Basic Engineering Study for
Aung Sinkha Development Project Phase 1A

SPECIFICATION FOR ONSHORE CATHODIC PROTECTION

PTTEP

PTT Exploration and Production Public Company Limited
Aung Sinkha Development Project Phase 1A
Basic Engineering

- [x] 1. APPROVED
- [ ] 2. APPROVED with comments (Proceed to IFB)
- [ ] 3. Review with comments
- [ ] 4. Rejected to be reissued
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Signed: Petch Jawbanjong

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COMMENT NO.	SECT.	PAGE & REF.	CLIENT COMMENTS (REVIEWER)	T.EN RESPONSE	COMMENT STATUS OPEN/CLOSED

Comment by*

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1. INTRODUCTION

1.1 Project Overview

PTTEP International Limited (PTTEPI) intends to develop and produce hydrocarbon from the offshore Block M3 named Aung Sinkha (ASK) field. The project is under Production Sharing Contract (PSC) with Myanmar Oil & Gas Enterprise (MOGE) signed on 7th August 2004 while the PSC effective date was on 1st November 2004.

PTTEPI as an Operator had performed 2,842 line-km of 2D seismic, 619 km^2 of 3D seismic, and drilled 11 Exploration and Appraisal wells. After successful exploration and appraisal drilling campaigns in 2015, PTTEPI completed the ASK Field Development Plan and submitted it to MOGE for approval. MOGE approved ASK Field Development Plan in April 2021.

The ASK field is located offshore in the Gulf of Moattama, Myanmar, as illustrated in Figure 1-1. The field is located approximately 70 km from Land Fall Point (LFP) at Daw Nyein village and 200 km south-west of Yangon with a water depth range of 15 - 25 meters.

The feed gas will be transported from two (2) offshore wellhead platforms through an offshore export pipeline to ASK Onshore Processing Facilities (APF) located in Daw Nyein village for processing. The sales gas after processing will be exported to the tie-in point at Gas Receiving Station no. 2 (GRS#2), of Domestic Gas to Power Pipeline Development Project, nearby the APF. The condensate will be kept in onshore storage tanks before loading, transporting/ offloading to customers. The design of the surface facilities will be based on a Contractual Daily Capacity (CDC) of 60 MMscfd with provision for future expansion to 100 MMscfd. The gas production is planned to start up by Q4 of 2025.

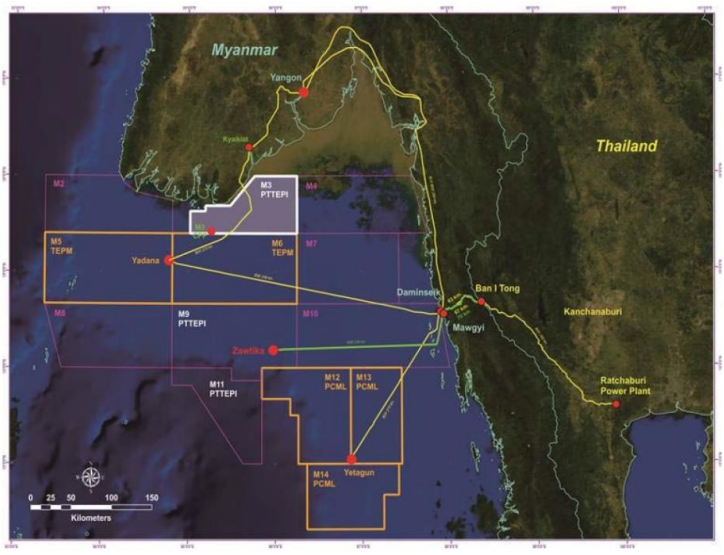

Figure 1-1: Block M3 – Aung Sinkha Field, Offshore Myanmar

The development of Phase 1A consists of the following facilities, as illustrated in Figure 2.0.

- 2 Wellhead Platforms (WPA-1 and WPA-2)
- 1 Intra-field pipeline which links between WPA-1 and WPA-2
- 1 Multiphase export pipeline to transport combined fluid of WPA-1 and WPA-2 to ASK Onshore Processing Facilities (APF)
- ASK Onshore Processing Facilities (APF)
- Onshore pipelines from APF to Gas Receiving Station#2 (GRS#2)
- Onshore infrastructure i.e. condensate offtake facilities, accommodation, Personal Material Transfer Facilities, telecommunication system, roads, etc.
- APL01 Onshore pipeline from landfall to APF

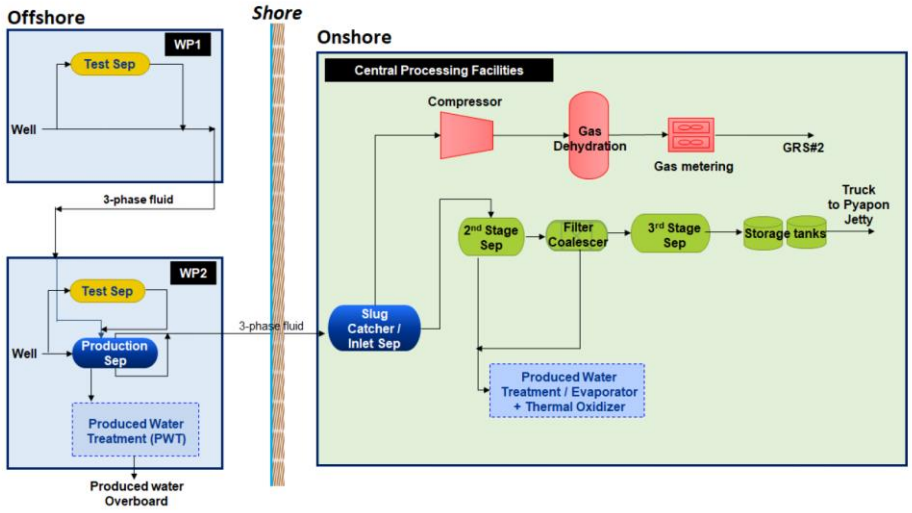

Figure 1-2: Field Block Flow Diagram

1.2 Abbreviation

AC	Alternating Current
AEML	Approved Equipment and Material List
BV	Block Valve Station
CIPS	Close Interval Potential Survey
CP	Cathodic Protection
CSE	Copper/Copper Sulphate Reference Electrode
DC	Direct Current
DCVG	Direct Current Voltage Gradient
FOC	Fibre Optic Cable

GPS	Global Positioning System
GPT	Garlock Pipeline Technology
HDD	Horizontal Directional Drilling
ICCP	Impressed Current Cathodic Protection
IP	Internet Protocol/Ingress Protection
LEF	Longitudinal Electric Field
LNG	Liquefied Natural Gas
mA	Milliampere
OD	Overall Dimension
PRCI	Pipeline Research Council International
PTTEP	PTT Exploration and Production Public Company Limited
ROW	Right of Way
SCADA	Supervisory Control and Data Acquisition
SSD	Solid State Decoupler
UTM	Universal Transverse Mercator

1.3 The Parties Involved

COMPANY	PTTEP International Limited
CONTRACTOR	For the purposes of this document, CONTRACTOR shall mean any person who has entered into a formal written contract with the COMPANY for the performance of work and or services for and or in connection with the COMPANY for and or in connection with ASK Development Project, or any part thereof.
SUBCONTRACTOR	For the purposes of this document, SUBCONTRACTOR shall mean any person to whom the performance of any part of the WORK is subcontracted including subcontractors of any tier.
SUPPLIER or VENDOR	For the purposes of this document, SUPPLIER or VENDOR shall mean a supplier of any of; skid mounted assembly, packaged equipment and associated items, itemized (tagged) materials and equipment, linepipe and associated materials, non-itemized (bulk) materials and all other

materials and things, for use in the ASK Development Project or for handover to the COMPANY. The term VENDOR shall include vendors of any tier.

2. GENERAL INFORMATION

2.1 Purpose of Document

This specification defines specification for onshore cathodic protection in Basic Engineering Study for Aung Sinkha Development Project Phase 1A. All pipelines are operated and in "Severe Sour Service" condition.

Cathodic protection, coatings, supply of flanges, fittings and additional requirements for the supply of bends and other items pertaining to subsea pipeline systems are presented in separate specifications.

2.2 Language

The English Language shall be used in all project communications, reports, correspondences, drawings, specifications, calculations, and invoices etc., submitted to COMPANY. All drawings and documents shall be annotated in S.I. units with other units in parenthesis, where applicable.

In this document, the words should and shall have the following meanings:

Approval	The authorization in writing given by the COMPANY to the Contractor on a procedure or to proceed with the performance of a specific part of the work without releasing in any way the Contractor from any of his obligations to conform with the technical specifications, requisitions, etc. The words "Approve", "Approved" and "Approval" shall be construed accordingly
Purchase Order	The order issued by Purchaser consisting Terms and Conditions and attachments thereto including but not limited to Data Sheets and Drawings, Specifications including referenced documentation therein, and all other documents and attachments.
Shall	Used to indicate that a provision is mandatory.

Should	Used to indicate that a provision is not mandatory but is recommended as good practice.
May	Used to indicate that a provision is optional
PPS	Designates Project Particular Specification detailing the additional tests and requirements or the possible modifications to the present specification, based on the particular design conditions or the local legislation of the project.

2.3 Reference Document

This specification defined as the Project Particular Specification (PPS) shall be read jointly with the following COMPANY's general specification:

MM-ASK-1A-APF-COR-SPE-0001	Specification for DC Decouplers and Over Voltage Protector
MM-ASK-1A-APF-COR-SPE-0002	Specification for Insulating Flange Kits and Monolithic Isolation Joint
MM-ASK-1A-APF-COR-SPE-0004	Specification for Cathodic Protection System Installation
MM-ASK-1A-APF-COR-SPE-0006	Specification for Soil Resistivity Survey & Testing
MM-ASK-1A-APF-COR-SPE-0007	Specification for Internal Corrosion Monitoring
MM-ASK-1A-APF-COR-PHI-0001	Cathodic Protection Design Philosophy
MM-ASK-1A-APF-COR-RPT-0002	Cathodic Protection System Conceptual Design Report
MM-ASK-1A-APF-COR-MTO-0001	Provisional Material Take Off for Cathodic Protection System
MM-ASK-1A-APF-COR-SPE-0003	Material Specification for Cathodic Protection System
MM-ASK-1A-APF-COR-DTS-0001	Datasheet for Cathodic Protection System DC Decoupler and Over Voltage Protector
MM-ASK-1A-APF-COR-DTS-0002	Datasheet for Cathodic Protection System Pipeline Insulation Joints and Gasket Kits
MM-ASK-1A-APF-COR-TYP-0001	Typical Installation Details for Cathodic Protection System Cover Sheet
MM-ASK-1A-APF-COR-TYP-0002	Typical Installation Details for Cathodic Protection System Index

MM-ASK-1A-APF-COR-TYP-0003	Typical Exothermic Welding Installation Details
MM-ASK-1A-APF-COR-TYP-0004	Typical Test Station Installation Details (Type A)
MM-ASK-1A-APF-COR-TYP-0005	Typical Test Station Installation Details (Type F)
MM-ASK-1A-APF-COR-TYP-0006	Typical Test Station Installation Details (Type D)
MM-ASK-1A-APF-COR-TYP-0007	Typical Test Station Installation Details (Type CR for Foreign Pipeline)
MM-ASK-1A-APF-COR-TYP-0008	Typical Test Station Installation Details (Type E)
MM-ASK-1A-APF-COR-TYP-0009	Typical Test Post Guard Rail
MM-ASK-1A-APF-COR-TYP-0010	Typical Sacrificial Anode Installation Details (Type AM)
MM-ASK-1A-APF-COR-TYP-0011	Typical DC Decoupler Installation Details
MM-ASK-1A-APF-COR-TYP-0012	Typical Test Station and Bond Box Details
MM-ASK-1A-APF-COR-SCH-0001	CP/AC Schematic Diagram and Test Facility Schedule

The present PPS provides confirmations and/or modifications and/or additional requirements to the COMPANY's general specification. The matters covered in the general specification, which are not mentioned under this specification, shall apply in full.

2.4 Regulation, Standards and Code of Practice

The Aung Sinkha Development Project shall be designed primarily in accordance with PTTEP's general specifications (PEGSs) and corporate specifications, as appropriate, and the applicable Myanmar legislative requirements. Where such standards are not applicable, accepted international codes/industry good engineering practices will be adopted. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published on the effective date of a contract.

Any deviation from the standard shall be documented for derogation and proper permission from PTTEP in writing.

The order of precedence of the applicable documents shall be:

1) Government Laws, Rules and Regulations

2) Purchase Order/ Service Order/ Contract Documents

3) Data Sheet, Drawings and Project Particular Specification (PPS)

4) PTTEP Engineering General Specification (PEGS)

5) Other COMPANY specifications, standards, and documents

6) International Codes and Standards

In case of conflicts/contradictions between the various codes, standards, regulations and specifications, unless otherwise agreed or decided by COMPANY, it is understood that the more stringent requirement shall apply.

Exceptions to or deviations from this specification are not permitted unless they have been raised during the bidding stage and previously accepted in writing by the COMPANY. For this purpose, requests for substitutions or changes of any kind shall be completed with all pertinent information required for COMPANY assessment. COMPANY's approval, nevertheless, will not, in any way, relieve the SUPPLIER's responsibility to meet the requirements of the industry Codes and Standards referred to and amended herein, in the event of a conflict.

2.5 CONTRACTOR/ SUPPLIER’s Responsibility

All work shall be carried out in compliance with this specification, reference documents, Codes and Standards, and Specifications listed unless otherwise stated. The SUPPLIER’s submissions should provide sufficient data to allow the equipment to be evaluated against the total life and field costs estimated to be incurred. In this respect, equipment capital cost, weight, size, cost of spares, utility and power requirements, maintenance, reliability and production downtime costs may be considered.

SUPPLIER is required to have relevant proven prior experience in the fabrication and testing of line pipes, which is to be supplied.

3. CODES, STANDARDS AND REGULATIONS

The following codes, standards and specifications (latest edition) have been used or/are referred to in this specification. In the event of conflict the Contractor shall inform Owner/Consultant.

NACE SP0169	Recommended Practice “Control of External Corrosion on Underground or Submerged Metallic Piping Systems”

NACE SP0177	Recommended Practice “Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control System”
NACE SP0286	Recommended Practice “The Electrical isolation of Cathodically Protected Pipelines”
NACE TM0497	Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
10008-STD-6-COR-022-R00	Design of Cathodic Protection of Buried Pipeines
10008-STD-6-COR-023-R00	Design of Cathodic Protection of Onshore Facilities

4. SITE CONDITIONS

The Environment outside buildings (climatic) at normal operating conditions in per the Weather Forecast Bureau recorded temperature minimum/maximum of 10°C and 42.2°C respectively and humidity of 11% to 95.2%.

The Environment inside buildings at normal operating conditions are temperature within air conditioned Control Rooms, in the range of minimum/maximum 22°C -25°C.

5. DESIGN SCOPE

Unless the contract specifies otherwise, the cathodic protection project shall include all of the tasks listed below.

- During the site survey, all relevant information/documents concerning the following shall be collected:

    i) The corrosivity of the environment along the pipeline right of way including, soil resistivity values, soil pH and the presence or otherwise of active soil bacteria.

    ii) The presence of nearby metallic structures such as pipelines and railway lines whether cathodically protected or not, and where appropriate these structures - to-soil potentials via accessible points and above ground appurtenances, with the permission of the Company and structure Company/operator.

    iii) Details of facilities likely to emit or cause stray current interference.

    iv) Details of any and all high/medium voltage transmission lines and systems DC current carrying, including details of electric power stations, transformer stations and any system which when in operation or under fault conditions may present

a risk to the coated pipeline system. This shall include recording the Longitudinal Electrical Field (LEF) where appropriate.

v) Availability of electrical power for the supply of cathodic protection stations.

vi) Identification of non-hazardous areas for the installation of electrical equipment, and possible locations for anode ground beds.

- All documents and information concerning the characteristics of the pipeline to be protected shall be collected including; diameter, length, material of construction, quality of the coating material, field joint coating and anything which is likely to influence the design of the cathodic protection system.
- A detailed study shall be carried out and a report covering the following aspects shall be issued to the Company for approval:

  i) Estimation of the corrosion risk based on the collected data and site measurements

  ii) Economical and technical evaluation of various cathodic protection systems for the protection of the subject pipeline.

  iii) Justifying the selected design with design hypotheses, particularly for the insulation values of the coatings, and effect of ageing.

  iv) Description of the methodology used for the design.

  v) Design notes justifying the sizing and layout of equipment: anodes, transformers-rectifiers, cables, etc.

  vi) List of materials, including assembly accessories, and the corresponding technical specifications, schematic diagrams and detailed equipment diagrams

  vii) List of possible suppliers.

  viii) Detailed installation drawings, indicating the location of insulating joints, electrical bonding to be installed, layout of different types of equipment and their relevant installation procedures, wiring diagrams for electrical equipment

  ix) Instructions proper for installations, indicating all precautions to be taken. Particular emphasis shall be placed on the construction of ground beds, connections on anode circuits, insulations between protected and non-protected parts, insulations between parts protected by different systems, remedial

solutions to interferences between the pipeline to be protected and neighbouring works, reference electrode installations at fixed points.

As a general rule, the location of electrical equipment in hazardous areas shall be avoided. If this is impossible, the use of equipment corresponding with the safety classification of the area in question will be specified.

6. GENERAL REQUIREMENTS

6.1 Required Certification Level for Personnel

Design of CP systems shall be carried out by competent certified personnel. The level of certification of the individuals involved in the design shall be as follows:

6.1.1 Design personnel

- Design work to be carried out by certified personnel to NACE CP level 3 or above, or Corrosion specialist
- 10 years minimum relevant past and proven experience in the design of cathodic protections systems for oil & gas pipelines.

6.1.2 Survey personnel

- Survey Lead
  - i) Survey work shall be carried out under the direction of a certified personnel holding NACE CP Technician (level 2) certification.
  - ii) 10 years minimum relevant past and proven experience in the surveying and testing of cathodic protections systems for oil & gas pipelines.
- Team Lead
  - i) Survey lead work shall be performed by a certified personnel holding NACE CP Tester (level 1).
  - ii) 3 years minimum relevant past and proven experience in the surveying and testing of cathodic protections systems for oil & gas pipelines.

The qualification of personnel shall be demonstrated by the Contractor to the Company before commencement of the job.

6.2 Quality Assurance Procedures

At the beginning of the design, a Quality Plan must be drawn up by the Contractor, detailing all the actions related to the cathodic protection calculation, definitions of the systems to install, material supplies, checking and reception of equipment, and the commissioning on site. These shall be described with detailed procedures. All the calculations, systems, and materials that will be used shall be approved by the Company.

6.3 Sub-Contractors

The choice of sub-contractor(s) for any part of cathodic protection design and installation is subject to Company. approval. Notwithstanding the above provision, the Contractor remains responsible for the successful completion of the cathodic protection project.

6.4 Legal and Administrative Issues

The following defines the Contractor's and Company responsibilities when dealing with legal and administrative issues:

- If local legislation requires preparation of a legal file before installation of a cathodic protection system, the preparation of the file is the Contractor's responsibility. However, the Company is responsible for transmitting the file to the competent administrative body. The Company shall also receive the results of the enquiry.
- Contractor is responsible for providing the Company with all the information and documents required dealing with the property matters, including extracts of land survey maps and delimitation on the land survey maps of the land to be acquired, including the temporary and/or permanent rights of way to be acquired. However, the Company is responsible for answering any question related to these matters. The Company shall likewise deal with the acquisition of land and rights of way and settle all additional costs and compensation for any loss of crops.
- Contractor is responsible for carrying out formalities with the local energy distribution Company if the installations require a power supply from the local distribution network. However, the network extension and connection costs shall be borne by the Company.

7. SPECIFIC REQUIREMENTS

The pipelines and station facilities shall be provided with a CP design, stray DC interference evaluation and mitigation from cross bonding with existing pipelines.

7.1 Site Survey for The Design of Cathodic Protection

The survey result shall provide sufficient detail to establish the location accurately by using GPS coordinate system WGS84.

7.1.1 Soil resistivity and pH measurement

At 1 km intervals, soil resistivity shall be surveyed along the right of way at depths of 1m, 2m, 3m, 5m and 10m. At the preselected areas for deep anode ground bed installation, the soil resistivity at the 0.5m, 1m, 2m, 3m, 5m, 10m, 15m, 20m, 25m, 30m, 40m, 50m, 60m, 70m, 80m, 90m and 100m shall be measured.

The Werner 4-pin method shall be conducted in perpendicular to proposed pipeline and anode ground bed. The survey area shall avoid the existence of underground metallic structure according to ASTM G57 and NACE SP0502. The Werner test equipment shall be AC voltage type to protect the adverse effect of polarization.

The surface soil pH value shall be taken at pipeline depth of every 1 km interval along the pipeline.

7.1.2 Source of electrical interference

The presence of nearby metallic structures such as pipeline, rails etc. (whether cathodically protected or not) and their pipe-to-soil potentials, access points to the existing metallic structures, the presence of works likely to emit stray currents, the presence of high voltage cables or transmission lines, electric power stations, transformer stations and any system which, if faulty, may damage cathodic protection installations, coatings, or the pipelines shall be collected. During the site survey, the risks of DC or AC stray currents or telluric currents shall be evaluated.

At 1km intervals under power lines, the longitudinal electric field (LEF) shall be measured by using as a minimum a 10m test lead arrangement parallel to power lines.

7.2 Cathodic Protection

The design of cathodic protection system shall be performed to ensure that both temporary (during construction phase) and permanent cathodic protection are applied to the pipeline.

The anode for the permanent cathodic protection system shall have a design life of at least 20 years.

A temporary cathodic protection system shall be immediately provided after backfill and until the permanent cathodic protection system is commissioned. The protection level shall meet the NACE criteria. The magnesium sacrificial anodes with high potential maybe utilized for this purpose.

The connections of sacrificial anodes to pipelines shall be made at the permanent test stations and the sacrificial anodes shall be disconnected prior to the commissioning of the impressed current CP systems.

Permanent cathodic protection shall be provided by an impressed current CP system (ICCP). The transformer rectifiers and anode ground beds shall be installed at station facilities. Additional land for ground bed installation which is remote from the pipeline ROW will be identified during detailed design. Good lengthwise conductivity along cathodically protected sections shall be ensured to allow for efficient cathodic protection current return path.

Test posts shall be installed every 1 kilometre spacing for monitoring purposes. At river crossings and HDD sections, two test posts shall be provided at the start and end of crossing/section respectively.

Isolating joints shall be installed for strategic segregation of pipeline sections when required. The joints shall allow better monitoring of corrosion activities or provide isolation from unwanted current drainage and shall be specified in detailed design.

All isolation joints and isolation flanges shall be protected against insulation damage by suitable DC decoupling devices. Spark gap type devices are not allowed in any cases.

In order to avoid any adverse effect between either zinc or any grounding systems and cathodically protected pipelines, DC decoupling devices shall be installed in series between them to isolate the DC electrical circuit. The direct connection of either zinc or grounding systems to the cathodically protected pipeline shall be not allowed.

CP readings and CP rectifier units reading shall be connected to the Company's SCADA system. Pipe to soil reading, rectifier condition (output current and voltage) shall be monitored and transmitted through the SCADA system. Transformer rectifier units shall have installed SCADA controlled output current interrupter units.

7.2.1 Design criteria for the CP system

The cathodic protection system shall have adequate capacity to achieve a minimum "polarized" potential on the buried steel piping and appurtenances as follows:

i) In aerated soils, more negative than -0.850 volts with respect to a standard saturated copper-copper sulphate (CSE) positioned in the soil directly above or adjacent the pipeline

ii) In deaerated soils or where sulphate reducing bacteria are present, more negative than 0.950 volts with respect to a standard saturated copper-copper sulphate (CSE) positioned in the soil directly above or adjacent the pipeline or structure.

The definition of "polarized potential" is listed in the NACE International Standard Practice SP0169 "Control of External Corrosion of Underground or Submerged Metallic Piping."

The maximum "OFF" potential shall be less than –1.20 volts CSE. The maximum "ON" potential shall be less than -3.00 volts CSE. The maximum "OFF" cycle during the interrupted surveys shall be 3 seconds.

Where necessary, especially in the station facilities, other criteria for protection in NACE SP0169 may be evaluated during the commissioning and adjustment; however, the maximum "ON" and "OFF" potentials shall not be exceeded.

The cathodic protection systems shall be designed for a minimum 20 year service life.

The minimum current density for three-layer polyethylene (3LPE) coated pipeline shall not be less than 0.01 mA/m^2 in non-AC mitigation areas and 0.03 mA/m^2 for AC mitigation areas where zinc ribbon/grounding is installed.

For CP design calculations, the maximum coating resistance shall be 33,333.00 $\Omega.m^2$ for 3LPE and 10,000 $\Omega.m^2$ FBE.

For CP design calculations, the native potential of pipeline shall be -0.50 volts (CSE), the maximum allowable negative voltage shift at the drain point shall be 0.7 volts. The minimum negative voltage shift shall be 0.35 volts at the end or midpoint of CP systems.

The impressed current anode beds for the mainline will be designed to be electrically remote from the mainline and foreign metallic structures. For earth potential rise calculations, the maximum allowable voltage shift at the pipeline shall be 3.00V.

The DC current output capacity of the transformer rectifiers shall be 50% greater than the design requirement and the DC voltage output capacity shall be 50% greater than the design requirement.

7.2.2 DC Interference and Mitigation

Bonding boxes shall be added wherever the new pipeline crosses or becomes close to other underground utilities and existing pipelines to protect the pipeline from DC interference.

The following data of interfering/interfered pipelines is required for DC interference study as a minimum:

- Layout Maps and Details
- Pipeline Dimensions and Depth
- Coating Resistance
- Location of Existing Cathodic Protection Systems
- Details and Operating Characteristics of Existing CP Systems
- Location of Insulating Joints and Flanges
- Resource Person
- AC Power Availability (from Electric Utility)

8. DRAWING

The typical detail drawings shall be developed by Contractor and approved by Company.

9. PRODUCTS

9.1 General Description of Materials

The materials shall include, but are not limited to, the following:

- Transformer Rectifiers
- Impressed Current Anodes
- Coke Breeze Backfill
- Junction Boxes
- Direct Burial DC Cable
- Electrical Isolation Devices
- Exothermic Welding Materials
- Insulated Conductors
- Test Stations
- Permanent Reference Electrodes
- Magnesium Anodes
- Zinc Ribbon
- Zinc Electrodes and Grounding Cells
- Sacrificial Anode Backfill
- Shunts, Resistors

- Surge Protection Units
- DC Decoupler Units
- Splicing Materials and Coatings
- Remote Monitoring Hardware and Software

9.2 Anodes

9.2.1 Impressed Current Shallow Anodes - Conventional and Distributed

Anodes shall be centreconnected tubular type, mixed metal oxide (MMO) on titanium substrate with epoxy caps.

9.2.2 Impressed Current Deep Anodes

Anodes shall be centreconnected tubular type, mixed metal oxide (MMO) on titanium substrate with epoxy caps.

9.2.3 Magnesium Anodes

Magnesium anode alloy specifications shall be rated as High Potential grade. The anodes shall be pre-packaged with backfill, and the lead wire shall be silver soldered to the core and coated with epoxy. The anodes shall conform to the following anode chemistry:

- Al = 0.0100% max.
- Mn = 0.50 to 1.3% max.
- Zn = 0.002% max.
- Cu = 0.02% max.
- Si = 0.05% max.
- Ni = 0.001% max.
- Fe = 0.03% max.
- Other = 0.05% each or 0.30% max. total
- Mg = Remainder

9.2.4 Zinc Anodes

Zinc electrode composition shall conform to ASTM B418 (Latest Edition) Type II. The anodes shall be pre-packaged with backfill and the lead wire shall be silver soldered to the core and coated with epoxy.

9.2.5 Zinc Ribbon

Zinc anode ribbon shall conform to ASTM B418 (Latest Edition) Type II; 1/2" x 9/16" ribbon (0.6 lb./ft) with a 0.130" diameter or higher capacity depending on calculation according to

NACE SP0177. Calculation shall be submitted to Company for approval. Steel core wire may be used for gradient control grids and mats at test stations, block valves and fences.

9.2.6 Zinc Grounding cell

Zinc grounding cell shall be consist of two (2) or four (4) 2 inch x 2 inch x 6inch (50mm.x 50 mm. x 1,525 mm) zinc electrodes separated by 1 inch (254.mm) spacers.

Each electrode shall conform to ASTM B418-(latest edition) Type II, with a normal weight of sixty (60) pounds (27.21 kg) of zinc. The grounding cells shall be pre-packaged with backfill.

9.3 Anode Backfill

9.3.1 Shallow Impressed Current Anode Backfill

Shallow subsurface ground beds shall be backfilled with calcined fluid petroleum coke breeze, Loresco Type SWK, or equal, unless the local conditions make its use impractical (i.e., swampland).

9.3.2 Deep Impressed Current Anode Backfill

Calcined petroleum coke breeze, Loresco Type SC-3, or equivalent, shall be used to backfill deep anode ground beds.

Properties of backfill shall be:

- Minimum specific gravity of 1.90
- Minimum bulk density of 1,040 kg/m3
- Small-diameter spherical shape with approximately 98% passing a 20-mesh
- screen and more than 80% retained on a 100-mesh screen
- Fixed carbon content in excess of 98%
- Volatile contest less than 0.3%

9.3.3 Sacrificial Anode Backfill

The sacrificial anode backfill shall consist of the following composition: Magnesium anode by weight:

- Ground Hydrated Gypsum: 75%
- Powdered Bentonite: 20%
- Anhydrous Sodium Sulphate: 5%

Zinc anode (by weight);

- Ground Hydrated Gypsum : 50%
- Powdered Bentonite : 50%

The backfill shall have a grain size such that one hundred percent (100%) is capable of passing through a 20-mesh screen and a 100-mesh screen shall retain fifty percent (50%).

The pre-packaged anode backfill mixture shall be firmly prepared around the anodes /electrode(s) within a cotton bag.

9.4 Junction Boxes

Junction boxes shall be required at mainline insulating joints, at strategic locations for possible bond connections to foreign pipelines, negative drain connections to foreign rectifiers, im-pressed current anode terminations for deep and distributed systems, etc.

9.4.1 Enclosures

Junction boxes located in non-hazardous BV station areas shall be constructed of 11 gauge galvanized steel or 0.125 gauge anodized aluminum, meet IP67 standard, and suitable for post mounting. Alternate materials, such as fiberglass enclosures, may be submitted for review and approval by Company. Junction boxes shall be rain tight (i.e., IP67). If junction boxes are located in hazardous areas, they shall be stainless or galvanized steel enclosures rated for an NEC Class 1, Division 1 and 2, Group D environment. Provisions for trimming resistors of suitable resistance and wattage shall be included on each branch circuit.

9.4.2 Shunts

Each branch circuit shall have a metering shunt with an accuracy of plus or minus one percent (1%). The minimum rating shall be five (5) amperes minimum capacity (e.g., Holloway Type SW, 5 A - 50 mV). All shunts shall be similar in design and be appropriately sized for the specific application.

Shunts shall have separate current and potential taps and shall be mounted on the Bakelite panel in the junction box.

A total circuit shunt and individual branch circuit shunts shall be installed in each unction box, suitably rated for the specific load.

9.4.3 Bus Bars

Bus bar injunction boxes shall be solid copper bars not less than 1/8" x 3/4" (3.18 m x 19.05 mm), mounted on phenolic panel.

9.4.4 Phenolic Panel

Fully engraved, 3/16" (4.76 mm) Grade XXX black phenolic panel shall be included.

9.4.5 Trimming Resistors

Adjustable power resistors shall be appropriately designed for the specific circuit. As a minimum, a safety factor of 2 shall be utilized in the wattage calculations for the design power rating.

9.5 Conductors/Cables

All conductors shall be insulated copper and all lead wires are to be of sufficient length to avoid the necessity of underground splices.

If splicing becomes necessary, a suitable compression fitting and hydraulic press tool, manufactured by Burndy, or equal, shall be used. The connections shall be waterproofed with epoxy splice kits manufactured by 3M, such as Type 90-B1 for "Y" splices and Type 82-A1 for in line splices, or equal. The low contact resistance shall be tested.

Outer sheath (Jacket) of conductors/cables shall be coloured as follow:

- Positive cable is RED
- Ground cable and Zinc cable are GREEN with YELLOW
- Negative cable is BLACK
- Foreign cable is BLUE
- SSD cable is BROWN
- FOC cable is GRAY
- Impressed current anode cable is BLACK
- Sacrificial anode cable is RED
- Reference electrode cable is YELLOW

9.6 Subsurface Cables

Lead wires for each individual impressed current shallow anodes shall be 10 mm^2 (#8 AWG), seven (7) strand copper with high molecular weight polyethylene insulation (HMWPE) as a minimum.

The DC positive cable from the rectifier to the anode terminal box, the DC negative cable from the rectifier or negative junction box to the pipeline and any pipe bond cable shall be a minimum 35 mm^2 (#2 AWG) seven (7) strand copper with XLPE/PVC and XLPE/SWA/PVC insulation for outdoor in station area.

The insulation shall be specifically designed for CP purposes, shall comply with ASTMD1248 Type I, Class C, Grade 5, black high molecular weight polyethylene.

The thickness of insulation shall comply to IEC standards.

Lead wire for pre-packaged magnesium anodes shall be insulated copper strand 10 mm^2 with XLPE/PVC insulation and XLPE/SWA/PVC insulation for outdoor in station facility areas.

Lead wire for zinc grounding cells shall be a minimum of 25 mm^2 (#3 AWG) stranded copper with XLPE/PVC and XLPE/SWA/PVC insulation for outdoor in station area. insulation; however, the lead wires shall be site specifically sized.

Test lead wires for test station shall be sized or per the typical test station type drawing (typically 10 mm^2 or 16 mm^2) with XLPE/PVC insulation.

Lead wire used for any AC mitigation installation shall be appropriately sized for the maximum fault current and duration and be insulated with XLPE/PVC and XLPE/SWA/PVC insulation for outdoor in station area.

9.6.1 Deep Well Anode Lead Wires

The lead wire splices shall be avoided. The down hole lead wires for the deep anodes shall be insulated with a Halar (E-CTFE) or Kynar (PVDF) primary insulation with a polyethylene outer jacket. The anode lead wires shall comply with the following:

- Size No. 6 AWG (10mm^2) minimum requirement
- No. of Strands: 7
- Conductor OD: 0.146 inch (3.7 mm)
- Insulation: Halar or Kynar
- Insulation Thickness: 0.20 inch (5.08 mm)
- Jacket: HMWPE (black)
- Jacket Thickness: 0.065 inch - 0.080 inch (1.65 mm -2.03 mm)

9.7 Electrical Isolation Devices

Requirements for devices to electrically isolate the pipeline from foreign metallic structures shall include casing spacers, casing and wail sleeve end seals, insulating joints, flange insula-tion kits, and insulating unions.

9.7.1 Casing Spacers

Casing spacers shall be non-metallic material, manufactured from UV resistant polypropyl-ene, of high impact strength, excellent compressive strength, high dielectric strength and wide temperature range as manufactured by GPT or equal.

9.7.2 End Seals

End seals for both casing and wall sleeves shall be a modular, mechanical type consisting of expandable, interlocking synthetic rubber links shaped to continuously fill and seal the annular space between the pipe and casing or sleeve opening. Each seal shall be provided with stainless steel threaded fasteners. Centring blocks shall be included in the lower supporting segments to prevent cold flow and settlement of the pipeline.

Service and size designations of the seal shall meet the instructions of manufacturer for each specific application. End seals shall be Link-Seal as manufactured by Thunder line GPT, or equal.

9.7.3 Insulating Joints

All IJs shall be of the proper ANSI rating, grade of pipe material, wall thickness, and temperature rating to satisfy the pipeline design and testing criteria. The insulating and sealing material shall also be compatible with the through put product of the specific pipeline. Each IJ shall be subject to acceptance criteria, including pressure tight and electrical resistance tests, after the installation.

9.7.4 Insulating Flanges

See MM-ASK-1A-APF-COR-SPE-0002 Specification for Insulating Flange Kits and Monolithic Isolation Joint

9.7.5 Insulating Unions

All Insulating Unions (IU) shall be of the proper ANSI rating, grade of pipe material, wall thickness, and temperature rating to satisfy the pipeline design and testing criteria.

The insulating and sealing material shall also be compatible with the through put product of the specific pipeline. Each IU shall be subject to acceptance criteria, including both pressure tight and electrical resistance tests, after the installation.

9.7.6 Mainline Valves (MLV), Metering & Facilities and Scraper Stations

To minimize the undesirable galvanic corrosion effects and CP current requirements for the buried pipeline, the following may be utilized at the MLV, Metering & Facilities and Scraper Stations:

Use of galvanized steel grounding rods, etc.

Use of PVC coated steel or non-metallic electrical conduits for underground service.

Use of galvanized steel fence posts.

Use of insulated copper conductors for underground bonding, where approved by Electrical Design.

The materials used in such installations shall be selected according to Project Specifications and approval by Company.

9.7.7 DC Decoupling Devices

See MM-ASK-1A-APF-COR-SPE-0001 Specification for DC Decouplers and Over Voltage Protector

9.8 Test Stations

Test station shall be installed approximately every km along the mainline and at each rectifier, block valve, foreign line crossing, major water crossings, metering station, insulating joint, cased crossing, foreign bond, etc.

The test post number, type, KP and UTM coordination shall be specifying at the tag of each test post.

9.9 Reference Electrodes

Permanent reference electrodes shall be installed at all the BV stations, insulating joints coupon test stations and foreign line crossings stations. The permanent reference electrodes shall be copper-copper-sulphate (CSE), unless contamination of chlorides is anticipated. In these areas, silver-silver chloride electrodes shall be used.

In certain situations, zinc reference electrodes may also be used, if approved by Company.

The permanent reference electrodes shall be rated for a minimum of 40 years of continuous service. The reference electrode shall have end caps with 50 ft. minimum length of at least 2.5 mm^2 (#14 AWG) stranded copper conductor XLPE/PVC insulated, 10 mV stability with a 3 microampere load, and an operating temperature range of 0ºC to 60ºC

9.10 Venting Facilities for Deep Anode Bed

Non-metallic, perforated vent pipes such as thermoplastics and reinforced thermosets shall be used. The perforation shall be throughout the active zone. The perforation range shall be in be-tween 150-230 micron to avoid gas blockage and debris intrusion.

10. INSTALLATIONS

10.1 Shallow Impressed Current Anode Installations

10.1.1 Storage of Materials

All materials and equipment to be used in construction shall be stored in such a manner to be protected from detrimental effects from the elements.

10.1.2 Shallow Anodes

All shallow anodes shall be specified on the Project Drawings by the Contractor. Conventional beds shall be installed at a site specific designed separation distance between the mainline and the first anode. Distributed anodes installed in the stations shall maintain a minimum dis-tance of 6 m away from the underground piping and other structures.

10.1.3 Depth

Vertical anodes shall be installed in minimum 150-mm diameter augured holes, to a depth of 3 m to 12 m, depending on the optimum soil resistivity, etc. Horizontal anodes shall be installed at a minimum of depth of 2 m.

10.1.4 Placement

Anodes shall be lowered into the augured hole or trench with care and shall be centered in the hole prior to backfilling. Anodes shall at no time be lowered using their lead wires.

10.1.5 Backfill

For vertical anodes, a minimum of 300-mm of backfill shall be placed in the bottom of the hole prior to placement of the anode. The annulus between the anode and the augured hole shall then be backfilled with coke breeze to a depth of 600-mm above the anode. Pea gravel may be installed to 300-mm below grade. The drilling spoils may be used to backfill the remainder of the hole to grade.

For horizontal anodes, coke breeze shall be poured around each individual anode, extending out 300-mm from each end of the anode.

The coke breeze backfill shall be thoroughly compacted carefully around all anodes to avoid damaging the anode. If either vertical or horizontal anodes are under black top or concrete, a suitable frame and cover shall be utilized at grade level, with pea gravel installed to 300-mm below grade, to allow for anode venting.

10.1.6 Handling

Anodes shall not be handled by the lead wires nor dropped during transport or placement. Anodes shall be lowered into excavations by ropes or equivalent means.

10.1.7 Anode Wire

Underground cables, conduits, wires and connections shall be buried at a minimum depth of 600-mm below grade, with a 300-mm minimum separation from other underground structures if necessary, the cables shall be installed in a conduit for mechanical protection.

10.1.8 Connection

All distributed anodes lead wires will be of sufficient length to avoid the necessity of underground splices. All distributed anode leads shall be run directly into a junction box with suitable individual shunts and resistor provisions. If splicing becomes necessary, connections shall be made as previously specified. Company shall approve all splices.

Lead wires for conventional shallow anode bed installations for the mainline shall be spliced to a header cable conductor. The connection shall be made with a suitable Burndy "Crimpit" or equal and Hi Press hydraulic compression tool. The splices shall be electrically insulated and waterproofed with 3M epoxy splice kits (e.g., 90-B1 for “wye” and 82-A1 for straight splices) or a layered system of 3M Putty Tape, 3M 23 Splicing Tape, 3M 33+ vinyl Plastic Tape and 3M Scotchkote Liquid Coating.

10.2 Deep Impressed Current Anode Installations

10.2.1 Storage of Materials

All materials and equipment to be used in construction shall be stored in such a manner as to be protected from detrimental effects from the elements. Materials and equipment shall be stacked well above ground level and protected from the elements as appropriate.

Damage to anode electrical cable insulation shall also be avoided. Handling of anodes between storage and job sites shall be kept to a minimum.

10.2.2 Deep Anode Drilling

Deep well beds shall be installed as per the NACE International SP0572 "Design, Installation, Operation and Maintenance of Impressed Current Deep Anode Beds".

Permit requirements, imposed by the appropriate authority(s) having jurisdiction, shall also be followed.

As a minimum, the outside circumference of the 300 mm (~12 in.) OD surface casing shall have a 50 mm (~2 in.) cement seal and the inactive hole volume shall be backfilled to an elevation of 15 m (~50 ft.). The top 15 m shall be plugged with a cement grout. The vent pipe shall be extended to a well-ventilated area and installed above the flood elevation.

The anode holes shall be drilled by means of a rotary drill using circulating water base drilling mud if necessary. A pilot hole using a hand auger or other suitable means shall first be drilled to a depth of 3 m (~10 ft.) to ensure that the location is free from any underground utility structures or obstructions.

10.2.3 The hole shall be drilled to accommodate the 300 mm (~12 in.) surface casing to a minimum depth of 6 m (~20 ft.). The remainder of the well shall be drilled using a bit to obtain a nominal 260 mm (~10 in.) diameter hole. The hole shall be drilled to the minimum depth indicated on the site specific drawings prepared by the Contractor and approved by Company. The hole

Mud and Cuttings

Drilling mud and cuttings shall be disposed of Company approved sites. Contractor shall be responsible for the proper disposal of the mud and cuttings.

10.2.4 Notice

Preparation of the anode hole and loading of anodes and other equipment in the hole shall be done in the presence of Company.

10.2.5 Geological Log

As the hole is being drilled, a geological log shall be recorded that indicates the subsurface material and layers that are encountered from grade to the total depth.

10.2.6 Resistance Log

The well shall be resistance-logged after drilling to identify the optimum positioning for the individual anodes (i.e., the active column of the hole) Company shall approve of the actual anode positioning prior to the anode loading.

10.2.7 Abandonment

If an excavation is abandoned for any reason, the Contractor shall be responsible for ensuring that the work site is cleared and that the excavation is fully backfilled, compacted and made safe and in accordance with applicable regulatory requirements.

10.2.8 Deep Anode Installation

Depending on the site specific design, a PVC (e.g., Sch. 40) or steel casing shall be required. The casing will typically be a 6 m long by 0.3 m OD (~20 ft. long by 1 ft. OD) PVC surface

casing. Drilling conditions may require that a casing extend to the total depth of the well. In this situation, the active column shall be encased in steel and the inactive column shall be encased in PVC. Proposed casings must be approved by Company.

Deep ground beds shall consist of anodes installed to maximum depths of 100 m (~330 ft.). The top of the uppermost anode should be at a minimum depth of 30 m (~100 ft.), with a minimum centrelines spacing of approximately 3 m (~10 ft.) between anodes.

The anode positioning for each well shall be site specific determined by design and actual resistance log measurements. Any volume of the well not utilized below the actual position of the first anode shall be filled with spoils and coke breeze.

10.2.9 Deep Anode Bed Hardware

Anode leads shall be unrolled in such a manner as to ensure no spiralling or sharp bends. The lead lengths shall be verified and the end of each anode lead labelled.

Sufficient slack shall be maintained in the lead cables to prevent excessive tension as a result of backfill sediment. Just prior to installation, an electrical continuity check shall be taken from the anode end to the end of the lead cable.

Anodes shall not be handled by the lead wires nor dropped during transport or placement. Anodes shall be lowered into excavations by ropes or equivalent means.

The Contractor shall visually inspect the insulation on the lead cables for abrasion or other damage to the insulation and cable as the anode is lowered into place. Under no circumstances shall splices or any form of cable repair be allowed on the anode lead cable from the point of connection at the anode, to the top of the deep anode hole.

Company shall reject all anodes with damaged insulation or cable and they shall not be installed.

The vent pipe, anodes, anode centring devices, and anode supports will be assembled and installed in the bore hole. All anodes shall be installed in sequential order and cables shall be tagged and numbered similarly at their termination inside the anode lead junction box. Anode No.1 shall be used at the bottom of the anode string.

The vent pipe shall be a minimum 25.4 mm ID Sch. 40 PVC, with 50 mm long x 0.15 mm wide slots parallel to the longitudinal centrelines, with centre to centre spacing of 150 mm and 25.4 mm in circumferential distance from the preceding slot in the active column.

All plastic casing and vent pipe shall be glued and screwed together at the joints.

10.2.10 Backfill

Pre-soaking of packaged anodes with potable water shall be performed to minimize the absorption of mud.

All contaminates which could create extensive electrolytic discharge from the anodes and lessen their life shall be removed by flushing the excavation with water until the water is fairly clear. The excavation shall then be filled with the proper amount of the petroleum coke slurry by pumping from the bottom up to the required depth to displace the drilling mud and water. The pumping process shall be done via a temporary fill pipe continuously (i.e., not the vent pipe) and allowed to settle to the proper elevation. Inspection shall be made to ensure the active volume is completely filled with coke breeze.

The observation of the change in anode resistance to earth shall be used to determine whether the backfill material has been placed around the anode.

10.2.11 Completion

Upon completion of the installation of the anodes and backfill, the remainder of the annulus of the hole, to grade, shall be filled with spoils and cement grout. The individual anode lead wires shall be run to the anode lead junction box mounted adjacent to the rectifier unit and the vent pipe permanently mounted above the flood elevation. The ground bed resistance to earth shall be measured, via a suitable AC resistance meter, and submitted to Company.

10.3 Anode (for supplying CP current)

10.3.1 Type Zinc Anode (SACP)

Any brand and Model which complies with the following Specification below:

1. MIL-A-18001 or ASTM B418 Type I – for salt water and brackish water application.
2. ASTM B418 Type II – high purity for underground and fresh water use application.

MIL SPEC	**ASTM B-418-01**	
A-18001K	**TYPE I**	**TYPE II**
Al 0.10-0.50%	Al 0.10-0.50%	Al 0.005% max
Cd 0.025-0.07%	Cd 0.025-0.07%	Cd 0.003% max
Fe 0.005% max	Fe 0.005% max	Fe 0.0014% max
Pb 0.006% max	Pb 0.006% max	Pb 0.003% max
Cu 0.005% max	Cu 0.005% max	Cu 0.002% max
Si 0.125% max	---	---

MIL SPEC	ASTM B-418-01	
A-18001K	**TYPE I**	**TYPE II**
Zn remainder	Zn remainder	Zn remainder

10.3.2 Type High-potential alloy magnesium anode (SACP)

Any brand and Model which complies with following Specification below:

Element	High-potential
Al	0.010%max
Mn	0.50 - 1.30%
Zn	---
Si	0.05%max
Cu	0.02%max
Ni	0.001%max
Fe	0.03%max
Other (total)	0.30%max
Mg	remainder

10.4 Zinc Ribbon/Zinc Ground mat

ASTM B418 Type II – high purity for underground and freshwater use.

10.5 Rectifier and Cable Installation

10.5.1 Electrical Service, Remote Operating and Monitoring Communication

The Contractor shall provide electrical service for rectifier operation, a communication link for remote operating and monitoring for each unit. The Contractor shall be responsible for furnishing and installing the necessary wiring, conduits, cables, meter panels, splice boxes and equipment for AC power and the remote monitoring communication, hardware and software.

10.5.2 Rectifier Units

Rectifier tests shall be conducted following the installation and backfilling of the anode bed and associated wiring. These tests shall ensure that the cables are electrically continuous and properly connected with particular attention to ensure correct polarity of the installation.

10.5.3 Placement

The rectifier units shall be specified on the Project Drawings by the Contractor.

10.5.4 Mounting

The rectifier units shall be securely mounted with the enclosure grounded with a minimum 35 mm^2 (# 2 AWG) copper conductor.

10.5.5 Wiring

All AC wiring shall conform to the cited reference standards.

10.5.6 Cable Installation

All underground wires, cables, and connections shall be installed at a minimum 600mm Below final grade with a minimum separation of 300-mm from other underground structures.

All above grade cables and anode lead wires shall be placed in rigid galvanized steel conduit (RGS). Insulating bushings shall be used at the ends of all conduits. The RGS conduit shall extend a minimum 300-mm below grade. If necessary, the underground cables shall be installed in conduit for mechanical protection.

10.5.7 Cable Connections to Steel Pipe

Cable to steel pipe connections for all CP and AC mitigation devices shall be installed by exo-thermic welding.

Coating materials shall be removed from the surface over an area just sufficient to make the connection, and the surface cleaned with solvents to remove any coating residue. The metal surface shall be cleaned to white metal by grinding or filing prior to welding the conductor. A resin impregnated grinding wheel shall not be used for grinding purposes. After grinding, the cleaned surface shall be dressed with a fine fabric.

The conductor shall be welded to the structure by the exothermic process of a 15 g maximum charge (with a copper sleeve fitted over the conductor where required). The maximum size of conductors welded to pipeline shall be 16 mm^2 (#6 AWG). The multiple set of conductors welded to pipeline shall be allowed. Adjacent welds shall have a minimum of 300-mm separation. Welds shall be a minimum of 300-mm away from pipe welds.

Only sufficient insulation shall be removed from the conductor to allow placing in the welding mold. After the weld has cooled, all slag shall be removed, and the weld shall be tested with a sharp hammer blow to ensure proper metallurgical bond. All defective welds shall be removed and replaced at a minimum distance of 300-mm away from the original location. The entire area shall be coated in accordance with the underground corrosion coating specifications.

All CP cables connected to the pipeline shall be completely wrapped around the pipeline and tied off (e.g., half hitch). A minimum 500-mm length of cable shall extend past the half hitch on top of the pipeline, with the end exothermic welded to the steel.

10.6 Electrical Isolation Devices

10.6.1 Casing Spacers and End Seals

All casing spacers and end seals shall be installed as approved by Company and in accordance with the manufacturers' recommendations. Prior to the "tie-in" to adjacent buried piping; the pipe to casing resistance shall be measured via a suitable resistance meter to ensure that adequate electrical isolation is achieved. After the “tie-in”

and backfilling, additional electrical tests shall be performed to ensure electrical isolation is maintained. Records of these tests shall be provided to Company.

10.6.2 Through Wall Sleeves

All piping penetrations through walls shall be provided with a sleeve and end seals as approved by Company. Installation shall be in accordance with the manufacturers' recommendations. The assembly shall be tested to ensure that the piping is electrically isolated. Records of these tests shall be provided to Company.

10.6.3 Insulating Joints, Unions and Flange Kits

Insulating joints, unions and flange kits shall be installed in accordance with the manufacturers’ recommendations, and as approved by Company. Electrical tests shall be performed before and after the installation to ensure adequate isolation is achieved. Records of these tests shall be provided to Company.

10.7 Test Stations

10.7.1 Location and Types

Test stations shall be installed directly above the pipeline where practical. Test stations for the pipelines shall be installed approximately every 1 km, at each rectifier, block valve, foreign line crossing, metering station, insulating joints, cased crossing and at foreign bond and both ends of HDDs and major crossings locations.

Access paths shall be made for operators in swamps or distant areas.

IR drop-current span (4 wire type) test stations shall be installed at approximately 8 km intervals and at any pipelines rectifier site not located near pipelines insulating joints (completely on one side of the drain cable).

IR drop test stations shall be engineered so that 1 ampere of current produces a 1 mV voltage drop across the potential tap leads.

Adjacent test leads shall have a minimum separation distance of one pipe diameter, except for the span between the IR drop potential tap leads.

Pipelines test stations at insulating joints, MLV, Metering & Facilities and Scraper Stations and pipeline crossings shall be equipped with permanent reference electrodes. The permanent reference electrode shall be installed close to pipeline as much as possible.

Test stations shall be installed at representative locations throughout the station facilities to ensure an adequate sampling of the protected underground piping and structures.

Test station types shall be, but not limited to, as follows:

- CP Potential
- Cased Crossing
- Foreign Line Crossing and Bonding locations
- Current span
- Insulating Joint
- Sacrificial Anode Installation

10.7.2 Test Leads

Potential leads shall be a minimum 10 mm2 (#8 AWG) insulated solid. Current carrying leads for sacrificial anode installations shall be a minimum of 10 mm2 (#8 AWG) insulated stranded copper wire. All leads shall be connected to the pipe by exothermic weld. One (1) coil of slack wire shall be wrapped around the pipe. As a minimum, a pair of test leads shall be installed at each test station.

10.7.3 Conduit

The test station conduit shall extend a minimum 600 mm below grade. Approximately 150 mm below the base of the conduit, one (1) coil of each of the test leads and electrode cable shall be made to provide slack in the wire should backfill settlement occur. During compaction, care shall be exercised to avoid damaging the wire and cable insulation.

10.7.4 Inspection

After the test lead connection is backfilled, the test station shall be checked to verity its performance and the resulting pipe-to-soil potentials, calibration data (IR drop), line current, etc., shall be recorded and transmitted to Company.

10.7.5 Cable Connections to Steel Pipe

Cable to steel pipe connections shall be established by the exothermic weld process, with a 15 g maximum charge, as previously described in this specification.

10.8 Pre-packaged Sacrificial Anodes

If approved, pre-packaged sacrificial anodes may be installed to augment the impressed current CP system at selected areas. The anodes shall be positioned a minimum distance of 3 m from the pipe on minimum 3 m centre. The top of the anode shall be, as a minimum, at the bottom of the pipe elevation. Deeper anode depths with anodes positioned vertically above one another with 300-mm separation may be used to take advantage of favourable soil resistivity.

Test stations shall be included for sacrificial anode installations (used for CP, not AC mitigation). A minimum 6 mm^2 (#10 AWG) stranded copper conductor with XLPE/PVC cover shall be utilized as an anode header cable and terminated in a test station. The circuit may be connected in the test station through a shunt. A potential tap test lead shall also be included in the test station.

10.9 Gradient Control Wires

Zinc ribbon for the pipeline shall be installed in the pipeline trench, where determined necessary, for AC mitigation. The ribbon shall be positioned at the bottom of the trench, at a mini-mum of 100 mm off the pipe. Where necessary, a pair of zinc ribbons shall be installed in the trench, with one on each side of the pipeline. The maximum interval between connections to the pipeline shall be 1 km.

All Zinc Ribbon connections to the pipeline shall be via suitably sized DC decoupling devices.

Where dry/rocky trench conditions are encountered, the zinc anode backfill mixture as previously described may be used. The backfill should encompass a 50 mm^2 cross sectional area around the ribbon.

10.10 DC Decoupling Devices

Properly sized DC decoupling devices shall be installed at each insulating joint, insulating flange and where required at MLV, Metering & Facilities and Scraper Stations, etc. They shall be specified on the project drawings. Conductor sizes for these devices shall be site specific de-signed for the maximum anticipated fault current and duration.

10.11 Gradient Control Mats

Gradient control mats shall be installed at any above grade pipeline appurtenance, including test stations, valve sterns, fences (both sides), etc., where hazardous AC conditions are antici-pated from nearby AC power systems. The criteria for hazardous conditions are noted in Sec-tion 3 of reference document NACE SP0177 and in the design criteria in this specification. All above ground appurtenances within 300m of high voltage AC power systems shall be evaluat-ed for the necessity of a gradient control mat.

11. COMMISSIONING

11.1 Scope

The work shall be performed under the direction of the certified personnel at NACE CP specialist (level 4) or NACE corrosion specialist, and in accordance with the provisions in the spec-ifications, applicable plans, codes, and standards, and subject to other terms and conditions of Project's Contract Documents.

11.2 Description

The commissioning shall include, but not be limited to the following:

- Native Potential Profile
- CP System Commissioning and Adjustment
- Interference Testing
- Post Commissioning Survey with CIPS, DCVG
- Report Preparation and Submittals
- Coating Conductance Test

11.3 Native Potential Profile

Upon completion of pipeline construction and prior to energizing or connecting any of the CP systems, a native state pipe-to-soil potential survey shall be performed with DC potentials col-lected along the pipeline and throughout the stations and associated facilities.

The survey shall include the pre-commissioning of all the CP equipment. This includes the test stations, rectifiers, reference electrodes, electrical isolation tests of insulating joints and casings, etc. Appropriate checklist forms shall be completed during the survey.

This data shall be taken at all test stations and block valves and other above grade pipeline appurtenances. In conjunction with the survey, casing-to-soil potentials, foreign line potentials and AC potentials and currents shall also be measured.

11.4 CP System Commissioning and Adjustment

Following the Native Potential Profile Survey, an engineering survey shall be performed to en-ergize and adjust the new and existing CP systems. Any deficiencies identified during the Na-tive Survey shall be corrected prior to conducting the Commissioning Survey. The systems shall be energized to polarize the pipeline and station protected structures to be within a -1,200 mV and -850 mV (" instant off ") potential via a CSE. The other criteria in the listed NACE Standard Practices may be evaluated for protection, if necessary. The following shall be in-cluded in the scope of the survey:

Rectifier current and voltage readings and settings (including individual anode currents, resistor settings and wattage, shunt types, online remote current interrupter synchroniza-tion with SCADA or PTT net etc.)

DC Instant-off Pipe-to-soil potentials via “instant-off” survey (“on” and “off” potentials) and AC Pipe-to-soil potentials at test stations, block valves and throughout the stations and as-sociated facilities, etc.,

- Sacrificial anode current measurements
- Casing-to-electrolyte potentials on normal cathodic protection and cycling the rectifier, Casing internal resistance,
- Foreign line potential measurements
- Insulator effectiveness tests
- Calibration of IR drop test stations
- Line current readings of IR drop test stations
- CP current density tests (e.g., at IR drop T/S's)
- Coating conductance tests (i.e., between adjacent IR drop T/S's and IJ's, etc.)

- DC decoupling device commissioning (if used)
- Remote Monitoring Commissioning and Alarm Settings
- Other measurements as necessary

11.5 Interference Testing

11.5.1 General

After it has been confirmed that all systems are adjusted, interference tests shall be conducted with foreign CP systems to make certain that the installed systems are neither adversely affecting, nor being adversely affected by the foreign systems.

This shall require notification to other operators of all CP systems and joint "interrupted" rectifier interference tests. Conversely, foreign rectifiers shall be identified and tested to ensure no adverse effects to this Project underground structure.

In stray current areas, the testing can be quite complex and cooperative solutions must be reached. During this series of tests, any proposed bonding shall be documented and have the solutions calculated. All proposed bonds and bonding locations shall be approved by Company.

11.5.2 DC Interference Test

Within thirty (30) days of energizing and adjusting the CP system, joint interference tests shall be performed with those foreign line operators identified during the Native Potential Profile Survey.

11.6 Post Commissioning Survey

After the CP systems have been energized and adjusted, the protected structures shall be al-lowed to polarize for a period of approximately three (3) months. A Post Commissioning Sur-vey shall then be performed.

Any deficiencies or interference situations identified during the previous surveys shall be cor-rected prior to conducting the Post Commissioning Survey.

The scope of Post Commissioning survey shall be identical to the Commissioning Survey. Any deficiencies shall be highlighted in the reports.

Following commissioning of the cathodic protection system and all necessary interference test-ing and mitigation measures have been conducted and installed. The following surveys shall be conducted over the entire accessible length of the pipeline.

11.6.1 Close Interval Potential Survey

A full interrupted DC/AC ON/OFF close interval potential survey (CIPS) at 1m intervals, utilizing a maximum interrupted cycle of 3 seconds 'ON' and 1 second 'OFF'. All impressed current stations and bonds installed upon the pipeline shall be required to be synchronously inter-rupted at the same time– no partial area or local area interruption shall be permitted.

Datalogging equipment shall be utilized, in conjunction with sub-meter GPS, allowing for full collection and hand-over of all CIPS data as a minimum in Microsoft excel format.

Upon completion of all works a full CIPS survey report shall be generated including x-y plots of distance against ON/OFF pipe to soil potential.

The surveyed AC potential profile along the pipeline shall be plotted with the design value to compare the effectiveness of the AC mitigation design.

11.6.2 Direct Current Voltage Gradient Survey

A full continuous Direct Gradient Voltage Gradient Survey (DCVG) shall be conducted across the entire accessible length of the pipeline utilizing Analogue type DCVG equipment only. Interruption cycles for effected impressed current stations and temporary impressed current stations as may be required shall be in accordance with the recommendations of the DCVG equipment manufacturer.

Upon completion of all works a full DCVG survey report shall be generated including x-y plots in conjunction with sub-meter GPS of distance against identified coating defect magnitude. (%IR drop). The defect that %IR drop greater than 5% shall be recoated.

11.7 Coating Conductance Test

HDD, bored and microtunneled pipeline crossings and pipeline sections, failing to meet the ac-ceptance criteria shall be further tested, removed, examined coating repaired and or replaced as directed by Company/Contractor.

Coating conductance testing shall be performed and certified by a third party holding NACE certifications. The acceptance criterion for coating conductance value shall be as below:

The design current density for three layer polyethylene (3LPE) coatings shall not be greater than 0.01 mA/m^2.

A normalized Specific Coating Conductance below 100 µS/m^2 equivalent to a high order 'Good' to 'Excellent' coating quality as detailed in table.

Pipeline Section	Acceptance Criteria	
	Required Normalized Specific Conductance (Gn)	Coating Quality
ILI piggable or can perform CIPS/DCVG and excavation (Direct assessment) along HDD section	< 500 µS/m^2	Good
ILI unpiggable or can perform CIPS/DCVG and excavation (Direct assessment) along HDD section	< 100 µS/m^2	Excellent

Table 1 Table of Specific Coating Conductance vs Coating Quality for 1,000 Ω-cm soil.

12. REPORTS

All reports shall include an introduction, summary, conclusions and recommendations with data collection sheets and prepared graphs. Every cable connection (Exothermic welding, Pin Braz-ing etc.) to the pipeline, test post, bond boxes, rectifiers and anode locations shall be specified in the approved report format. The location shall be specified in both KP and UTM coordination.

Each test point shall be identified by a unique number (e.g., TP) and shown in tabular form. Graphs of the potentials, etc., shall also be prepared for the pipeline potentials, with a CP po-tential verse distance X - Y plot.

The reports shall be submitted after the completion of the specific field survey. Several draft versions of the reports may be required before acceptance by Company.

12.1 Phase I - Native Potential Profile

Following the completion of the initial field work, a Phase I report shall be submitted containing all test data, pre-commissioning checklists of equipment, analysis, deficiency list, and recom-mendations. The report shall contain the following information:

- Electrical isolation pre-commissioning inspection checklists (insulating joints and casings)
- Test station pre-commissioning inspection checklists
- Rectifier pre-commissioning inspection checklists
- Permanent reference electrode pre-commissioning inspection checklists
- Locations for joint interference tests with foreign line operators
- DC and AC pipe-to-soil potentials and currents
- Data collection sheets with test points uniquely identified and applicable graphic and schematic layout presentations
- Deficiency list
- Conclusions
- Recommendations
- Other information as required

12.2 Phase II - CP Energizing and Adjustments (Commissioning)

Following completion of the CP Energizing and Adjustment survey, a Phase II report shall be submitted which documents and analyses all data from the CP commissioning.

The report shall compile all data collected and include a tabular form and graphic presentations of pipe to soil potentials ("on" and "instant off" vs. distance, with an -850 mV delineation line), with a description of physical features, line current, etc., for the mainline. Station CP data shall be presented in tabular form with a schematic drawing showing the test point locations, etc.

All IR drop test station calibrations, rectifier output, anode currents, resistor settings and voltage ratings, casing and foreign pipeline crossing pipe to soil potentials, line CP current densities, coating resistance, etc. shall be included.

Data collection sheets and applicable graphic presentations shall be included. The report shall also highlight any deficiencies identified during the survey. Conclusions and ecommendations shall also be included.

The above document shall be considered as the "Commissioning Report".

12.3 Phase III - Interference Testing

The Phase III report shall contain all DC interference test data. Any proposed bonds, auxiliary drainage designs and interference test data shall be compiled and submitted in conjunction with this report.

The report shall also include all additional AC interference testing necessary to design any re-quired supplemental mitigation devices. Data collection sheets with test points uniquely identi-fied and applicable graphic and schematic layout presentations shall be included.

12.4 Phase IV - Post Commissioning

Following the completion of the Post Commissioning Survey, a Phase IV report shall be sub-mitted which documents and analyses all the data from the polarized potential survey.

The report format and requirements shall be similar to the Commissioning Report but contain all details of the close interval potential surveys (CIPS) and direct current voltage gradient (DCVG)

Any pertinent DC or AC interference data associated with work completed after Phase III test-ing shall also be included.

Data collection sheets, with test points uniquely identified and applicable graphic and schematic layout presentations, shall be included.

13. DEFICIENCIES

The Contractor shall be responsible for correcting all deficiencies that are identified in the Na-tive, Commissioning, Interference and Post Commissioning Surveys and Reports. This in-cludes any required remedial action design, retrofit and final checkout surveys.

The intent of the Post Commissioning Survey is to document the "final" CP and AC conditions, which satisfy the specifications, to be submitted to Company.

Therefore, all deficiencies should be corrected prior to the Post Commissioning Survey.

After the installation and commissioning, a CP and AC Mitigation Commissioning Book shall be submitted. As a minimum, this document shall contain the following:

- Complete Report with Discussion, Conclusions, Recommendations
- Deficiency List
- CP/AC Data & Plots of all Surveys, Tests, Measurements and Inspections
- Pre-commissioning and Commissioning Check List Forms for Equipment
- Complete Set of Reduced Size As-Built CP and AC Mitigation Drawings
- Operations and Maintenance Manual for Equipment & CP/AC System

14. TRAINING

14.1 General Training

Training needs for site personnel for design, operation, installation, commissioning, trouble-shooting and maintenance of cathodic protection system equipment and systems need to be identified and provided.

As a minimum Training for following category of Operations and plant personnel shall be considered:

- General Principals of Corrosion and Cathodic Protection
- System Design, Installation and Operation training for Engineers
- System Maintenance and Inspection Training for Technicians
- System Troubleshooting General

Training shall include the provision of all necessary documentation and training aides as may be appropriate.

Training shall be conducted both in classroom and in the field, all training shall be conducted at the Company convenience.

END