to DEP Standard Drawing 41.016.
3. Spacing of anodes in the string shall be as specified by the Principal in (Appendix 1) and (Appendix 2).
4. Anodes and associated components shall be inspected concurrent with their installation. Damaged and/or defective components shall not be used.
5. Anode cables shall be checked for proper length prior to installation of anodes.
6. Anode cables shall be free of splices, nicks, gouges, or other defects.
7. Anode cables shall not be damaged during the lowering operation. If a cable is damaged, the entire length of cable shall be replaced including the connection to the anode. Splicing or patching the cable is prohibited.
8. Anodes shall be provided with centralisers to centre them in the hole and to prevent cable damage of lower anodes.

9. Anodes shall be lowered on PVC vent pipe in the hole to the specified depth. Anodes shall not be handled, lifted, or lowered using the anode cable, unless specifically allowed by the Manufacturer in the installation instructions, e.g., stringed anodes.
10. Anode lead wires shall be permanently identified before installation. Each anode cable shall be tagged with a unique number or code showing at what depth the anode was set at. This identification shall also be made within the anode shunt box. Care shall be taken that anode cables have sufficient slack to cope with any backfill settlement.

3.6.2 Vent pipe

1. Plastic vent pipe shall extend from the bottom of the anode hole to a minimum of 1.5 m (5 ft.) above grade.
2. Vent pipe section in the anode string area shall be nominal DN 25 (NPS 1) ID slotted PVC Allvent™ as manufactured by Cathodic Engineering Equipment Co., or approved equal.
3. Vent pipe section inside the casing and above grade shall be nominal DN 25 (NPS 1) PVC solid pipe without perforations.
4. Bottom of the vent pipe shall have a cap that can withstand 8.3 bar g (120 psig).

3.6.3 Installation of graphite/cast iron anodes

1. A partial list of materials required for installing a graphite or cast iron anode bed shall be furnished by the Principal as in (Appendix 1).
2. The electrical log data and soil strata, as shown in (Appendix 3), shall be used to determine spacing of anodes in the anode hole.
3. The anode hole shall be flushed prior to installing anodes.
 - a. Unless otherwise specified, flushing shall be done with clean, fresh water.
 - b. Hole may be flushed with another method if, in the opinion of the Principal, a water flush may damage the hole wall.
4. Bottom anode shall be strapped to the vent pipe to facilitate insertion of the vent pipe. Anode shall be strapped to the vent pipe at top and bottom of anode with a stainless steel hose clamp or glass reinforced filament tape. Plastic tape, such as electrician's tape, shall not be used.
5. Unless otherwise specified, bottom anode, with vent pipe attached, shall be lowered to within 1.5 m (5 ft.) of the bottom of the hole.
6. Other anodes shall be manually lowered individually to their required depth.
7. After the anodes are at their required depth, their cables shall be temporarily anchored during installation of the coke breeze.
8. Details of anode placement shall be documented using (Appendix 4).

3.6.4 Installation of mixed metal oxide or LIDA® anodes

1. A partial list of materials required for installing a mixed metal oxide or LIDA® (or equivalent) anode bed shall be furnished by the Principal in (Appendix 2).
2. If the anodes are mounted on a single conductor, spacing of the anodes shall be determined from the hydrogeologic profile, prior to drilling the anode hole.
3. The anode hole shall be flushed prior to installing anodes.
 - a. Unless otherwise specified, flushing shall be done with clean, fresh water.
 - b. Hole may be flushed with another method if, in the opinion of the Principal, a water flush may damage the hole wall.
4. Anode centralizers and bottom weight shall be installed prior to lowering the anode string.

5. After anode string is lowered to its required depth, cable(s) shall be temporarily anchored at the top of the hole.

3.6.5 Installation of coke breeze

3.6.5.1 General

1. Unless otherwise specified by the Principal in (Appendix 1) or (Appendix 2), Loresco SC-3® calcined petroleum coke breeze shall be used.
2. Unless otherwise specified, coke breeze for graphite/cast iron anodes shall be installed by the pumping method. Installation of coke breeze by the pouring method requires approval by the Principal prior to drilling the anode hole.
3. Coke breeze for mixed metal oxide or LIDA® anodes shall be installed by the pumping method.

3.6.5.2 Pumped coke breeze

1. Pumped coke breeze shall be installed in a slurry form.
2. Pipe for coke breeze slurry shall be installed prior to installation of the vent pipe and anode string.
3. Pump size shall not be larger than required to move the slurry to the bottom of the anode hole.
4. A column of fresh water shall be pumped through the pipe prior to pumping the slurry.
5. Slurry shall be prepared using clean, fresh water.
6. Velocity of the slurry at the pipe discharge point shall be slow enough to permit uniform settling and compaction of the coke breeze.
7. During the pumping operation, the pipe shall be pulled out of the slurry at a rate that prevents excessive backpressure on the pump.
8. Excessive agitation of in-place coke breeze indicated by excess coke breeze being carried to top of the hole is prohibited.
9. An electrical test shall be used to confirm that the anodes are being covered with coke breeze.
10. If the top anode is within 7.6 m (25 ft.) of the bottom of the casing, the top of the coke breeze column shall be a minimum of 3 m (10 ft.) above the top anode and a minimum of 1.5 m (5 ft.) above the bottom of the casing.
 - a. If the top anode is placed more than 7.6 m (25 ft.) below the bottom of the casing,
 - b. the top of the coke breeze column shall be a minimum of 4.6 m (15 ft.) above the top anode.
11. The anode hole, above the coke breeze column, shall be filled with pea gravel to within 1.5 m (5 ft.) of the bottom of the casing.
12. Height of coke breeze column shall be checked with a gage line a minimum of 12 hours after the coke breeze is installed. If required, additional coke breeze shall be poured into the casing to obtain proper column height.

3.6.5.3 Poured coke breeze

1. Coke breeze shall be poured in a manner that precludes soil or other extraneous material from lodging against the anode or becoming entrapped within the coke breeze.
2. Coke breeze shall be poured after each anode is lowered to its required depth. This may be done using a large diameter hose that is lowered down to the bottom of the hole and is retracted as the level of coke backfill rises. The quantity of the backfill material shall be recorded. The top of the hole shall be backfilled with graded soil or gravel to prevent cable isolation damage.

3. Resistance measurements shall be taken for each anode during pouring of the coke breeze to confirm that the coke breeze has covered the anode.
4. If the coke breeze bridges the hole, the next anode may be lowered and used to gently tap the bridge open.
5. If the top anode is within 7.6 m (25 ft.) of the bottom of the casing, the top of the coke breeze column shall be a minimum of 3 m (10 ft.) above the top anode and a minimum of 1.5 m (5 ft.) above the bottom of the casing.
6. If the top anode is placed more than 7.6 m (25 ft.) below the bottom of the casing, the top of the coke breeze column shall be a minimum of 4.6 m (15 ft.) above the top anode.
7. The anode hole, above the coke breeze column, shall be filled with pea gravel to within 1.5 m (5 ft.) of the bottom of the casing.
8. Height of coke breeze column shall be checked with a gage line a minimum of 12 hours after the coke breeze is installed. If required, additional coke breeze shall be poured into the casing to obtain proper column height.

3.6.5.4 Bentonite plug

1. After the coke breeze column has been adjusted, a bentonite plug shall be installed above the coke breeze to provide an environmental seal.
2. Bentonite shall be AquaPlug™ or PermaPlug™ as supplied by Corpro or Principal-approved equal.
3. If the top of the coke breeze column is 1.5 m (5 ft.) above the bottom of the casing, a 1.5 m (5 ft.) minimum bentonite plug shall be installed above the top of the coke breeze.
4. If the coke breeze is covered with pea gravel to within 1.5 m (5 ft.) of the bottom of the casing, a 3 m (10 ft.) minimum bentonite plug shall be installed above the pea gravel.

3.7 INSTALLATION OF CABLES

3.7.1 Digging of cable trench

Prior to digging the cable trench, drawings and maps shall be reviewed and trench route shall be surveyed with pipe and cable locators to determine location of underground piping, cables, or other objects. The following requirements apply:

1. Location of underground objects crossing the trench shall be flagged and dug out by hand.
2. Unless otherwise specified, the Installation Contractor shall notify the Principal prior to crossing a foreign pipeline or cable.
3. Trench shall conform to the requirements of the location and this DEP.
4. Trench shall be dug to allow a minimum clearance of 0.3 m (1 ft.) between the cable and other buried structures.
5. Unless otherwise specified, depth of trench shall be 0.6 m (2 ft.).
6. Trench shall be free of objects that may damage the cable such as sharp rocks.

3.7.2 Laying of cable

3.7.2.1 General

Unless otherwise specified, cable “moles”, or other mechanical laying devices, shall not be used.

3.7.2.2 AC cable

Unless otherwise specified, laying of AC cable from the disconnect switch (breaker) to the rectifier shall be the responsibility of the Contractor installing the rectifier.

3.7.2.3 DC cable

1. DC cable shall be installed so that it is not twisted and with sufficient slack to allow for future shifting of the soil.
2. Cables installed underground shall be suitable for direct burial. The cable between the rectifier and the junction box may be installed in conduit.
3. If required by local plant regulations, the cable conduit shall be encased in concrete.
4. Cable shall be inspected to ensure that it is free of cuts, nicks, gouges, and other defects.
5. Direct-buried cable shall have a plastic warning tape installed directly above the cable 300 mm (12 in.) below grade.
 - a. Tape shall extend throughout the length of the direct-buried cable.
 - b. Tape shall be yellow, 75 mm (3 in.) wide, and shall be labelled "Cathodic Protection Cable Buried Below."
6. Above ground cables shall be installed in conduit as directed by the Principal, in accordance to API RP500. Conduit shall be free of burrs or other foreign material.
7. Cathodic protection cables shall be handled and laid with extreme care as damage to the insulation and/or sheathing may result in premature cable failure. During installation the cable reel shall be supported so that cable can be pulled from the reel without causing kinking or twisting.
8. The cable type and size shall be checked for compliance with the design. Underground cables shall be identified by color or tags.
9. Header cables shall be installed at the specified depth in sand padding. Cable warning tape and/or cable tiles shall be used.
10. A cable run shall be of one continuous length. Joints shall not be acceptable except with the written permission of the Principal.
11. When allowed, cable joints shall be made using an approved splice and seal, using splice encapsulation kits. The joints shall be sealed to prevent moisture penetration and ensure electrical isolation from the environment. Submerged joints require seals suitable for the water pressures and environment to which they can be subjected.
12. Any damage to the insulation or sheathing of all cables, including anode connection cables, shall be reported to the Principal.

3.8 SYSTEM REQUIREMENTS AT GRADE

3.8.1 Casing

1. Holes shall be drilled in the casing at the top to accommodate anode cables and the cable tie-off bar.
2. The casing shall have a cap with a 38 mm (1½ in.) hole for the vent pipe.
3. Holes for tie-off bar and anode cables shall be sealed with electrical duct seal, or equal, prior to grouting.
4. The area outside the casing holes shall be sealed with cement grout to prevent entry of surface water.

3.8.2 Anode cable tie-off

1. Anode cables shall be tied-off using a temporary tie-off bar as near the top of the casing as possible. Refer to DEP Standard Drawing 41.017.
2. Tie-off bar shall be a nominal DN 50 (NPS 2) fibreglass-reinforced Schedule 80 pipe or a DN 50 (NPS 2) steel pipe with a polyethylene outer sleeve.

3. Anode cables shall be bundled, neatly nested, and covered for approximately 0.6 m (2 ft.) with plastic electrician's tape. This covered section of cables shall be looped around the tie-off bar.
4. Below the tie-off bar, the anode cables shall be bundled, neatly nested, and covered for approximately 150 mm (6 in.) with three layers of glass reinforced filament tape. End of tape shall be multiple half-hitched for long time security.
5. Cable loop and cable slack shall be pushed into the top of the casing and secured by inserting the tie-off bar through casing holes and cable loop.
6. Anode cables shall have enough slack inside the casing to allow settlement of the coke breeze.

3.8.3 Concrete pad

1. Unless otherwise specified, the concrete pad shall conform to DEP Standard Drawing 41.017.
2. Outside ends of cable and tie-off bar shall be positioned near the center of the concrete pad, approximately 75 mm (3 in.) below the concrete pad surface.

3.8.4 Vent pipe

1. Juncture of the vent pipe through the casing cap shall be sealed with a rubber grommet to obtain a water-tight seal.
2. Vent pipe shall extend to a sufficient height above the casing cap to prevent intrusion of liquids. For anode beds inside tank dikes, the vent pipe shall include a horizontal clapper type check valve as shown in DEP Standard Drawing 41.017.
3. End of vent pipe shall have a screw-on PVC cap or a plastic screen.
 - a. PVC cap shall have four 1.5 mm (1/16 in.) drilled holes.
 - b. Screen shall be attached to the vent pipe with a stainless steel gear hose clamp. Screen shall have openings of 1.5 mm (1/16 in.) or smaller.

3.8.5 Shunt box

1. Unless otherwise specified, anode bed shall have an aboveground shunt box.
2. The shunt box shall conform to DEP Standard Drawing 41.018 or 41.019.
3. The underground shunt box may be used around roads and high traffic areas.
4. The underground shunt box shall be properly sealed with a plumber's plug or similar device to prevent subsurface contamination.
5. Each anode cable within the shunt box shall be tagged with a unique number or code showing at what depth the anode was set at.

3.9 INSPECTION AND TESTING

3.9.1 Visual inspection

1. Anodes, anode lead wires and cables shall be visually inspected prior to installation.
2. Anode lead wires and cable shall be free of breaks, kinks and insulation flaws.

3.9.2 Destructive testing

At the request of the Principal, an anode shall be cut open to allow inspection of the lead cable connection to the anode core. Cost of the anode shall be borne by the Principal.

3.9.3 Electrical inspection

1. At the request of the Principal, all positive circuit cable, including anode lead cables, shall be subjected to an electrical inspection of the insulation.

2. Inspection voltage shall be 150 volts per mil (0.001 inch or 0.025 mm) of insulation thickness for dry inspection and 70 volts per mil of insulation thickness for wet sponge inspection.

3.10 ENERGIZING THE SYSTEM

3.10.1 General

1. The system shall be energized and tested as specified below.
2. Adequate level of corrosion protection shall be determined in accordance with NACE SP0169.

3.10.2 Pre-Energizing requirements

1. All temporary cathodic protection, bonds with foreign structures, and grounding facilities that could affect CP, shall be disconnected.
2. If sacrificial anodes are installed on the carrier pipe or a related casing, they shall be disconnected to allow the natural potential of the carrier pipe and the open circuit potential of the anodes to be measured.
3. Prior to energizing the deep anode bed system, native structure-to-soil potentials for the structure(s) to be protected, and any other structure in the vicinity that may be affected by the deep anode bed system, shall be recorded at designated test points.
4. Recorded potentials shall be submitted to the Principal.

3.10.3 Energizing

1. System shall initially be energized on low tap settings to verify/determine the following:
 - a. Rectifier(s), shunt boxes, and cables are operational.
 - b. Polarity of the cables is correct.
 - c. Interference from stray currents is not present.
 - d. Requirement for any remedial measures such as installation of additional test stations.
2. After initial energizing, the rectifier shall be set at an operating output as instructed by the Principal. Individual anode outputs shall be measured and recorded. If resistors have been provided in individual anode circuits, the outputs of the anodes shall be balanced within the design capacity. Resultant voltage and current outputs shall be recorded.
3. If more than one structure is protected by the same power source, the current to each structure shall be adjusted by changing the resistor value in each drain cable.
4. After polarization is complete, structure-to-soil ON/OFF potentials shall be measured at all test facilities. The measurements shall be carried out by interrupting the power source at a duration cycle as instructed by the Principal. The permissible duration of the interruption depends on the rate of depolarization, which is determined by local conditions.

NOTE For uncoated structures and for structures with aged coatings, full polarization may require from several days up to several months. For these structures, interruption cycles shall not be more than one second per minute.

5. If grounding facilities/polarization cells have been installed to mitigate induced AC voltages, AC potentials shall be recorded prior to, and after, the connection of the grounding.
6. The insulating effectiveness of isolating joints and isolating flanges shall be checked in accordance with the procedure in (13).
7. If sacrificial anodes are installed on the carrier pipe or a related casing, they shall be connected and the potential of the carrier pipe and the current output of the sacrificial

anode shall be measured and recorded. The current measurement shall be done performed using a shunt.

8. Interference testing on all foreign structures/pipelines crossing or in close proximity to the object shall be carried out. If bonds exist, adjustments shall be made to the resistive bonds so that interference between the structures/pipelines remains within acceptable limits.
9. If automatic potential controlled power sources are used, ON/OFF potential measurements shall be performed with the potential control circuit switched off and the unit adjusted manually to the required potential. Once testing is complete, the potential setting shall be adjusted to the required drain point potential and the potential control switched on.
10. If voltage and/or current limiting circuits have been installed, the settings of these circuits shall be adjusted to a value approximately 10% higher than the recorded voltage and current output. Such a setting prevents overprotection in case of failure of the potential control circuit, while allowing sufficient swing in case of a change in current demand.

3.11 SYSTEM DATA

3.11.1 General

The following data shall be prepared for the deep anode bed system:

1. Material list that contains:
 - a. Size, type, and number of anodes.
 - b. Type and amount of coke breeze.
 - c. Size, type, and length of positive and negative cables.
2. Preliminary hydrogeology profile.
3. Installation log that contains:
 - a. Drilling log with types of soil and approximate depth.
 - b. Anode resistance log.
 - c. Anode current output log.
 - d. Anode depth log.

3.11.2 Manual

A manual shall be prepared for the deep anode bed system. Manual shall contain:

1. Location of the system.
2. Rectifier data.
3. Inspection, testing, and energizing data.

3.11.3 Plot plan

A plot plan of the as-built deep anode bed system shall be prepared. Plot plan shall show:

1. Exact location of the various components of the system including rectifiers, ground beds, bond boxes, cross bonds, test points and insulating devices with reference to the structures being protected.
2. Foreign flanges and foreign lines in the protected area.

4. INSTALLATION OF IMPRESSED CURRENT SURFACE ANODE BED SYSTEMS

4.1 GENERAL REQUIREMENTS

4.1.1 General installation requirements

1. Installation of surface anode beds shall be conducted by a company that has been engaged in the installation of surface anode beds for a period of no less than five years.
2. Anode bed systems shall be installed in accordance with applicable government regulations, local requirements, NACE SP0169 and this DEP.
3. Electrical portion of the anode bed systems shall be installed in accordance with applicable local codes, the National Electrical Code, and API RP500.

4.1.2 Personnel qualifications

1. Personnel engaged in installing cathodic protection surface anode beds shall be qualified by education, training, and experience to fulfill requirements of this DEP.
2. Documentation of qualifications shall be available upon request.

4.1.3 Equipment and tools

1. Equipment, tools, and materials used to install surface anode beds shall be proper and adequate for the job.
2. Equipment and tools shall be maintained in a manner that ensures their safe use.
3. Safety equipment shall be used by installation personnel as required for the job.

4.1.4 Technical literature for materials

1. Manufacturer's technical literature shall be provided for each item required by this DEP.
2. Technical literature shall include the Manufacturer's name and shall verify that the material meets the requirements of this DEP.
3. If more than one item or catalog number appears on the technical literature, the proposed item shall be clearly identified.

4.1.5 Principal inspection

1. All equipment, materials, fabrications, and installations are subject to inspection, testing, and approval by the Principal.
2. Unless otherwise specified, a party designated by the Principal shall inspect installation work.

4.1.6 Drawings

Installation Contractor shall provide as-built drawings with details of the cathodic protection system installation. Details shall include types, locations, and number of anodes and details of the connections to electric power, rectifier, and protected structures.

4.1.7 Permits

Installation Contractor shall obtain the required safety and work permits, including hot work permits, before proceeding with the installation work.

4.1.8 Safety

1. Installation Contractor shall be familiar with applicable government regulations and Shell safety guidelines and requirements and shall adhere to them.
2. Location of third-party structure locations shall be performed before any excavation by making the required local contacts with One Call or equivalent service providers.

4.2 MATERIALS

4.2.1 Anodes

Type, size, and number of anodes shall conform to (Appendix 5).

4.2.2 Lead cable

Lead cable type, size, and length shall conform to (Appendix 5). Also, the lead cable shall be continuous from the anode to the shunt box without splices.

4.2.3 Positive header and negative cables

1. Positive header and negative cable shall be AWG stranded copper conductor with HMWPE, Kynar® or Halar® insulation (or Principal-approved equivalent) and of adequate size to carry the current from the entire anode bed.
2. Type, size, and length of cable shall conform to (Appendix 5).

4.2.4 Coke breeze

Type and quantity of coke breeze shall conform to (Appendix 5).

4.2.5 Junction box

Junction box shall conform to (Appendix 5).

4.2.6 Electrical connection

1. Unless otherwise specified, electrical connection of the negative cable to the structure shall be made by Thermite welding.
2. Materials required for Thermite welding and coating of the welds shall conform to (11.3).

4.2.7 Warning tape

Warning tape shall be yellow, 75 mm (3 in.) wide, and shall be labelled "Cathodic Protection Cable Buried Below."

4.3 INSTALLATION OF ANODE BED

All installation requirements in this DEP shall be followed. (Appendix 9) includes a checklist for impressed current surface groundbed installation.

4.3.1 Excavation of cable trenches

1. Prior to excavation of cable trenches, drawings and maps shall be reviewed and trench route shall be surveyed with pipe and cable locators to determine location of underground piping, cables, or other objects.
2. Location of underground objects crossing the trenches shall be flagged and dug out by hand.
3. Trenches shall conform to the requirements of the location and this DEP.
4. Trenches shall be excavated to allow a minimum clearance of 300 mm (12 in.) between the cable and other buried structures.
5. Unless otherwise specified, depth of trenches shall be 0.6 m (2 ft.)
6. Trenches shall be free of objects that may damage the cable such as sharp rocks.
7. Unless otherwise specified, required notifications prior to crossing a foreign pipeline or cable are not the responsibility of the Installation Contractor.
8. If an unknown pipeline or cable is encountered, the Principal shall be notified immediately.

4.3.2 Installation of cable

4.3.2.1 General

Unless otherwise specified, cable “moles”, or other mechanical laying devices, shall not be used.

4.3.2.2 AC cable

Unless otherwise specified, laying of AC cable from the disconnect switch (breaker) to the rectifier shall be the responsibility of the Contractor installing the rectifier.

4.3.2.3 DC cable

1. DC cable shall be installed so that it is not twisted and with sufficient slack to allow for future shifting of the soil.
2. Cables installed underground shall be suitable for direct burial. The cable between the rectifier and the junction box may be installed in conduit.
3. If required by local plant regulations, the cable conduit shall be encased in concrete.
4. Cable shall be inspected to ensure that it is free of cuts, nicks, gouges, and other defects.
5. Direct-buried cable shall have a plastic warning tape installed directly above the cable, 300 mm (12 in.) below grade.
 - a. Tape shall extend throughout the length of the direct-buried cable.
 - b. Tape shall be yellow, 75 mm (3 in.) wide, and shall be labelled “Cathodic Protection Cable Buried Below.”
6. Above-ground cables shall be installed in conduit as directed by the Principal, in accordance to API RP500. Conduit shall be free of burrs or other foreign material.
7. Header cables shall be laid in the trench in a layer of soft sand in order to mitigate possible damage to insulation during backfill. To mitigate possible damage due to the acidic environment in the vicinity of active anodes, header cables shall not be laid above anodes.
8. If a central distribution box is used, the anode cable tails shall be terminated in the distribution box, numbered sequentially, and shown on corresponding as-built drawings.
9. Cable warning tape or cable protection tiles shall be used. Sufficient slack shall exist in the anode cables to avoid strain.
10. On completion of the groundbed the resistivity of the groundbed and, if possible, the individual anodes shall be measured to remote earth using a low resistance earth Megger. If the groundbed resistivity is outside usable limits for operation within the design parameters, the Principal and the Contractor shall investigate the cause and take remedial actions.
11. Cable connections to the rectifier from both the anodes and the structure shall be mechanically secure and electrically conductive. Before the power source is energized, verification should be made that (1) the negative [-] conductor is connected to the structure to be protected, and (2) the positive [+] conductor is connected to the anodes, and (3) the system is free of short circuits.
12. The location of the groundbed shall be indicated by groundbed marker posts located at both extremities of the groundbed.
13. Cathodic protection cables shall be handled and laid with extreme care as damage to the insulation and/or sheathing may result in premature cable failure. During installation the cable reel shall be supported so that cable may be pulled from the reel without causing kinking or twisting.

14. The cable type and size shall be checked for compliance with the design. Underground cables shall be identified by color or tags.
15. The cables shall be installed at the specified depth in sand padding. Cable warning tape and/or cable tiles shall be used.
16. A cable run shall be of one continuous length. Joints shall not be acceptable except with the written permission of the Principal.
17. When allowed, cable joints shall be made using an approved splice and seal, using splice encapsulation kits. The joints shall be sealed to prevent moisture penetration and ensure electrical isolation from the environment. Submerged joints require seals suitable for the water pressures and environment to which they can be subjected.
18. Any damage to the insulation or sheathing of all cables, including anode connection cables, shall be reported to the Principal.

4.3.3 Anode holes/trenches

4.3.3.1 Vertical holes

1. Unless otherwise specified, anodes shall be installed in vertical holes and have a diameter and depth according to the project specification. Vertical holes shall conform to Detail "A" in DEP Standard Drawing 41.012.
2. Holes shall be excavated so that they have a straight and uniform wall without cavities. If there is major deformation of the wall, the hole shall be filled and packed with moist dirt and excavated again.
3. In dry environments, holes shall be excavated with a power auger. Excavation with a hollow stem auger is permitted only if soil conditions do not allow the use of a power auger or backfill with coke breeze around the anode is not possible. In which case, pre-packaged canister anodes shall be used. Holes for canister anodes shall conform to Detail "B" in DEP Standard Drawing 41.012.
4. In marsh environments or areas in which the permanent water table is above the anode depth, water jetting may be used. Water jetting shall not be used in dry environments for installing anodes due to the high shrinkage of the borehole around the anode.

4.3.3.2 Horizontal trenches

1. If vertical holes are impractical, anodes may be installed in horizontal trenches.
2. A proposal for horizontal anode trenches shall be submitted to the Principal for approval.
3. Trenches shall conform to Detail "C" in DEP Standard Drawing 41.012.

4.3.4 Installation of anodes

4.3.4.1 General

1. Anode hole shall be free of debris and foreign material.
2. Anodes shall be installed in accordance with the following DEP Standard Drawings:
 - a. 41.010
 - b. 41.011
 - c. 41.012
 - d. 41.014
 - e. 41.015
3. Depth of anodes shall conform to (Appendix 5).
4. If holes are excavated with a hollow stem auger, anodes shall be pre-packaged with coke breeze in metal canisters. Native backfill shall be installed in 150 mm (6 in.) lifts.

Each lift shall be tamped to ensure full contact between the pre-packaged anode and soil. Refer to Detail "B" in DEP Standard Drawing 41.012.

5. Anodes and associated components shall be subject to inspection prior to installation. Damaged and/or defective components shall be rejected.
6. Unless otherwise specified, anodes installed in an operating unit shall be located a minimum of 1.8 m (6 ft.) away from all structures. Exceptions to this requirement shall be submitted to the Principal for approval.

4.3.4.2 Lead cables

1. Lead cables shall be of sufficient length to reach the anode shunt box terminals without splices. Cables shall be checked for proper length prior to installation of anodes.
2. Lead cables shall not be twisted or damaged during installation. If a cable is damaged, the entire cable, including the connection to the anode, shall be replaced. Splicing or patching of cables is prohibited.
3. Each anode cable shall be tagged with a unique number or code showing at what depth the anode was set at. This identification shall also be made within the anode shunt box.
4. Anodes shall not be handled, lifted, or lowered using the anode cable, unless specifically allowed by the Manufacturer in the installation instructions, e.g., stringed anodes.
5. The location of the groundbed shall be indicated, e.g., by groundbed marker posts located at both extremities of the groundbed.
6. Cathodic protection cables shall be handled and laid with extreme care as damage to the insulation and/or sheathing may result in premature cable failure. During installation the cable reel shall be supported so that cable may be pulled from the reel without causing kinking or twisting.
7. The cable type and size shall be checked for compliance with the design. Underground cables shall be identified by color or tags.
8. The cables shall be installed at the specified depth in sand padding. Cable warning tape and/or cable tiles shall be used.
9. A cable run shall be of one continuous length. Joints shall not be acceptable except with the written permission of the Principal.
10. When allowed, cable joints shall be made using an approved splice and seal, using splice encapsulation kits. The joints shall be sealed to prevent moisture penetration and ensure electrical isolation from the environment. Submerged joints require seals suitable for the water pressures and environment to which they can be subjected.
11. Any damage to the insulation or sheathing of all cables, including anode connection cables, shall be reported to the Principal.

4.3.5 Installation of coke breeze

1. Vertical anode holes shall be completely backfilled with coke breeze to depth of the cable trench.
2. Unless otherwise specified, coal coke breeze shall be used. Refer to (Appendix 5). Petroleum coke breeze shall be used in canister anode assemblies.
3. Coke breeze shall be installed by pouring,
4. Coke breeze clean and free of rocks, dirt, and other foreign material.
5. Coke breeze installed in 150 mm (6 in.) lifts. Each lift shall be tamped to ensure full contact between the anode, soil, and coke breeze.
6. Tamping of coke breeze shall be carried out with a tamping tool of proper size.

7. Anode hole above coke breeze column may be filled with native soil, washed gravel, or crushed stone.

4.4 INSTALLATION OF ANODE SHUNT BOXES

1. Shunts and their cable connections shall be housed in a shunt box and installed in accordance with DEP Standard Drawing 41.013.
2. Unless otherwise specified, each anode shall have a current measuring shunt.
3. Each positive cable from the anode shunt boxes shall terminate in a positive junction box as shown in DEP Standard Drawing 41.009.
4. A single positive cable shall be installed from the positive junction box to the rectifier.
5. Each anode cable within the shunt box shall be tagged with a unique number or code showing at what depth the anode was set.

4.5 INSTALLATION OF RECTIFIERS

4.5.1 Air-cooled, pole-mounted

Air-cooled, pole-mounted rectifiers shall be installed in accordance with (9).

4.5.2 Oil-immersed, pad-mounted

Oil-immersed, pad-mounted rectifiers shall be installed in accordance with (10).

4.6 INSPECTION AND TESTING

4.6.1 General

1. Principal retains the right to inspect equipment and materials prior to, and during, installation.
2. Determination of deficiencies in the installation of anodes shall be made by the Principal.
3. Installation Contractor shall correct all deficiencies in the anode installations.

4.6.2 Visual inspection

1. Anodes, anode lead wires and cables shall be visually inspected prior to installation.
2. Anode lead wires and cable shall be free of breaks, kinks, and insulation flaws.

4.6.3 Destructive testing

At the request of the Principal, an anode shall be cut open to allow inspection of the lead cable connection to the anode core. Cost of the anode shall be borne by the Principal.

4.6.4 Electrical inspection

1. At the request of the Principal, all positive circuit cable, including anode lead cables, shall be subjected to an electrical inspection of the insulation.
2. Inspection voltage shall be 150 volts per mil (0.001 inch or 0.025 mm) of insulation thickness for dry inspection and 70 volts per mil of insulation thickness for wet sponge inspection.

4.7 ENERGIZING THE SYSTEM

4.7.1 General

1. If required by the Principal, the system shall be energized and tested as specified in this DEP.
2. Adequate level of corrosion protection shall be determined in accordance with NACE SP0169 and SP0572.

4.7.2 Pre-energizing requirements

1. All temporary cathodic protection, bonds with foreign structures, and grounding facilities that could affect CP, shall be disconnected.
2. If sacrificial anodes are installed on the carrier pipe or a related casing, they shall be disconnected to allow the natural potential of the carrier pipe and the open circuit potential of the anodes to be measured.
3. Prior to energizing the deep anode bed system, native structure-to-soil potentials for the structure(s) to be protected, and any other structure in the vicinity that may be affected by the deep anode bed system, shall be recorded at designated test points.
4. Recorded potentials shall be submitted to the Principal.

4.7.3 Energizing

1. The system shall initially be energized on low tap settings to verify/determine the following:
 - a. Rectifier(s), shunt boxes, and cables are operational.
 - b. Polarity of the cables is correct.
 - c. Interference from stray currents is not present.
 - d. Requirement for any remedial measures such as installation of additional test stations.
2. After initial energizing, the rectifier shall be set at an operating output as instructed by the Principal. Individual anode outputs shall be measured and recorded. If resistors have been provided in individual anode circuits, the outputs of the anodes shall be balanced within the design capacity. Resultant voltage and current outputs shall be recorded.
3. If more than one structure is protected by the same power source, the current to each structure shall be adjusted by changing the resistor value in each drain cable.
4. After polarisation is complete, structure-to-soil ON/OFF potentials shall be measured at all test facilities. The measurements shall be carried out by interrupting the power source at a duration cycle as instructed by the Principal. The permissible duration of the interruption depends on the rate of depolarisation, which is determined by local conditions.

NOTE: For uncoated structures and for structures with aged coatings, full polarisation may require from several days up to several months. Where highly resistive soil environments exist, as in sand, interruption cycles shall not be more than one second per minute.

5. If grounding facilities/polarisation cells have been installed to mitigate induced AC voltages, AC potentials shall be recorded prior to, and after, the connection of the grounding.
6. The insulating effectiveness of isolating joints and isolating flanges shall be checked in accordance with the procedure in (13).
7. If sacrificial anodes are installed on the carrier pipe or a related casing, they shall be connected and the potential of the carrier pipe and the current output of the sacrificial anode shall be measured and recorded. The current measurement shall be done performed using a shunt.
8. Interference testing on all foreign structures/pipelines crossing or in close proximity to the object shall be carried out. If bonds exist, adjustments shall be made to the resistive bonds so that interference between the structures/pipelines remains within acceptable limits.
9. If automatic potential controlled power sources are used, ON/OFF potential measurements shall be performed with the potential control circuit switched off and the unit adjusted manually to the required potential. Once testing is complete, the potential

setting shall be adjusted to the required drain point potential and the potential control switched on.

10. If voltage and/or current limiting circuits have been installed, the settings of these circuits shall be adjusted to a value approximately 10% higher than the recorded voltage and current output. Such a setting prevents overprotection in case of failure of the potential control circuit, while allowing sufficient swing in case of a change in current demand.

4.8 DATA AND DOCUMENTATION

4.8.1 General

1. A material list shall be prepared for the anode bed system using form in (Appendix 2).
2. The material list shall contain the following:
 - a. Size, type, and number of anodes.
 - b. Type and amount of coke breeze.
 - c. Size, type, and length of positive and negative cables.
 - d. Size, type, and number of shunt and junction boxes.
 - e. Current output from each of the anodes.

4.8.2 Manual

1. A manual shall be prepared for the anode bed system.
2. Manual shall contain:
 - a. Location of the system.
 - b. Rectifier data.
 - c. Inspection, testing, and energizing data.

4.8.3 Plot plan

1. A plot plan of the as-built anode bed system shall be prepared.
2. The plot plan shall show:
 - a. Exact location of the various components of the system including rectifiers, ground beds, bond boxes, cross bonds, test points and insulating devices with reference to the structures being protected.
 - b. Foreign lines and foreign flanges in the protected area.

5. INSTALLATION OF HORIZONTAL IMPRESSED CURRENT ANODE SYSTEMS FOR NEW AND REPLACEMENT TANK BOTTOMS

5.1 GENERAL REQUIREMENTS

5.1.1 General installation requirements

1. Cathodic protection systems shall be installed by a Contractor that has been engaged in this type of work for a period of not less than five years. Documentation of Contractor qualifications shall be available upon request.
2. Cathodic protection systems shall be installed under the supervision of a NACE-certified cathodic protection or corrosion specialist.
3. Electrical portion of the cathodic protection systems shall be installed in accordance with applicable local codes, the National Electrical Code, and API RP500.
4. Cathodic protection systems shall be installed in accordance with NACE SP0169 and RP0193 and API RP 651.

5.1.2 Personnel qualifications

1. Personnel engaged in installing cathodic protection surface anode beds shall be qualified by education, training, and experience to fulfill the requirements of this DEP.
2. Documentation of qualifications shall be available upon request.

5.1.3 Equipment and tools

1. Equipment, tools, and materials used to install surface anode beds shall be proper and adequate for the job.
2. Equipment and tools shall be maintained in a manner that ensures their safe use.
3. Safety equipment shall be used by installation personnel as required for the job.

5.1.4 Technical literature for materials

1. Manufacturer's technical literature shall be provided for each item required by this DEP.
2. Technical literature shall include the Manufacturer's name and shall verify that the material meets the requirements of this DEP.
3. If more than one item or catalog number appears on the technical literature, the proposed item shall be clearly identified.

5.1.5 Principal inspection

1. All equipment, materials, fabrications, and installations are subject to inspection, testing, and approval by the Principal.
2. Unless otherwise specified, a party designated by the Principal shall inspect installation work.

5.1.6 Drawings

Installation Contractor shall provide as-built drawings with details of the cathodic protection system installation. Details shall include types, models, and locations of the rectifiers, anodes, junction boxes, cables, and connections to tanks.

5.1.7 Permits

Installation Contractor shall obtain the required safety and work permits, including hot work permits, before proceeding with the installation work.

5.1.8 Safety

Installation Contractor shall be familiar with applicable government regulations and Shell safety guidelines and requirements and shall adhere to them.

Location of third party structure locations shall be performed before any excavation by making the required local contacts with One Call or equivalent service providers.

5.2 MATERIALS

5.2.1 General

Polyvinyl chloride (PVC) pipe and pipe fittings shall conform to NEMA TC2.

5.2.2 Anodes

1. Anodes shall be titanium wire that conforms to ASTM B 265, Grade I.
2. Wire shall be 1.6 mm (0.062 in.) diameter, coated with iridium based TIR 2000 mixed metal oxide, as supplied by Corpro Companies, Inc. or approved equal.

5.2.3 Anode pipe

1. Anode pipe shall conform to NEMA TC2.
2. Anode pipe shall be polyvinyl chloride (PVC) schedule 80, nominal DN 100 (NPS 4) diameter belled end pipe.
3. Joints of pipe shall have one end with male threads and one end with female threads.
4. Threaded ends shall be manufactured so that made-up joints have a flush outside surface. Slots on pipe shall conform to DEP Standard Drawing 41.032.

5.2.4 Anode vent pipe

Anode vent pipe shall be slotted PVC schedule 40, nominal DN 20 (NPS ¾) diameter.

5.2.5 Monitoring pipe

1. Monitoring pipe shall be slotted PVC schedule 80, nominal DN 65 (NPS 2-½) diameter, with modified acme threaded joints.
2. Slots on pipe shall conform to DEP Standard Drawing 41.067.
3. Joints of pipe shall have one end with male threads and one end with female threads. Threaded ends shall be manufactured so that made-up joints have a flush outside surface.

5.2.6 Pipe fittings

1. Pipe fittings shall be PVC.
2. Exposed ends of the anode and monitoring pipes shall have PVC caps.
3. If specified for visual leak detection, PVC caps on the monitoring pipe shall have 6 mm (¼ in.) diameter holes drilled at the 12 and 6 o'clock positions.

5.2.7 Cables

Anode header cable shall be #8 AWG stranded copper conductor with Duralar®/Halar® insulation or Principal-approved equivalent.

5.2.8 Junction boxes

1. Junction boxes shall be made of aluminum, galvanized steel, or reinforced plastic,
2. Junction boxes shall conform to NEMA 4X requirements, and
3. Junction boxes shall have wire terminals to accommodate the following:
 - a. Lead wire for corrosion coupon or probe with cathodic protection.
 - b. Lead wire for corrosion coupon or probe without cathodic protection.
 - c. Reference electrodes lead wires.
 - d. Tank lead wire.

5.2.9 Permanent reference electrodes

1. Permanent reference electrodes shall be zinc or copper/copper sulphate, as indicated on the project drawings.

2. Zinc electrodes shall be 35 mm x 35 mm x 230 mm (1.4 in. x 1.4 in. x 9 in.), pre-packaged in quick wetting backfill.
 - a. Zinc alloy shall conform to ASTM B-418-80, Type II.
 - b. Electrodes shall be Cathodic Protection Services Model AZR5AC or Principal-approved equivalent.
3. Copper/copper sulfate electrodes shall:
 - a. have a design life of 30 years and a stability of ± 5 millivolts under a 3.0 microamp load.
 - b. have an ion trap to prevent contamination
 - c. be shipped in a cloth sack with special backfill.
 - d. be Electrochemical Devices, Inc. Model UL-CUG-LW or Principal-approved equivalent.
4. Permanent reference electrodes shall be equipped with a number 14 AWG, standard copper lead wire with red high molecular weight polyethylene insulation.
5. Lead wires shall be of sufficient length to extend to the junction box without splicing.

5.2.10 Coupons

1. Coupons shall be bare, cold-rolled steel with a surface area of 865 mm² (1.34 sq. in.) and have two No. 12 AWG stranded wires.
 - a. Wires shall be silver soldered.
 - b. Wires shall be of sufficient length to extend to the junction box without splicing.
2. Coupons shall be M. C. Miller Co.[®] IR-Free Coupon, Model No. COU100 or Principal-approved equivalent.

5.3 INSTALLATION

5.3.1 General

1. Anode system shall not be installed until after the tank ring wall foundation has been constructed.
2. If the tank is to have secondary containment, the anode system shall not be installed until the secondary containment liner and a compacted single lift of sand is in place
3. If the tank is to have double bottom, the anode system shall not be installed until the HDPE liner is installed and 25 mm (1 in.) of sand is placed on the liner.
4. General system configuration of the anode system shall conform to DEP Standard Drawing 41.071.

5.3.2 Ringwall penetration

1. The ringwall shall be core drilled for access to the soil directly below the tank bottom.
2. The drilled core hole shall be of adequate size for the anode system piping.

5.3.3 Assembly of PVC pipes

1. All PVC pipe joints except end caps and threaded joints shall be glued with commercially available cement.
2. Joints to be glued shall be first cleaned with a commercially available solvent cleaner.
3. Cement shall not be applied until cleaner has dried.

5.3.4 Anode and monitoring pipes

1. Anode and monitoring pipes shall be installed as shown on DEP Standard Drawing 41.071.

2. Anode pipe installed under the tank within the ring wall shall be one continuous length of pipe.
3. Anode pipe that extends from the inside of the ring wall or rim to the termination point shall be solid (no slots).
4. Monitoring pipe installed under the tank shall be one continuous length of pipe.
5. Monitoring pipe that extends from the inside of the ring wall or rim to the termination point shall be solid (no slots).
6. After the anode and monitoring pipes are installed, the annular space between the pipes and the ringwall shall be epoxy grouted to produce a liquid-tight seal.

5.3.5 Anode assemblies

1. Anodes and associated lead cables, anode centralizers, and vent pipe shall be installed inside the anode pipe as an assembly.
2. Anode assembly shall be made by clamping the centralizers to the vent pipe at 2.1 m (7 ft.) to 2.4 m (8 ft.) intervals.
3. Vent pipe shall be long enough to extend along the entire length of the anode wire.
4. Centralizers shall consist of rigid metallic frames, 230 mm (9 in.) to 300 mm (12 in.) long. Centralizers shall be designed so that there is an annular clearance between the centralizers and the inside of the anode pipe of approximately 3 mm (1/8 in.).
5. Anode assembly shall be pulled into the anode pipe with a rope. Pulling operation shall be done in a manner that does not damage the anode assembly. Anodes shall be positioned as shown on DEP Standard Drawing 41.032.
6. A flexible tremie pipe to be used for installation of the coke breeze shall be fed with the anode assembly.
7. Centralizers shall keep the anode centered in the anode pipe during anode installation and pumping of coke breeze. Refer to DEP Standard Drawing 41.032.
8. Anode lead cable shall be continuous (no splices) from the anode assembly to the main header cable.
9. Anode header cable shall be connected to the anode using a copper crimp. Connection shall be epoxy sealed.

5.3.6 Coke breeze

1. Backfill installed in the anode pipe shall be calcined-petroleum coke with the following composition:

Moisture	0.05%
Volatiles	0.7% max
Ash	0.6% max
Carbon	Remainder
Bulk Density	1185 kg/m ³ (74 lbs/ft ³)

2. Coke breeze shall be installed in a slurry form.
3. After the anode assemblies are in place, the coke breeze slurry shall be pumped into the anode tube using the tremie pipe.
4. Tremie pipe shall be pulled back slowly as the coke breeze is pumped into the anode tube. This minimizes the possibility of voids in the anode tube.

5.3.7 Cable termination

1. Anode lead cables shall be spliced to the header cable and the header cable shall be run to the rectifier as shown on the project drawings.
2. Negative cable shall be connected to the tank in accordance with (11.3).

5.3.8 Permanent reference electrodes

1. Permanent reference electrodes shall be installed in accordance with the drawings.
2. Electrodes shall be installed with the following procedure:
 - a. Soak the cloth sack containing the electrode in a container of water for 15 to 20 minutes.
 - b. Dig a hole in the sand for placement of the electrode.
 - c. Place the electrode in the hole.
 - d. Backfill the hole with sand. Compact the sand around the electrode by hand.
 - e. Route the electrode lead wires to the conduit penetration in the ring wall.

5.3.9 Coupons

1. Coupons shall be polished to remove all corrosion before the coupons are inserted.
2. Edges of coupons shall be sealed so that their sides and back do not contact the soil.
3. Coupons shall be electrically isolated from each other.
4. Coupons shall be installed:
 - a. 50 mm (2 in.) below the surface of the compacted sand pad with the carbon steel element facing down.
 - b. As close as possible to the center of the tank.
 - c. With the aid of a PVC push pipe.
5. Coupon lead cables shall be routed to the junction box and one lead cable shall be connected to one of the tank test wires.
6. Coupons to be bonded to the tank will be designated by the Principal. Coupons shall be bonded using a connector as shown in the drawings.

5.3.10 Junction box

1. All reference electrode, coupon, and tank leads shall be terminated in the junction box.
2. Junction box shall be mounted near the ring wall.
3. Lead cables shall be terminated on the numbered, insulated terminal block. Identification number for each electrode and each coupon shall be recorded on the as-built drawing.
4. 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.

5.3.11 Backfilling

1. Backfilling operation within the ring wall shall be performed by the Tank Construction Contractor.
2. It shall be conducted in a manner that avoids damage to the anode system.
3. Backfilling operation shall be suspended if damage to the anode system is indicated by tests. See (5.4.3).

5.4 INSPECTION

5.4.1 General

1. Equipment and materials used for the cathodic protection system are subject to inspection and acceptance by the Principal.
2. Unless otherwise specified, installation work shall be inspected by the Principal.

5.4.2 Visual inspection

1. Anodes, reference electrodes, and cables shall be visually inspected prior to installation.
2. Wire and cable shall be free of breaks, kinks, and insulation flaws.

5.4.3 Resistance/potential considerations

1. Resistance and/or potential of the anode system shall be monitored during backfill operations.
2. Abrupt increases/changes in resistance/potential may indicate damage to the system components.
3. Backfilling shall cease for investigation/repair.

5.4.4 Installation deficiencies

1. Determination of system deficiencies shall be made by the Principal.
2. Deficiencies shall be corrected by the Installation Contractor.

5.5 COMMISSIONING

1. The cathodic protection system shall be commissioned with the following procedure:
 - a. Ensure that access pipes are free of obstructions.
 - b. Record native potential measurements at eight points around the tank shell and on 1.5 m (5 ft.) centers within the monitoring pipe installed under the tank.
 - c. Energize rectifiers on low tap settings to verify/determine the following:
 - Rectifier, shunt boxes, and other components are operational
 - Polarity of the cables is correct
 - Interference from stray currents is not present
 - Requirement for any remedial measures
 - d. Adjust rectifier output as necessary and record potential measurements.
 - e. Allow rectifiers to operate continuously for a minimum of seven days.
 - f. Repeat potential measurements with current applied (on) and interrupted (instant off). Use an interruption cycle of 30 seconds "on", 3 seconds "off."
 - g. Make adjustments until all points meet the NACE -850 millivolt CSE (copper sulphate electrode) polarized potential criterion or the 100 millivolt polarization shift criterion as directed by Shell.
2. A commissioning report along with the as-built drawings shall be submitted to Shell including all the data gathered, findings and recommendations.

6. INSTALLATION OF HORIZONTALLY BORED IMPRESSED CURRENT ANODE SYSTEMS UNDER EXISTING TANKS

6.1 GENERAL REQUIREMENTS

6.1.1 General installation requirements

1. Cathodic protection systems shall be installed by a Contractor that has been engaged in this type of work for a period of not less than five years. Documentation of Contractor qualifications shall be available upon request.
2. Cathodic protection systems shall be installed under the supervision of a NACE-certified cathodic protection or corrosion specialist.
3. Electrical portion of the cathodic protection systems shall be installed in accordance with applicable local codes, the National Electrical Code, and API RP500.
4. Cathodic protection systems shall be installed in accordance with NACE SP0169 and RP0193 and API RP 651.

6.1.2 Personnel qualifications

1. Personnel engaged in installing cathodic protection surface anode beds shall be qualified by education, training, and experience to fulfill requirements of this DEP.
2. Documentation of qualifications shall be available upon request.

6.1.3 Equipment and tools

1. Equipment, tools, and materials used to install surface anode beds shall be proper and adequate for the job.
2. Equipment and tools shall be maintained in a manner that ensures their safe use.
3. Safety equipment shall be used by installation personnel as required for the job.

6.1.4 Technical literature for materials

1. Manufacturer's technical literature shall be provided for each item required by this DEP.
2. Technical literature shall include the Manufacturer's name and shall verify that the material meets the requirements of this DEP.
3. If more than one item or catalog number appears on the technical literature, the proposed item shall be clearly identified.

6.1.5 Principal inspection

1. All equipment, materials, fabrications, and installations are subject to inspection, testing, and approval by the Principal.
2. Unless otherwise specified, a party designated by the Principal shall inspect installation work.

6.1.6 Drawings

Installation Contractor shall provide as-built drawings with details of the cathodic protection system installation. Details shall include types, models, and locations of the rectifiers, anodes, junction boxes, cables, and connections to tanks.

6.1.7 Permits

Installation Contractor shall obtain the required safety and work permits, including hot work permits, before proceeding with the installation work.

6.1.8 Safety

Installation Contractor shall be familiar with applicable government regulations and Shell safety guidelines and requirements and shall adhere to them.

Location of third party structure locations shall be performed before any excavation by making the required local contacts with One Call or equivalent service providers.

6.2 MATERIALS

6.2.1 Anodes

1. Anodes shall be titanium wire that conforms to ASTM B265, Grade I.
2. Wire shall be 1.6 mm (0.062 in.) diameter, coated with iridium based TIR 2000 mixed metal oxide, as supplied by Corrpro Companies, Inc. or approved equal.

6.2.2 Anode pipe

1. Anode pipe shall conform to NEMA TC2.
2. Anode pipe shall be polyvinyl chloride (PVC), Schedule 80, nominal DN 100 (NPS 4) diameter belled-end pipe.
3. Joints of pipe shall have one end with male threads and one end with female threads. Threaded ends shall be manufactured so that made-up joints have a flush outside surface.
4. Slots on pipe shall conform to DEP Standard Drawing 41.032.

6.2.3 Anode vent pipe

Anode vent pipe shall be slotted PVC, Schedule 40, nominal DN 20 (NPS $\frac{3}{4}$) diameter.

6.2.4 Monitoring pipe

1. Monitoring pipe shall be slotted PVC, Schedule 80, nominal DN 65 (NPS $2\frac{1}{2}$) diameter, with modified acme threaded joints.
2. Slots on pipe shall conform to DEP Standard Drawing 41.067.
3. Joints of pipe shall have one end with male threads and one end with female threads. Threaded ends shall be manufactured so that made-up joints have a flush outside surface.

6.2.5 Pipe fittings

1. Pipe fittings shall be PVC.
2. Ends of anode and monitoring pipes shall have PVC caps.
3. If specified for visual leak detection, the PVC caps on the monitoring pipe shall have 6 mm ($\frac{1}{4}$ in.) diameter holes drilled at the 12 and 6 o'clock positions.

6.2.6 Cables

Anode header cable shall be #8 AWG stranded copper conductor with Duralar®/Halar® insulation or Principal-approved equivalent.

6.3 INSTALLATION EQUIPMENT

6.3.1 Boring equipment

1. Boring equipment shall be a directional, horizontal, extended range, fluid-assisted boring system, suitable for trenchless installation in a variety of soil conditions.
2. Equipment shall not be of the water jet type due to possible wash outs and voids in the soil under the tank foundation.
3. Equipment shall be capable of being operated from a surface launch position that eliminates the need for a pit.
4. Equipment shall have an electronic location and wire line transmitter or sonde unit in the boring tool. Transmitter shall be used to obtain location and guidance information. Transmitter shall be able to be detected at all times.

6.3.2 Locating equipment

1. Locating equipment shall be a magnetometer/accelerometer guidance wire line type system. A radio beacon/receiver, "walk over" guidance system is unacceptable.

2. Locating equipment shall be able to be monitored at a display console by the directional drill operator from the operator workstation.

6.3.3 Computer tracking system

1. Data from the locating equipment shall be fed into a computer tracking system.
2. Computer tracking system shall monitor and display the depth of the tool, length of the bore, and time of day in real time.
3. Recorded data shall be submitted to Principal on request.

6.3.4 Electrical strike system

1. Boring equipment frame shall be equipped with an electrical strike system.
2. Electrical strike system shall be capable of indicating an electrical strike through both current and voltage sensing devices. The system shall include warning strobes on both drill frame and power unit.
3. Grounding mats for both the operator and helper shall be supplied. The mat for helper shall be positioned so that stepping off the mat is not required while performing his duties.
4. The electrical strike system shall be connected to the trailer so that the trailer is at the same potential as the system.
5. Standard safety cones for barricading the job site and three pairs of certified 20kV boots and gloves shall be available.

6.4 INSTALLATION

6.4.1 Underground utilities

After the position of the anode tube is determined, all underground utilities shall be located prior to any excavation or boring.

6.4.2 Fluid pit excavation

1. A fluid pit shall be excavated to contain all drilling fluids required for the horizontal boring.
2. Drilling fluids used shall be environmentally benign.
3. Drilling fluids shall remain on site unless otherwise specified by the Principal.

6.4.3 Ringwall penetration

1. Tank ringwall shall be core drilled for access to the soil directly below the tank bottom.
2. The drilled core hole shall be of adequate size for the anode system piping.

6.4.4 Performing bore

1. Horizontal bore equipment shall be set into place and anchored.
2. The boring process shall include monitoring and logging of the head elevation at all times to ensure that the bore does not come closer than 0.6 m (2 ft.) from the tank bottom. The boring process shall be stopped if the elevation of the head cannot be determined.
3. Boring shall be performed so that no voids are created in the soil foundation.
4. Bore hole shall traverse the entire distance under the tank and exit as shown on the project drawings.

6.4.5 Assembly of PVC pipes

1. All PVC pipe joints, except end caps and threaded joints, shall be glued with commercially available cement.
2. Joints to be glued shall be cleaned first with a commercially available solvent cleaner.

3. Cement shall not be applied until cleaner has dried.

6.4.6 Anode and monitoring pipes

1. Anode and monitoring pipes shall be installed using the boring equipment.
2. Each pipe shall be attached to the drill stem and pulled back through the borehole. Operator shall continuously monitor the thrust pullback to ensure the pipes are not damaged during installation.
3. If required, the borehole diameter may be enlarged using a back reamer drill.
4. Anode pipe installed under the tank shall be one continuous length.
5. Anode pipe that extends from the inside of the ring wall or rim to the termination point shall be solid (no slots). Pipe shall be terminated as shown on DEP Standard Drawing 41.031.
6. Monitoring pipe installed under the tank shall be one continuous length.
7. Monitoring pipe that extends from the inside of the ring wall or rim to the termination point shall be solid (no slots). Pipe shall be terminated as shown on DEP Standard Drawing 41.031. After the anode and monitoring pipes are installed, the annular space between the pipes and the ringwall hole shall be epoxy-grouted to produce a liquid seal.

6.4.7 Anode assemblies

1. Anodes and associated lead cables, anode centralizers, and vent pipe shall be installed inside the anode pipe as an assembly.
2. Anode assembly shall be made by clamping the centralizers to the vent pipe at 2.1 m (7 ft.) to 2.4 m (8 ft.) intervals.
3. Vent pipe shall be long enough to extend along the entire length of the anode wire.
4. Centralizers shall consist of rigid metallic frames, 230 mm (9 in.) to 300 mm (12 in.) long. Centralizers shall be designed so that there is an annular clearance between the centralizers and the inside of the anode pipe of approximately 3 mm (1/8 in.).
5. Anode assembly shall be pulled into the anode pipe with a rope. Pulling operation shall be done in a manner that does not damage the anode assembly. Anodes shall be positioned as shown on DEP Standard Drawing 41.032.
6. A flexible tremie pipe to be used for installation of the coke breeze shall be fed with the anode assembly.
7. Centralizers shall keep the anode centered in the anode pipe during anode installation and pumping of coke breeze. Refer to DEP Standard Drawing 41.032.
8. Anode header cable shall be continuous (no splices) from the anode assembly to the main system header cable.
9. Anode header cable shall be connected to the anode using a copper crimp. Connection shall be epoxy sealed.

6.4.8 Cables

1. The location of all groundbed cables shall be indicated e.g., by groundbed marker posts located at both extremities of the groundbed.
2. Cathodic protection cables shall be handled and laid with extreme care as damage to the insulation and/or sheathing may result in premature cable failure. During installation the cable reel shall be supported so that cable can be pulled from the reel without causing kinking or twisting.
3. The cable type and size shall be checked for compliance with the design. Underground cables shall be identified by color or tags.

4. All trenched in cables shall be installed at the specified depth in sand padding. Cable warning tape and/or cable tiles shall be used.
5. A cable run shall be of one continuous length. Joints shall not be acceptable except with the written permission of the Principal.
6. When allowed, cable joints shall be made using an approved splice and seal, using splice encapsulation kits. The joints shall be sealed to prevent moisture penetration and ensure electrical isolation from the environment. Submerged joints require seals suitable for the water pressures and environment to which they can be subjected.
7. Any damage to the insulation or sheathing of all cables, including anode connection cables, shall be reported to the Principal.

6.4.9 Coke breeze

1. Backfill installed in the anode pipe shall be calcined petroleum coke with the following composition:

Moisture	0.05%
Volatiles	0.7% max.
Ash	0.6% max.
Carbon	Remainder
Bulk Density	1185 kg/m ³ (74 lbs/ft. ³)

2. Coke breeze shall be installed in a slurry form.
3. After the anode assemblies are in place, the coke breeze slurry shall be pumped into the anode tube using the tremie pipe.
4. Tremie pipe shall be pulled back slowly as the coke breeze is pumped into the anode tube. This minimizes the possibility of voids in the anode tube.

6.4.10 Cable termination

1. Anode header cables shall be spliced to the main header cable. The header cable shall be run to the rectifier as shown on the project drawings.
2. Negative cable shall be connected to the tank in accordance with (11.3) of this DEP.

6.5 INSPECTION

6.5.1 General

1. Equipment and materials used for the cathodic protection system are subject to inspection and acceptance by the Principal.
2. Unless otherwise specified, installation work shall be inspected by the Principal.

6.5.2 Visual inspection

1. Anodes and cables shall be visually inspected prior to installation.
2. Wire and cable shall be free of breaks, kinks and insulation flaws.

6.5.3 Installation deficiencies

1. Determination of deficiencies shall be made by the Principal.
2. Installation deficiencies as determined by the Principal shall be corrected by the Installation Contractor.

6.6 COMMISSIONING

Impressed current cathodic protection system shall be commissioned with the following procedure:

1. Prior to energizing the rectifier, with the tank filled to a minimum of 1.5 m (5 ft.) of water or product, native state potential measurements between the tank bottom and each reference electrode shall be measured and recorded. Potential measurements shall be made using a calibrated voltmeter with minimum 10 megohm input impedance.
2. Ensure that access pipes are free of obstructions.
3. Record native potential measurements at eight points around the tank shell and on 1.5 m (5 ft.) centers within the monitoring tube installed under the tank.
4. Energize rectifiers on low tap settings to verify/determine the following:
 - a. Rectifier, shunt boxes, and other components are operational.
 - b. Polarity of the cables is correct.
 - c. Interference from stray currents is not present.
 - d. Requirement for any remedial measures.
5. The rectifier output shall then be increased sequentially until design current is supplied to the tank. Individual power feed circuits will be checked and the rectifier will be allowed to operate for a minimum of 4 hours before further potential testing is conducted.
6. After the rectifier has been in continuous operation for a minimum of 4 hours, "On" and "Instant Off" (polarized) potentials shall be measured at all permanent reference electrodes and in eight evenly spaced locations around the tank perimeter. An interruption cycle ratio of no less than 10:1 shall be used.
7. Final adjustments to the system shall be made after sufficient time is allowed for polarization (minimum of seven days). For ambient temperature tank fluid, the polarization criteria shall be a potential shift of at least 100 millivolts more negative than native state potentials or an "Instant Off" (polarized) potential of -0.85 volt vs. copper/copper sulfate reference electrode. For elevated temperature tank fluid, criteria shall be provided by Shell.
8. A commissioning report shall be submitted by the Contractor with "As-Built" drawings, all data, an analysis of the data, and recommendations for operation and maintenance of the system.

6.7 SUBMITTALS

6.7.1 Proposals

1. Proposals shall provide a lump sum price for performing work as defined in this specification.
2. A detailed listing of all services and materials to be provided shall be provided.
3. Design calculations shall be provided indicating current density, system design life, anode spacing, total current required, and the rating of the rectifier to be provided.
4. Any exceptions to this specification and associated typical detail drawings shall be clearly documented and supported with technical justification.
5. Any work assumed to be performed by others within the scope of this specification, including, but not limited to, trenching, concrete placement, installation of structures or foundations, provision of power, installation of electrical wiring or conduit, shall be clearly defined.
6. A listing of the personnel to be used on the project and their qualifications and training shall be provided. All personnel shall have required safety training.
7. Timing to perform all work shall be provided.

6.7.2 Project documentation

Upon receipt of a Purchase Order from the Principal, submittals shall be provided and include the following:

1. An Introduction detailing the work to be performed
2. A Bill of Materials showing all materials to be used on the project
3. All Design Calculations indicating current density, system design life, anode spacing, total current required and rectifier rating
4. A Project Data Book providing Manufacturer's product data sheets and technical literature for all materials listed in the Bill of Materials, including, but not limited to:
 - a. Anodes
 - b. Cables and wire
 - c. Coke breeze
 - d. Junction box and all related hardware and appurtenances
5. Technical literature shall include the Manufacturer's name and specifications verifying that the material meets the requirements of this DEP. If more than one item or catalog number appears on a technical brochure, the proposed item shall be clearly identified.
6. Site specific Project Drawings in the format provided in this specification under (7.8).
7. An "Exception section" listing any variances to this specification, including revised drawings.
8. Equipment instruction manuals, parts lists, installation details and associated drawings.

7. INSTALLATION OF IMPRESSED CURRENT GRID SYSTEMS FOR ON GRADE STORAGE TANK BOTTOMS

7.1 GENERAL REQUIREMENTS

7.1.1 Application

This section covers requirements for installation of cathodic protection impressed current systems beneath new on-grade storage tank bottoms using mixed metal oxide titanium ribbon anode.

This technical specification shall apply to the design, furnishing of materials, and installation of an impressed current cathodic protection grid system directly under on-grade storage tank bottoms. This specification is applicable to the following tank bottom configurations: (1) new on-grade storage tanks with or without a secondary containment liner, (2) existing on-grade storage tanks with double steel bottoms and a liner over the old tank bottom and (3) existing on-grade storage tanks with the old bottom removed and equipped with or without a secondary containment liner beneath the new steel tank bottom.

This specification shall not apply to tank configurations where the tank foundation consists of concrete underlain by piers or pilings. In these cases, cathodic protection shall not be employed, but instead will utilize an above grade asphalt or bitumen/sand pad in contact with the tank bottom to mitigate corrosion.

7.1.2 References

Applicable requirements in the following referenced standards shall be considered an integral part of this DEP. Unless otherwise specified, the latest edition/revision of the referenced standards is applicable.

1. API RP 500
2. API RP 651
3. ASTM B265
4. ASTM B418
5. ASTM C144
6. ASTM C778
7. ASTM D512
8. ASTM D516
9. ASTM G51
10. ASTM G57
11. NACE RP0193
12. NEMA Standard 250 (Type 4X and 3R Enclosures)
13. NFPA NEC 70

7.1.3 General installation requirements

This section covers requirements for installation of cathodic protection impressed current systems beneath new on-grade storage tank bottoms using mixed metal oxide titanium ribbon anode.

1. This technical specification shall apply to the design, furnishing of materials, and installation of an impressed current cathodic protection grid system directly under on-grade storage tank bottoms. This specification is applicable to the following tank bottom configurations:
 - a. new on-grade storage tanks with or without a secondary containment liner,
 - b. existing on-grade storage tanks with double steel bottoms and a liner over the old tank bottom and

- c. existing on-grade storage tanks with the old bottom removed and equipped with or without a secondary containment liner beneath the new steel tank bottom.
2. This specification shall not apply to tank configurations where the tank foundation consists of concrete underlain by piers or pilings. In these cases, cathodic protection shall not be employed, but instead will utilize an above grade asphalt or bitumen/sand pad in contact with the tank bottom to mitigate corrosion.
3. All cathodic protection design, materials and technical services shall be supplied by a qualified Cathodic Protection Contractor who has a minimum of 5 years of experience in cathodic protection of on-grade storage tank bottoms. Tank bottom cathodic protection systems shall be installed by a Contractor that has been engaged in this type of work for a period of not less than five years. Documentation of qualifications shall be available upon request.
4. Installation of cathodic protection systems shall be carried out under the supervision of a NACE-certified cathodic protection or corrosion specialist.
5. Electrical portion of the cathodic protection system shall be installed in accordance with applicable local codes, the National Electrical Code, and API RP500.
6. Cathodic protection systems shall be installed in accordance with the latest revision of NACE RP0193 and API RP 651.
7. Design Criteria: The cathodic protection system shall be designed by a Cathodic Protection Specialist or registered Professional Engineer and shall be site specific based on the following:
 - a. Current density of 2 mA per 929 cm² (1 ft²) for tanks operated at ambient temperature and 4 mA per 929 cm² (1 ft²) [minimum] for tanks operated at elevated temperatures.
 - b. Cathodic protection system shall have a minimum design life expectancy of 40 years.
 - c. Ribbon anode spacing for tanks with or without a secondary containment liner shall be 1 m (3 ft.) separation between adjacent ribbon anodes and 450 mm (1½ ft.) from the tank ringwall for anode-to-tank bottom distances of at least 230 mm (9 in.) The ribbon anode spacing will decrease for anode-to-tank bottom distances less than 230 mm (9 in.).
 - d. Conductor bar spacing shall be a maximum of 4.6 m (15 ft.) separation between adjacent conductor bars and a maximum of 2.3 m (7½ ft.) from the ringwall.
8. Criteria for Protection: The criteria for cathodic protection shall be as set forth in NACE RP0193 and shall be either -100 millivolts of polarization or an IR free voltage of -0.85 volts DC vs. a copper/copper sulfate reference electrode.

7.1.4 Personnel qualifications

1. Personnel engaged in installing cathodic protection systems shall be qualified by education, training, and experience to fulfill requirements of this specification.
2. Documentation of qualifications shall be available upon request.

7.1.5 Equipment and tools

1. Equipment, tools, and materials used to install the cathodic protection systems shall be proper and adequate for the job.
2. Equipment and tools shall be maintained in a manner that ensures safe use.
3. Safety equipment shall be used by installation personnel as required for the job.

7.1.6 Permits

Installation Contractor shall obtain the required safety and work permits, including hot work permits, before proceeding with the installation work.