Pipeline Design, Engineering, Construction & Commissioning in GAIL

Amendment Details

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<th>Rev. No</th>
<th>Date</th>
<th>Purpose</th>
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<td>28.06.2018</td>
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1.0 Introduction

1.1 It is essential to ensure proper planning and correct design of the pipeline system or any modification thereof for assuring its integrity over its operating life. It is equally essential that the pipeline system is constructed strictly as per the design specifications and applicable quality standards.

1.2 This document aims to strengthen the design, engineering, construction and commissioning of pipelines in GAIL on the basis that integrity of a pipeline is established during its design and construction and maintained or improved during operations phase; this will aid in implementing a pipeline project of sound design and trouble free & safe operation during its service life. This document also includes feedbacks of SME’s, O&M personnel and learnings process on various aspects for enhancing the pipeline integrity.

2.0 General

2.1 An intranet based pipeline data and progress management system may be developed and deployed to monitor and capture all the activities and data & documents which will enable an effective project planning & monitoring at execution stage, aid in smooth handing over of completed & commissioned project to O&M group and in integrity management during operational phase. Some of the recommendations in this regard are given below:

2.1.1 In order to maintain such database for a project as above in a usable condition, the system shall be developed such that it is suitable for adding all future projects and has long term services support. The same may be deployed through Corporate Intranet portal (of Project and O&M) with authentication to GAIL personnel and authorized personnel of consultants, vendors & contractors for updating their data.

2.1.2 Further such a system should incorporate the following features for capturing all pertinent details during planning, pre-project, engineering/design, contracting, manufacturing, construction, commissioning and handover (HOTO) to O&M after which also the system will be alive in the O&M systems:

   a) Capture documents at project planning stage – Prefeasibility, DFR, Board Approval etc.

   b) Capture data and documents at pre-project stage – Route options, route selection, alignment survey, geotechnical survey, EIA, RRA, statutory
clearances, crossing permissions, cadastral maps, VII/XII extracts, compensation details and other land records linked to GIS portal in GAIL.

c) Engineering / Design – Design basis, Detailed Engineering & Drawings, material specifications, Material Requisitions etc.

d) Contracting – Tender documents, work orders, purchase orders.

e) Manufacturing – Purchase order – Data sheets, Manufacturing progress, test certificates, Inspection release notes, GRVs / SIVs etc. [provision for username / password to consultant, TPI, Vendors and Contractors for updating their data].

f) Construction / commissioning – Progress monitoring of all activities of construction and documentation – inspection reports, Hydrotest reports, pipe-books, as built drawings, commissioning reports etc.

g) GPS coordinates of each weld joint of pipeline, CP test lead points, locations of valves and fittings, ROU features such as markers etc., shall be acquired and incorporated in the geodatabase.

h) Cadastral data such as village maps, ROU extent, land owner details, compensation payment details, shall be mapped after collection of data and drawings and converting them to GIS database with due geo-referencing.

i) Pre-commissioning audits and clearances (PESO / OISD / PNGRB)

j) The entire Handing-Over-Taking Over (HOTO) process between Project / Construction group and O&M group shall be mapped and conducted through the system.

2.2 Quality of Natural Gas / LPG to be transported is the most important factor in the internal corrosion of pipeline in service. Accordingly, due care and caution shall be exercised in obtaining and evaluating the quality parameters. A full range of composition of the fluid shall be obtained (not only typical composition) including all the constituents especially the corrosive constituents. In accordance with the integrity requirement of pipelines, thresholds for corrosive constituents for Natural Gas and LPG suitable for pipeline transportation have been worked out and are given in Appendix-1. Natural Gas / LPG quality not meeting with any of the thresholds indicated shall be critically reviewed for treatment at Suppliers end and mitigation measures at design stage of the pipeline system by GAIL.

2.3 Project Execution Department may engage the services of Subject Matter Experts (SMEs) in geology & geotechnical engineering, advanced construction techniques (HDD, Mud Engineering), Metallurgy, Cathodic Protection, etc., for consultation during design and construction.
3.0 Pipeline route planning and detailed alignment, geotechnical & cadastral survey

3.1 Pipeline route planning, selection, detailed pipeline alignment survey, population density index (PDI) and geotechnical Surveys shall be performed with geo-referencing on a GIS platform. Satellite imagery is preferentially used in the initial corridor planning and identifying regional and local constraints for evaluation during ground validation and detailed alignment survey.

3.2 All geo-hazards both natural such as landslides, seismic activity, soft / unstable soil, underground voids / cavities etc., as well as man-made such as underground mining, landfills, soil contamination from chemical or other effluents etc., that may pose serious threat to pipeline integrity shall be identified and evaluated for type, nature, magnitude and extent.

3.3 At the route planning stage, consideration shall be given to the avoidance of the more obvious corrosion hazards, by routing to avoid, for example:
   · in stray AC/DC earth current areas
   · parallel to high voltage overhead power lines
   · near pylons
   · near HVDC Ground Beds & Other pipeline Cathodic Protection Ground Beds
   · in contaminated ground
   · in naturally aggressive ground.

3.4 When routing pipelines, long parallelisms with overhead power lines of 66 kV or greater should be avoided.
   · separation distance > 500 m should be maintained for parallelisms > 3 km
   · separation distance > 200 m should be maintained for parallelisms < 3 km

In case, the above separation distances cannot be ensured, the alignment of pipeline along with HT line alignment in GIS form along with details of power line characteristics, phase wire configurations, pylon locations etc., shall be captured during detailed alignment survey and shall input to appropriate design for interference mitigation. In any case, any overhead tower/pole of any voltage rating should not be located above pipeline.

3.5 Detailed route survey shall be undertaken to fix the construction alignment based on the most suitable corridor selected. Base maps and digital elevation model shall be preferably developed using photogrammetry processing of Stereo Pair High Resolution Satellite Imagery (HRSI) of a corridor of minimum 1.5 Km on either side of pipeline centerline and necessary Ground Control Points (GCP) shall be established to achieve close tolerances in above. The vertical control of GCPs shall be established by transfer of level from nearest monumented Survey Bench Marks.
3.6 All the field surveying for pipeline centerline alignment, topographic features, points of interest, etc., during detailed route survey shall be done using survey grade equipment in DGPS (with post processing) or RTK-GPS for developing a geodatabase for use in GIS applications. While carrying out the survey, geo-tagged photographs at each crossing and other important features across and along the route, shall be captured and documented. Guidance Document Ref. CIMG-GD-2017-001 “Geographic Information System (GIS) for Pipeline Asset Management”, shall be referred for further details.

3.7 All mapping work and geo database thereof shall be based on Geographic Coordinate System with WGS84 Datum.

3.8 All village maps, maps of individual land parcels shall be geo-referenced and validated on ground to be able to be integrated in the geo-database along with details of landowners (VII / XII extracts etc.).

3.9 Pipeline crossing or running parallel to other utilities (road / railway / power lines / foreign pipelines etc.,) shall be mapped for a corridor of minimum 200 m on either side of centerline alignment.

3.10 Population Density survey shall be carried out for the selected alignment by capturing GPS coordinates (using RTK-GPS technique) of dwellings, buildings and identified sites for the corridor width of at least 200 m on either side of pipeline centerline. In case of pipelines of large diameters (24” & above) expected to carry fluids at high pressure, as a good practice, the data as above should also be collected for a corridor width of minimum 500 m on either side.

3.11 Geotechnical investigations and site-specific surveys aim to identify the ‘good’ ground in which to install the pipeline, pipeline obstacle crossings and facilities. The geotechnical survey along the general pipeline route alignment shall include soil resistivity survey, soil corrosivity survey covering the parameters such as pH, redox potential, moisture content, clay content, microbial counts (SRB) etc.

3.12 Aerial photography and satellite Imagery are increasingly being employed for variety of planning and analytical work. There are a number of resources from where historical imageries of area of interest can be obtained, many of them in public domain. It has been demonstrated that the pipeline corridor can be analyzed using such platform. While selecting a pipeline alignment near population centers and across or along rivers and other water bodies, the imageries of such locations shall be examined to detect potential earth cover erosion (such as in river meandering cases) and potential for development of residential / commercial buildings & structure on or near the pipeline.
3.13 A complete set of data relevant to design, construction and the safe and reliable operation of the pipeline should be compiled from records, maps and physical surveys.

3.14 After preliminary design of the pipeline w.r.t size, material, thickness etc., locations of Above Ground Installations / Facilities such as SVs, IPs, Tap-offs shall be identified and included in the detailed survey with respect to locational feasibility, land availability, access roads. After input of these parameters, design of pipeline system shall be once again validated with regard to the selected locations.

3.15 All piping installations like SV / IP / Terminals / RR / Tap off / O&M bases etc. shall be easily accessible through motorable road for smooth operation, protection & safety of facilities.

3.16 The concerned pipeline construction group shall ensure that ROU of the pipeline conforms to the constructed pipeline alignment including any rerouting / realignment that may have taken place during the course of construction.

3.17 A post construction survey shall be carried out to validate that pipeline has been constructed as per the design alignment & depth of cover and capture the as-built route alignment in case of changes from design, along with the requisite cadastral maps and data and validation of Location class. The survey data shall be captured in a manner and form that can be readily incorporated in the existing ‘Pipeline Geographic Information System (PGIS)’ implemented in GAIL and deployed through O&M Intranet portal.

3.18 The guidelines for pipeline route survey during project stage are given in Appendix-2.

4.0 Design & Engineering

4.1 Pipeline System Design shall conform to all the applicable PNGRB Regulations (including their latest amendments). For confirming the exhaustiveness, PNGRB website shall be consulted for the latest additions, just prior to undertaking design as well as prior to pre-commissioning.

4.2 The ‘Pipeline Designing Agency (PDA)’, whether in-house or of a Third Party Engineering Consultant, shall arrange to vet the design basis and all the detailed engineering documents and drawings by the accredited Inspection Agencies, empanelled by PNGRB, for design adequacy and compliance with the regulation.

4.3 In addition, the provisions of the following standards (based on applicability) may be incorporated in the design taking the more stringent of the codes where differing requirements exist.

   a) ASME B31.3 / B31.4 / B31.8 / B31.8S Latest Edition

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b) ISO 13623/EN 14161 - Petroleum And Natural Gas Industries — Pipeline Transportation Systems

c) IGEM-TD/1 Edition 5 - Recommendation On Transmission And Distribution Practice – Steel Pipelines For High Pressure Gas Transmission.

d) BSI PD 8010 - Code Of Practice For Pipelines

e) Applicable OISD Standards

4.4 In addition to regulations and design codes, requirements of GAIL O&M Policy & Guidelines and GAIL Standard for Pipeline Integrity Assurance during Design, Construction and Commissioning (this Standard) shall be incorporated in the design of the pipeline system.

4.5 Distinction and designation shall be explicitly made with regard to whether the pipeline being considered is a transmission or distribution pipeline. All pipelines intended for supply of low volumes of gas to multiple customers shall be designated as distribution pipelines and the MAOP of these pipeline shall be restricted to 16 Kg/cm² by providing appropriate pressure regulating stations at the tap-off from transmission pipeline.

4.6 Selecting an appropriate design factor is a critical element of design. In case of natural gas, the criteria of ‘Potential Impact Radius’ (PIR) as mentioned in ASME B31.8 S is a measure of potential threat may be taken as basis since it represents the potential threat of high pressure gas pipelines to the public, infrastructure and environment more closely for the given size of pipeline and intended maximum pressure of operation than a fixed spatial window. The PIR is derived from the radial distance calculated for unacceptable thermal radiation from a failure with ignition which depends essentially on the size of pipeline and operating pressure. The factor $\sqrt{P.D^2}$ reflects the severity in such case and hence it is proposed to define design factors considering a combination of Class location and $\sqrt{P.D^2}$ factor as below:

<table>
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<tr>
<th>Class Location</th>
<th>$\sqrt{P.D^2} &lt; 1$</th>
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<td>Class II</td>
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<tr>
<td>Class III &amp; IV</td>
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* P = MAOP (Mpa) & D = OD (m)

4.7 Though provision for Location Class is not made in ASME B31.4 under which LPG pipelines had been designed in the past, future modification of existing pipelines or
future pipelines to be built for LPG service also should be designed with design factors in accordance with 4.6 above.

4.8 Due allowances shall be explicitly made for pipeline external loads due to construction practices (stresses induced during tie-ins), evaluation of earth loads (increase in overburden, vehicular movement etc.) and other environmental considerations.

4.9 Design & Engineering of a pipeline system shall proceed from a careful study of the pipeline inlet conditions and delivery requirements of fluid to be transported both physical and chemical (composition) and hydraulic requirements.

4.10 The ‘Pipeline Designing Agency (PDA)’ shall consult with the Framework Document – GAIL Corrosion Management System, Ref. CIMG-FW-5-2017-0001 (salient features are mentioned at Appendix-3) for incorporating requisite design and construction measures pertaining to corrosion management.

4.11 Data shall be collected from source (at the inlet and outlet of the upstream gas suppliers facility) – covering full range of composition, composition of corrosive constituents – suppliers process to remove corrosive constituent. Design of Upstream suppliers process facility with regard to plant availability shall be considered to incorporate offset conditions to be included in downstream GAIL facility and pipeline design. If such data is not available, 95% upstream process availability may be assumed.

4.12 Corrosion Risk Assessment based on flow modeling & corrosion modeling of the proposed pipeline with regard to the fluid to be handled at different flow rates (at 25%, 50% and 100%) to ascertain the potential corrosion mechanisms so that appropriate corrosion allowance, corrosion mitigation and monitoring systems can be built in to the system.

4.13 Based on the corrosion risk assessment, if injection of corrosion inhibitor is required, requisite system including metering pumps, CI transfer & storage system, injection quills and connected piping/tubing shall be incorporated in the design of the dispatch terminals and intermediate points (not exceeding 50 Km).

4.14 Corrosion monitoring system shall invariably be implemented in the pipeline system incorporating corrosion coupons and ER probes. As a minimum, requirements set out in Guidance Document Ref. CIMG-GD-5-2016-0006, “Internal Corrosion Monitoring”, shall be met.

4.15 Corrosion Allowance for line pipe, fittings and mainline valves shall be calculated based on the corrosion modeling at 4.12. Notwithstanding the modeling, a minimum corrosion allowance of 1.0 mm shall be incorporated in the pipeline wall thickness design in case of sweet & dry gas as per PNGRB Access Code specifications. If any
variation in gas quality is expected at initial or subsequent stages of operation, calculated corrosion allowance for the design economic life based on corrosion rate prediction or 2.0 mm whichever is higher shall be considered as corrosion allowance.

4.16 Flow Assurance (flow modeling) techniques shall be used to analyze the hydraulics of the pipeline including surge analysis. Gas Velocity should be chosen in such a way that any liquid dropping out in the pipeline is swept forward rather than getting collected at low points and cause corrosion problems. As far as practicable, the velocity window shall be kept between 3 – 15 m/sec in gas pipelines.

4.17 Notwithstanding any statutory stipulation, it is recommended that all new pipelines should be piggable irrespective of length and size of pipeline. In any case, pipelines traversing public land carrying wet gas (as per PNGRB Access Code specifications) shall mandatorily be provided with full bore valves and bends of min. 3D radius with pig barrels at either ends or with provisions for connecting temporary scraper barrels. However the above requirement may not apply for the Last Mile Connectivity pipelines where tap-offs are taken from pipelines within an enclosed industrial estate or enclave.

4.18 Cold Field Bending shall be limited to 40D. Minimum bend radius for factory made induction bends in pipelines shall be restricted as follows:
   a) 10D for pipelines 4" and smaller
   b) 6 D for 6" & larger
   c) At least three diameters of straight pipe should be installed between any two bends.

4.19 All tap- in / Tap-off connections to pipeline shall be made with flow tee only if the connection size is more than 1/3rd size of pipeline to which the connection is to be made.

4.20 Suitable Pressure Regulating System (PRS) shall be installed in all the branch / spur pipelines.

4.21 Taking connection for spur-lines or other connectivities by hot tapping the pipeline should be avoided. In case, it is unavoidable and if the hot-tap location falls outside GAIL stations, the same may be allowed subject to the condition that a plot of land covering the hot-tap connection location is acquired and an intermediate station built with necessary perimeter walls etc. along with provision of access road from the nearest all weather metaled road. In all such cases, a valve shall be provided after the tap-off to isolate the spurline or LMC. It shall further be ensured that if the tap-off size is 1/3rd or larger, of the pipeline size, then barred Tee shall be specified for the split tee, so as not to affect pigging activities.
4.22 Soil bearing strength and soil stability data shall be used to determine areas which may require anchoring. On the other hand, soft padding of min. 8” all around shall be required in hard strata (rocky terrain).

4.23 Pipeline Warning markers shall be installed at each & every kilometer. Apart from this, additional warning markers shall also be installed at each side of highways (NH/SH), major district roads (MDR), all metaled roads, railway crossings, water body crossings any other major crossings and at entrance to stations. For Urban Agglomeration (UAs) / Towns having a population of 1 Lakh or more, the warning marker shall be installed at least at every 50 meters and if required additional markers shall also be installed where there is a probability of damage or interference.

4.24 Directional Markers shall be provided at each Turning point and 150 m upstream and downstream of Turning points.

4.25 Aerial / Kilometer Markers shall be provided at a spacing of 1 Km along the pipeline route. The Aerial / Kilometer Markers having the warning details can also be treated as Warning Marker.

4.26 ROU Marker / Boundary marker shall be provided at maximum spacing of 400 m along the pipeline route. However, pipeline markers shall be installed preferably at every 25 m but not exceeding 50 m within the limits of Urban Agglomeration (UAs) / Towns having a population of one Lakh or more.

4.27 Criteria for Electrical Power Requirement and Battery Bank back-up hours shall be as given in the latest O&M Policy & Guidelines.

**Cathodic Protection System Design:**

4.28 Design of Cathodic Protection of buried pipelines shall be as per ISO 15589 – 1 or 2 Control of External Corrosion on Underground or Submerged Metallic Piping Systems and ISO 18086 – Corrosion of metals and alloys -- Determination of AC corrosion -- Protection criteria.

4.29 Isolating Joints (Insulation Joints) shall be provided to isolate the buried pipeline section protected with CP and above ground piping & equipment. Isolating joints shall also be provided to isolate pipeline sections crossing major water bodies, challenging stretches from CP point of view and all branch lines whether the tap-offs / tap-ins are located underground or aboveground.

4.30 The practice of connecting spur lines directly with mainline without any Isolating Joints makes it difficult in identifying/ rectifying/ controlling CP issues. Also monitoring of current density also becomes a difficult task. It is recommended that whenever new spur lines are connected to mainline, it should be connected through Isolating Joint
(IJ’s)’s and CP of mainline may be fed to spur lines through Test stations having shunt and Resistor of suitable rating.

4.31 All isolation devices (Isolating joints) shall be protected with surge diverters. This will also be applicable to the isolation device provided on SS tubing associated with tap-offs from pipelines for transmitters, gauges or other instruments.

4.32 Test Station Scheme and nomenclature shall be as per CIMG Guidance document “CIMG-DG-2-2015-0001: CP Test Station Connection Scheme & Type”.

4.33 Cased Crossings:

4.33.1 Cased crossings should be avoided as far as possible pipelines to be laid which instead may preferably be laid through HDD at a minimum specified depth as required by design or based on soil strata or as stipulated by the agency whose corridor is being crossed thus. In this regard, "Addendum & Corrigendum Slip No. S dated 10.04.2017 for Guidelines on Pipeline Crossing" issued by Indian Railways (RDSO), may be referred.

4.33.2 Wherever, cased crossings are unavoidable:

(a) Casings pipe shall be designed in accordance with API RP 1102 thickness & Grade, subject to a minimum thickness as mentioned therein.

(b) Minimum extent of the casing shall be governed by the width of ROW of the utility corridor & additional site requirements

(c) Casing pipe shall be bare at its internal & external surface.

(d) Casing pipe sizes shall be selected sufficiently large to avoid the damage to insulators during insertion of Carrier pipe in Casing. The difference between carrier & casing pipe size shall be as follows:

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<th>Carrier Pipe Size</th>
<th>Min. difference in Casing &amp; Carrier pipe size</th>
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<tr>
<td>Up to 12’’</td>
<td>6’’</td>
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<tr>
<td>14 to 24’’</td>
<td>8’’</td>
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<tr>
<td>26’’ and above</td>
<td>10’’</td>
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(e) No sacrificial anodes shall be used inside casing annular space.

(f) Annular space of Casing & Carrier shall be left clear without any filler inside.

(g) Post installation, it is to be ensured for sound isolation of Casing & Carrier Pipe and if any Electrolytic coupling or metallic shorting is observed, same shall be rectified during project/construction stage itself.
(h) Utmost care should be taken to avoid any possibility of Coating defect in Carrier pipe while laying the Casing & Carrier pipe. Suitable Insulator supports, without any metallic fasteners should be designed to take care the Carrier pipe load. (In most cases, poor quality of insulators and their poor installation on the carrier pipe leads to breakage / bunching of insulators at the insertion point). Insulators should be fixed on carrier in such manner that they are not easily dislodged (using epoxy adhesives etc.) and also additional insulators need to be installed at either ends. High strength Polyethylene spacers & rollers fixed on carrier pipe should be used for easier insertion.

(i) Workmanship during laying of Casings & Carrier pipe and quality of spacers and end seals are important factors in determining the integrity of the system.

(j) Further, wherever casings are unavoidable and installed, it shall be ensured that OFC duct or other cables etc., are not laid through the annulus between casing and carrier pipe.

(k) It is observed in many of the cased crossings that the insulators installed on the carrier pipe (to ensure that the carrier pipe does not come into contact with the casing), or of very poor quality or not installed properly (resulting in breakage / bunching of all insulators at the start of casing itself, etc.) or both. It is recommended that instead of conventional insulators, composite sleeves installed for a width of one diameter separated by max 1 m distance throughout the casing extent may be preferred or high strength Polyethylene spacers & rollers fixed on carrier pipe should be used.

4.34 The following shall be considered in the design of CP system in case of parallel lines:

4.34.1 The Anode Ground Bed of the foreign pipeline should be:
   a. Deep Well type (Preferred)
   b. Preferably located on the other side of foreign pipeline (not GAIL Pipeline side)
   c. Should be at remote earth with respect to GAIL’s pipeline

4.34.2 Then CP system of foreign Pipeline should be designed and implemented with the above consideration.

4.34.3 Post installation of ICCP system of foreign pipeline in all respect, an interference survey covering the affected section of GAIL pipeline and foreign pipeline to be conducted. Based on this survey the following to be done:
a. Bonding of both pipelines through bonding stations (variable resistance of suitable value + shunt + diode, if required) at required locations as per survey recommendation.

b. Polarization coupons shall be installed at every test station in the parallel section and at crossings. The interval of test station shall be 1 KM maximum.

c. If required ground bed of GAIL or foreign pipeline (If not addressed as per cl. 1 above) may require to be relocated / reconfigured.

4.34.4 DCVG of complete affected section shall be carried out at signal strength of more than 500 mv (to locate minor coating defects) and all coating defects should be repaired.

4.34.5 Detailed guidelines on design and implementation are given at Appendix-4.

### Facilities:

4.35 All pipeline installations like SV / IP / Terminals / RR / Tap off / O&M bases etc. shall be easily accessible through road and well maintained, irrespective of the ownership to comply all the relevant legislation, laws, standards, codes for smooth operation, protection & safety of facilities. In cases where, approach roads have not been laid and only kuccha road is available, new approach road shall be built and maintained.

4.36 All SVs / IPs / Tap off valves in pipelines shall be equipped with actuators. However, this is not applicable for following tap-off valves falling within Industrial corridor. Inlet and outlet valves in all the Dispatch and Receiving Terminals shall be provided with actuators with remote operation facility.

4.37 At least alternate SVs / IPs in trunk pipelines shall be remote operated. In addition to above, all the SV's within city location / high risk / vulnerable locations shall also have auto closure facility, operating from combination of at least two hard wired pressure switches / transmitters feedbacks in series, one for upstream pressure and another for downstream pressure of SV.

4.38 Vent line from across the mainline sectionalizing valves and vent line at Pigging Stations for pipeline section evacuation shall be of size minimum 1/3rd of the pipeline size. Vent lines should incorporate Quick Opening End Closure (QOEC) on the vent and open vent with spectacle blind at upstream of vent shall not be allowed.

4.39 Pipeline valves having electrical actuators shall be provided with double earthing through zinc anode and de-coupler.

4.40 Flexibility analysis of the station piping with connected equipment shall be carried out to identify location and type of supports to piping & equipment. All supports to piping shall be of welded saddle type (full encirclement welded saddle in case of piping.
operating at hoop stress >50% SMYS). Types of supports (anchor, guided & free) shall govern the concrete pedestal sizing and design.

4.41 A coalescing filter separator shall be provided in the gas dispatch terminal as a minimum in case of sweet / dry gas. In case of gas not meeting quality criteria at Appendix-1, additionally a multi-cyclone gas scrubber must be provided along with associated condensate handling and disposal system.

4.42 All scrapper barrels in pigging stations at Dispatch & Receiving Terminals and Intermediate Pigging stations, shall be provided with two full bore valves with a provision for spectacle blind or spacer/blinds in order to enable positive isolation of scrapper barrel for maintenance.

4.43 Inter-unit distances shall be strictly as per PNGRB regulations and OISD standards.

4.44 Non-intrusive pig signaler shall be preferred over intrusive type.

4.45 Arrangement to prevent freezing in impulse tubing / malfunction of regulators shall be provided.

4.46 Pig handling equipment that will include jib crane / lifting arrangement and wire rope & pulley arrangement for pushing in and retrieval of pigs into / from pig barrels shall be provided. The manual station for operation of the above shall be located away from pig barrel centerline such that personnel operating the same will not be directly in front of the pig barrel door.

4.47 In case of electrical actuators for valves in pigging stations, single phase actuators shall be provided with local operation only.

4.48 At least one Tap off provision with flow tees shall be provided at each sectionalizing valve stations and intermediate pigging stations. In addition, Tap-off points (TOPs) shall be provided at potential locations along the pipeline route for customer connection.

4.49 The following philosophy shall be adopted for valves in pipelines & facilities:

4.49.1 All mainline valves in gas pipeline shall be full-bore ball valve equipped with quarter-turn actuators. The same in LPG pipelines shall be Gate Valve with multi-turn gearboxes / actuators.

4.49.2 Only fully welded/forged body type valves shall be permitted for mainline applications i.e., all valves part of a pipeline including the first and last valves connecting to facility piping.

4.49.3 All mainline valves shall be provided with electric / Gas-over-Oil / hydraulic actuators.
4.50 Gas Source Quality Monitoring system shall be provided based on the following philosophy:

a) Online moisture analyzer shall be provided at dispatch terminals designed for handling gas flow of more than 1 MMSCMD in case of gas with PNGRB stipulated specifications (Access Code) and 0.1 MMSCMD otherwise. Online H2S analyzer shall be installed at dispatch terminals of 1 MMSCMD & above. In other locations, if not available already, portable type analyzers shall be provided.

b) Major Metering terminals (more than 1.0 MMSCMD) shall be equipped with on line Gas chromatograph approved for custody transfer application. In other locations, if not available already, lab chromatograph shall be provided.

4.51 All custody transfer metering systems shall be as per relevant AGA standard. Flow computers and associated meters & instruments shall be of type approved for custody transfer metering and shall comply with all provisions of Maintenance Policy guidelines.

4.52 Check Meters shall be installed at any new custody transfer receipt / intake point of GAIL, where the following conditions apply:

(a) Quantity of Gas flow > 1 MMSCMD and more than one customer on the supply side

(b) Quantity of Gas flow < 1 MMSCMD and > 0.1 MMSCMD and term of supply is more than 3 years

(c) Quantity of Gas flow < 1 MMSCMD and > 0.1 MMSCMD and Isolated fields with more customers/ complicated lines and where back to back calculation is not possible

4.53 Custody transfer meter at customer end shall be installed as per the minimum criterial given below:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Meter Type</th>
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<tbody>
<tr>
<td>Quantity of Gas Flow up to 25000 SCMD</td>
<td>For Dry Gas: RPD / Turbine / USM meter based skid (refer note 1 below)</td>
</tr>
<tr>
<td></td>
<td>For Wet Gas: Orifice meter based skid (refer note 1 below)</td>
</tr>
<tr>
<td>Quantity of Gas Flow &gt; 25000 SCMD &amp; &lt; 0.25 MMSCMD</td>
<td>For Dry Gas: Turbine Meter 1+1 stream with field mounted flow computer</td>
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<tr>
<td></td>
<td>For Wet Gas: Orifice Meter 1+1 stream with field</td>
</tr>
</tbody>
</table>
Criteria | Meter Type
--- | ---
Quantity of Gas Flow > 0.25 MMSCMD & < 1.0 MMSCMD | For Dry Gas: Turbine Meter 1+1 stream with control room mounted flow computer  For Wet Gas: Orifice Meter 1+1 stream with control room mounted flow computer  For Dry Gas, in case meter size is > 6” – USM Meter with control room facilities
Quantity of Gas Flow > 1.0 MMSCMD | Ultrasonic Meter 1+1 stream with full-fledged metering facility, GC, control room mounted flow computer, FCV etc. for both dry and wet gas
LPG Pipeline (Mass terms) | Coriolis Mass Flow Meter (1+1) sensor and transmitter with display of flow, density, and cumulative flow in control room.

Note:

(i) Skid consists of 2 filter streams, 2 PRS streams with or without Active Monitor configuration, single stream metering with local flow computer / EVC, with or without inter stream redundancy

(ii) For CGD / LMC customers with initial flow less than 25000 SCMD but projected flow within next 05 years exceeds 25000 SCMD, in addition to metering system requirement for 25000 SCMD as per table above, provision for additional streams to be provided to cater to such projected high flow requirement as per above table (incase where flow capacity is higher than the installed skid for 25000 SCMD)

(iii) Double decker configuration of metering streams may be considered but the same to comply with OISD / PNGRB regulations.

4.54 The check meter / reconciliation meters should be of similar accuracy / uncertainty as that of custody transfer meter. These meters may be installed in single run, double run or multi run configuration depending on the quantum of gas received but standby meter run is not required. In case of single run, bypass arrangement to be provided with double block & bleed valve arrangement.

Communications System and SCADA:

4.55 OFC based communication system to connect all the nodes of a pipeline system will be preferred. In remote areas and other difficult to access locations, alternate communication modes may be provided. In any event all pipeline nodes shall be provided with reliable communication. All critical nodes such as dispatch, receiving
terminals and sectionalizing valve stations shall be provided with a redundant path of
communication in addition to the primary connectivity.

**Monitoring Systems:**

4.56 OFC based Pipeline Intrusion Detection System (PIDS) shall be provided in all major
trunk lines. If no other system for Leak Detection is envisaged, OFC based Leak
Detection System (LDS) shall also be provided in all major trunk lines. In all other
pipelines, PIDS shall be installed for the sections falling in Urban Agglomerations (UA).

**Security Considerations & Surveillance**

4.57 Boundary wall of min. 3m from grade level shall be constructed for all intermediate
pipeline installations (SV, IP etc.). On top of the wall all around, concertina coil and
razor tape shall be installed on 'Y' structure grouted into the wall.

4.58 Video Surveillance with remote control provision shall be provided at SVs / IPs of
pipelines having dedicated communication.

4.59 Security Control Room for each network shall be established.

**5.0 Materials**

5.1 **Line pipe**

5.1.1 Line pipes having D/t ratio in excess of 60 shall be avoided; they may be prone to
deforation during transport and storage that leads to further problems of
mismatch during welding.

5.1.2 While procuring line pipes, minimum thickness requirement shall be critically
assessed from the point of view of Location Class Factor, Corrosion Allowance,
Combined Stresses on the pipeline, high construction loads (such as HDD) etc.

5.1.3 Line pipes intended for liquid service shall be selected based on anticipated
pressure cycling and fatigue resistance required.

5.1.4 For line pipes of outside diameter exceeding 323.9 mm, a full wall DWTT shall be
considered to assess resistance to brittle fracture. For line pipes of diameter not
exceeding 323.9 mm, extraction of a sample for DWTT is not possible and
fracture appearance using Charpy test may be substituted.

5.1.5 A quantity of line pipes (procured as surplus length for uncertainty and O&M
insurance spares) shall be specified for long term storage (Guidance Document
on Long term storage of PE coated line pipes, Ref. CIMG-GD-1-2016-0002 may be
referred).
5.2 Coating

5.2.1 Notwithstanding the quality of fluid in service, pipes should be internally coated to prevent rusting during transit and storage.

5.2.2 Requirement of internal coating shall be assessed and specified with regard to corrosion prevention and/or flow efficiency. The thickness of the internal coating material shall be selected to match the duties required, for example expected duration of storage, ability to resist corrosion of specific nature anticipated, ability to withstand pigging, etc.

5.2.3 Factory-applied external coating systems shall be such as to provide long term electrical and mechanical characteristics, which are suited to the diameter and operating conditions of the pipe and the nature of the environment. The coatings shall adhere strongly to the pipe and resist cathodic disbondment at holidays satisfactorily.

5.2.4 Coating applicators, supervisors and inspectors of the Coater and Inspectors of GAIL / PMC / Third party agencies shall be trained / certified.

5.2.5 The pipe surface shall be cleaned of mill scale, rust and other foreign matter by a blast cleaning or another abrasive cleaning method to achieve a minimum surface cleanliness of Sa 2½. The surface profile shall be as specified by the coating Manufacturer in his application instructions. During blast cleaning the pipe surface temperature shall be simultaneously higher than 5 °C and more than 3 °C above the ambient dew point. The ambient relative humidity shall not exceed 85%.

5.2.6 Two abrasive blast cleaning units are preferable to just one unit. (Contamination on the pipe is kept to a minimum and the profile capability is greater).

5.2.7 In order to achieve a surface cleanliness of Sa 2 1/2 in accordance with ISO 8501 Part A1 (visual assessment) the correct hardness and size of abrasive must be used:

- ISO 8501 Group E Metallic Cleaning Abrasives
- ISO 11124-1 Specification for Chilled Iron Grit
- ISO 11124-2 Specification for Cast Steel Shot and Grit

5.2.8 A dense, angular anchor pattern is required in order to obtain the greatest, cleaned surface area and maximum adhesion of the FBE to the substrate. A rounded, dished profile is not acceptable.
5.2.9 The peak to trough height of the anchor pattern should be governed by the thickness of the FBE. E.g., for a minimum of 180 microns of FBE the peak to trough height should be within the range 75 - 100 microns. (ISO 8503-1 C1 & C2 Surface Profile Comparators).

5.2.10 The surface profile shall be measured at regular intervals and on the first 5 pipes following each change of blast-cleaning material. If the surface profile is outside the specified limits, the blasting material shall be checked and replaced as necessary. The affected pipes shall be re-blasted.

5.2.11 Pipe ends shall be sealed to prevent ingress of blasting material (grit / shot).

5.2.12 Phosphoric acid / deionized water treatment, and chromate pre-treatment should be undertaken.

5.2.13 The maximum residual chloride level on the blast-cleaned surface shall be 20 mg/m2, in accordance with ISO 8502-2 or any other method approved by GAIL.

5.2.14 One of every 100 pipes shall be checked for chloride contamination on the blasted surface. If contamination of the surface occurs, the quality of the blast cleaning material and process shall be examined. If the conductivity of the blasting material is greater than 50 μS/cm, the blasting material shall be replaced.

5.2.15 Removal of dust should be via the use of vacuum "cleaning" and/or clean, dry air blast. The dust level on the blast-cleaned surface shall be of Class 1 in accordance with ISO 8502-3.

5.2.16 Blast cleaned pipes shall be coated within 4 hours. Pipes whose coating is delayed beyond this period, or pipes showing any visible rust stains, shall be blast cleaned again.

5.2.17 At the pipe ends, the coating shall be cut back over a length of 150 mm ± 20 mm unless otherwise specified. At the cutback, the coating edge shall be shaped to form a bevel angle of 30° to 45°.

5.2.18 At predetermined intervals, one pipe shall be selected for destructive testing of the coating. A sample length of approximately 1 m shall be cut from one end of this pipe and subjected to the adhesion, impact, indentation and elongation tests.

5.2.19 One sample, at predetermined intervals, shall be subjected to Cathodic disbondment test. To enable timely intervention in the coating process in case of failure, the 28-day test at (23 ± 2) °C may be replaced by a 7-day test at (40 ± 2) °C or a 2-day test at (65 ± 2) °C, if approved by GAIL. Such approval may be
obtained if during qualification testing the alternative tests were also done on the same sample as the 28-day test for comparison.

5.2.20 At predetermined intervals, one pipe shall be selected and a coating sample taken from the pipe for the cure test. The $\Delta T_g$ value (Glass Transition Temperature) shall be between -2 °C and +3 °C. The damage caused by the sampling shall be repaired.

5.3 **Mainline Ball Valves (NG Service)**

5.3.1 The valves shall be manufactured and tested in accordance with API 6D, Specification for Pipeline Valves and API 6D monogrammed. The same shall be supplemented with provisions given hereunder.

5.3.2 All valves shall be of ‘Fire Safe’ design and tested in accordance with API 607 or API 6FA.

5.3.3 Only fully welded/forged body type valves shall be permitted for mainline applications.

5.3.4 Balls shall be trunnion mounted and solid and the valves shall be welded body bi-directional type.

5.3.5 Stem Extensions to buried valves shall be provided such that the valve top works is at least 450 mm above finished ground level.

5.3.6 All valve body cavities including the gland extension shall be self-relieving or double piston effect seat design.

5.3.7 Dry Test: In order to predict the performance of the valves under operating conditions each ball valve shall be tested without injection of a lubricant on the ball and seat ring. This test is to determine the required breakaway (static at a fully closed position) torque at differential pressures between 27.6 bar and the design pressure of the valve. Four tests are to be conducted at about equal differential pressure increments.

5.3.8 After successfully performing the Dry Test above, the valve torque versus degrees of opening shall be determined for the initial 45° of travel from closed position while under design pressure.

5.3.9 Each completed valve shall be subject to a hydrostatic shell test and a hydrostatic seat test as specified in API 6D, Section 5.

5.4 **Isolating Joints (Isolating Joints)**

5.4.1 Isolating Joints shall be of Monolithic type construction with butt weld ends as per ANSI /ASME B 16.25. The isolating joint shall be formed by sandwiching and
locking in positions the isolating material in a bell and spigot type of joint. The joint shall be assembled in such a way that its various components are firmly locked in position and the completed joint is capable of withstanding stresses due to designed operating conditions and field hydrostatic testing. Construction shall not incorporate any flanges, bolts, nuts and threaded unions and structure shall be stiff, strong and suitable for maintenance free field installation, no matter if installed on buried or aboveground pipeline. Isolating joint design and materials shall be capable of being vacuum tested to 1 millibar.

5.4.2 Proven history of successful installations shall be mandatory requirement (feedback from internal users in GAIL shall be taken invariably to confirm satisfactory performance).

5.4.3 The isolating joint body shall be designed in accordance with the principles of ASME VIII Division 1 Appendix 2. As a minimum requirement, the design pressure shall be the same of the design pressure of the pipeline. If no requirement is specified instead, the design temperature shall be 0/+70°C. The isolating joints shall be designed to withstand the design pressure plus an external applied bending load that combined together are sufficient to induce a total longitudinal stress of 100% of the SMYS of the adjoining pups.

5.4.4 The average dielectric strength of the isolating joint shall be minimum 15 kilovolts. Insulation resistance of each isolating joint shall be at least 25 mega ohms, when checked with 500-1000 V DC.

5.4.5 Only continuously molded precision Viton seals shall be used (Minimum hardness 75 shore).

5.4.6 Dielectric Test and Megger Test: Upon completion of the assembly and prior to the hydrostatic test, each isolating joints shall be megger tested with 1000 V. d.c. Minimum resistance shall be 5 M Ohm. Each Isolating joint shall be also dielectric tested at 5000 V a.c. (50Hz) for 1 minute. No flashover, or breakdown shall occur during the test. The above tests shall be repeated immediately after hydrostatic test. The readings before and after hydrostatic test shall be equal. Moreover, megger test shall also be repeated on wet isolating joint. Test shall be performed right after water immersion, or internal surface water spraying. Tension test shall be 1000 V. d.c. minimum and resistance shall be 1 Mohm minimum.

5.4.7 Fatigue and Hydrostatic Test: A fatigue hydraulic test shall be carried out on each joint before the hydrostatic test. This test consists on 40 consecutive cycles of quick pressure variations from 1.000 kPa to 1.5 time of the design pressure, back and fore. After fatigue test, the isolating joint shall be hydrostatically tested, at 1.5 times of the design pressure. The test pressure shall be maintained for at
least 60 minutes. No leaks or unacceptable deformation shall occur during this test. Fatigue and hydrostatic tests shall be carried out in unrestrained conditions.

5.4.8 Standard Installation practice as recommended by its OEM to be adopted during construction so that to avoid any damage to its insulation.

5.5 **Flow Tees**

5.5.1 Flow tees shall be radial flow type, comprising of an oversized extruded outlet tee with forged end pieces, and a slotted guide tube. The annulus of the tee shall be sized to ensure that pressure does not drop during the pig passage, while the slotted guide tube allows for the maximum fluid flow while maintaining sufficient restrain for the sphere or pig.

5.5.2 Flow Tees shall be ASME Section VIII Div 2 compliant to meet ASME 31.8 or ASME B31.4 and applicable sections of MSS SP-75, unless otherwise specified. The materials of the tee and end pieces are selected to match the pipeline material.

5.5.3 All pressure boundary welds are 100% radiographed. Completed Assemblies shall be hydro-tested to minimum 1.5 times the design pressure for a minimum duration of 4 hours.

5.6 **Induction Bends**


5.6.2 Starting material shall be selected so that the anticipated contraction of the pipe diameter during bending shall result in a minimum inside diameter meeting the specified dimension. The tangent ends, including a distance of at least 4 inches from each weld bevel, shall meet the diameter requirements given below.

5.6.3 For bends from longitudinally welded pipe, the longitudinal weld seam shall be located as close as possible to the neutral axis of deformation in the bend. Bends shall contain no girth welds. Helical welded pipe shall not be used to make induction bends.

5.6.4 The minimum wall thickness shall meet the requirements of MSS SP-75[BA3], Paragraph 13.2 "Wall Thickness". The outside diameter of the pipe bend shall not be reduced in any circumferential plane by more than 2.5% of the nominal pipe diameter and shall meet the requirements of API 5L for a distance of 4 inches from each end. The minimum allowable inside diameter shall be as specified in the design information. This dimension shall be evaluated by passing a cylindrical gauging device through the bend with or without the assistance of power equipment. The gauging device shall have a diameter equal to the specified...
minimum allowable inside diameter. Any bend that does not allow unrestricted passage of the device shall be rejected.

5.6.5 The ovality of the bend zone shall be a maximum of 2.5% [z6]. The ovality of the tangents shall be a maximum of 1%. For bends which shall be considered segmentable, the ovality within the bend shall not exceed 1% per B16.49 Paragraph 15.3.

5.6.6 For pipe not supplied by GAIL the Manufacturer shall supply a mill test report (MTR) for review and approval by GAIL. For pipe supplied by GAIL the manufacturer shall review the related MTR and be responsible for determining the suitability of the pipe as a starting material that will be capable of meeting the required mechanical property and dimensional specifications for the finished bend Chemical analysis of the starting material shall meet the requirements of ASME B16.49 Section 7 except that:

- The maximum allowable carbon equivalent shall be 0.42.
- The maximum allowable nickel content shall be 0.5%
- The sum of copper, nickel, chromium, and molybdenum shall not exceed 1%.

5.6.7 The induction hot bends shall be made by induction heating 3600°C around the point of bending. The pipe shall be pushed through the inductor coil at a constant speed followed by a water quench. The pipe shall not contact copper-based material or other low melting temperature materials. All bending parameters within a given lot of steel shall be kept constant within the tolerances of the Manufacturer’s bending procedure for that heat. Records shall be kept for the following parameters during the bending process for both production bends and prototype bends and provided to the Company for review.

5.6.8 If seamless pipe is used, and circumferential variations in pipe thickness are detected, the thickest part of the pipe shall be oriented at the extrados of the bend.

5.6.9 Unless specified otherwise, the unbent tangents shall be at least two feet (0.6 m) in length, with a tolerance of +/- 2 inches (50 mm). No welding is permitted on any part of the bend except that necessary for temporary attachment of extensions required for pushing through the heating coil. The extension, plus at least ¼ inch of the adjacent bend tangent shall be removed prior to final heat treatment. The bevel shall be re-machined prior to shipment.

6.0 Pipeline Construction & Testing

6.1 ASME B31.8 code stipulates the following minimum requirement for pipelines to be operated at hoop stresses of 20% or more (841.2.2 paraphrased). It shall be required
that stage-wise inspections listed below with corresponding test / inspection record are incorporated in the QA/QC plan. It shall be required that a sample check (maximum sample size as per availability of resources) be performed by GAIL engineer to ensure strict inspection and quality surveillance by the third party agency:

6.1.1 Inspecting the surface of the pipe for surface defects just prior to coating
6.1.2 Inspecting the surface of pipe coating as it is lowered into the ditch to find coating lacerations that indicate the pipe might have been damaged after being coated.
6.1.3 Inspecting the fit-up of the joints before the weld is made.
6.1.4 Visually inspecting the stringer beads before subsequent beads are applied.
6.1.5 Non-destructive testing of welds
6.1.6 Inspecting the completed welds before they are covered with coating
6.1.7 Electrical testing of the entire coating including that of weld joints.
6.1.8 Inspecting the condition of the ditch bottom just before the pipe is lowered in
6.1.9 Inspecting the fit of the pipeline to the ditch before backfilling.
6.1.10 Inspecting all repairs, replacements, or changes ordered before they are covered.
6.1.11 Inspecting backfill material and procedure to ensure no damage occurs to the coating in the process of backfilling.

6.2 In addition to the above, the following practices shall be adopted keeping to the objective of sound and modern construction methodology to assure enhanced integrity:

6.3 100% Non-Destructive Testing of shall be carried out by Digital X Ray, owing to longevity of record, ease of storage and retrieval of records. In case of automatic weld, in addition to digital X-Ray, Automatic UT shall also be done to preclude the planar defects owing to narrow weld groove geometry.

6.4 Measurements for field bending shall be made to ensure that the welded pipeline section fits the trench and does not result in any free span.

6.5 After lowering, it is recommended that GPS coordinates of each Girth-weld joint should be taken and shall form part of the Pipe Book. In any case, GPS coordinates of all tie-in joints, fittings, valves etc., shall be mandatorily be taken and the same shall be incorporate in the pipe-book.

6.6 It is recognized as good practice, to install a short pup piece (1 – 3 m) every 1 Km to enable accurate measurement of pipeline features from ILI results.
6.7 Joint Coating System for pipeline section to be used in HDD section shall be selected and applied that it can take the abrasive and pull loads encountered by the pipe section when pulling the pipeline section in to the bored hole. The efficacy of the coating system can be checked by an extra joint (short pup with joint coating) at the start of section which when pulled out of ground and inspected can assure that the condition of unexposed joints based on the condition of the exposed first joint.

6.8 For coating the girth-weld joints of a pipeline made in field and for the buried sections of installations such as SVs that are typically fabricated from bare pipes, fittings and valves, any of the coating type i.e. Heat shrinkable wraparound sleeve (Type 2B – ISO 21809-3), Cold-applied coextruded three ply tape coating (Type 1D – ISO 21809-3) or Visco Elastic Self-healing Tape Coating system systems are acceptable. It must include the surface preparation and testing requirements in the field as required by the selected type of coating system to be applied.

6.9 If width of warning tape is in excess of 150 mm, then the same shall be of mesh type that allows CIPS survey on ground.

6.10 In pressure testing the pipeline post construction, highest possible pressure shall be targeted. It shall be targeted for a test pressure corresponding to 95% of SMYS at the lowest point of the section but not less than 1.25 or 1.5 times MAOP as per class location at any point. Reference shall be made to Guidance Document Ref: CIMG-GD-4-2016-0005, Pressure Testing of Pipelines & Piping Systems, some of the salient features of which are given as under:

6.11 Water for hydro-test shall be filtered through 50-µm filters. Depending on the quality of water, the duration of contact of line-fill water with the interior of the test section, the pre-commissioning requirements and the future use of the pipeline, treatment packages containing an oxygen scavenger and biocide may be added to the line-fill water. The Contractor shall demonstrate the environmental acceptability of any proposed treatment package e.g. toxicological, Biochemical Oxygen Demand, Chemical Oxygen Demand etc. after filtering/separation and/or neutralization. Environmentally acceptable line-fill treatment packages should be used.

6.12 To minimize biological fouling and/or bacterial corrosion to an acceptable level in the filled pipeline, the above concentrations shall not exceed the following limits:
- sulphate concentration 42 mg/kg
- fatty acids concentration 14 mg/kg
- ammonium concentration 3 mg/kg

6.13 Sodium hydroxide/sodium bicarbonate buffer shall be used for pH treatment which also achieves the required microbial control.
6.14 The oxygen scavenger treatment should achieve a dissolved oxygen content of 10 ppb or lower.

6.15 Where the line-fill water is to be transferred from one test section to another, the quality of the water shall be checked and the water shall be chemically retreated as necessary before it is transferred. The water shall be refiltered through 50-μm filters to reduce the entrainment of debris from one test section to another.

6.16 In-Line Inspection of new pipelines to be done using high resolution MFL tool with xyz mapping before commissioning / Handing over to O&M Department.

6.17 High Resolution Electronic Geometry Pigging (EGP) shall be done before commissioning, after hydro-test and all dents more than 2% of pipe diameter shall be cut out and replaced with pretested pipe piece.

6.18 Temporary Cathodic protection (TCP) should be converted to Permanent Cathodic protection (PCP) system based on best design practices as mentioned above. Before commissioning of the PCP system, all anodes installed during TCP shall be removed from the pipe connections in their respective TLP’s.

6.19 A CIPS of the entire pipeline shall be undertaken as soon as possible after complete commissioning of the CP system, in order to fully validate and provide a “fingerprint” of the CP system.

6.20 AC Interference Survey shall be performed with software modeling & simulation considering the steady state at rated currents of power lines & worst-case scenarios including the lightning strikes, along with the mitigation impedance requirements and its design. All 66KV and above power lines, within a separation distance of 1000 meters in rural & 300 Meters in Urban areas and Power lines below 66 KV & Underground Power cables within a separation distance of 50 Meters on either side of the pipeline shall be included in the Interference study.

6.21 AC Measuring Coupons of 1 cm² shall be installed with TLP’s with appropriate shunts at every vulnerable location as identified during AC Interference survey.

6.22 Underground portions of all connecting spur lines (if not passing though culverts) including the gas conditioning & metering skids shall be installed after installing the Isolating Joints so that the underground portion is cathodicaly protected and to prevent the current drainage from other above ground structures which are normally earthed.

6.23 Wherever CP system is hooked up from other pipeline, it has to be necessarily through shunts of proper rating with resistors in the respective test stations, to have the current measuring facility.
6.24 DC interference survey has to be carried out for each foreign pipeline crossings/parallel running and other DC stray current interferences and whatever is the level of the interference, it has to be recorded & documented during commissioning as base line data along with the mitigation measures like bonding etc.

6.25 Cables entries & exists in Test stations shall be filled up with non-settable compounds to prevent the entry of insects/rodents etc.

6.26 Wherever Electrical operated equipment like MOV’s etc. are installed at the cathodically protected portion of the Pipeline, it has to be earthed through solid state DC decouplers to the earthing system.

6.27 Instruments like Pressure & Temperature Transmitters shall be installed through dielectric decouplers of the appropriate ratings & class.

6.28 All Design documents & commissioning survey Reports i.e. CIPS, CAT, DCVG/CAT with “A” frame surveys, Current distribution surveys through “B” type test stations, Coating conductance surveys, Soil resistivity surveys, Soil testing reports shall be handed over to O&M at HOTO.

7.0 Quality Assurance in Pipeline Construction

7.1 All inspection and quality control activities shall be directly contracted by GAIL or the PMC and should not be part of the scope of fabrication or laying contractor, owing to the potential conflict of interest.

8.0 Pre-Commissioning and Commissioning

8.1 Pipeline Drying is a critical operation having a significant impact on the pipeline during service life from internal corrosion point of view. Vacuum Drying and Drying using Super Dry Air are two most commonly employed techniques. As against Super Dry Air technique which involves number of pigging runs (foam pigs of different densities) which is generally expected to provide a higher degree of cleanliness, in case Vacuum Drying is adopted as drying technique, the same shall be preceded by swabbing to remove liquid water from pipeline and also, upon commissioning, to be immediately followed by several pig runs (foam & brush pig) at the start of operations.

8.2 Special care for pipeline ball valves while testing & commissioning shall be taken so that valves provide the intended tight isolation and smooth operation during its service life. Some of the essential requirements to be adopted during testing and commissioning are listed under:

a) During pipeline water filling for hydro test, valves should be in a fully open position, to ensure that debris does not fall into the bottom of the valve body where it could plug the body vent or body bleed fitting.
b) Prior to pressurizing the pipeline, valves should be rotated to the half-closed/half-open position to prevent the possibility of a pressure differential in the valve body during hydrostatic testing. As cycling the valve at this stage might cause damage to the soft seat, a better method is to use the jumper hose assembly method, where a jumper hose is installed between the pipeline and the valve body cavity, as well as through the body drain/vent valve. This way, as the pipeline fills with water, so too will the body cavity.

c) After pipeline hydro-testing, it is recommended to dewater the valve body cavities and dry by passing dry air or nitrogen using drain and vent connections of the valve. A light synthetic lubricant shall then be injected to push away any remaining moisture in the seat pocket area. It is highly recommended to spray the valve cavity with suitable corrosion inhibitors.

8.3 PESO approval for commissioning, OISD pre-commissioning audit, T4S audit shall be completed by Projects Department before handing over to O&M. Clearance for commissioning of pipelines which does not fall under the purview of PESO shall be obtained from a third party agency such as Project Management Consultant / Third Party Agency having experience in the field of pipeline construction but other than those already involved in project management or inspection during construction.

8.4 Handing-over and taking-over (HOTO) between Projects and O&M group shall be completed within six months of commissioning at respective ED level. The handing over / taking over shall include all the statutory permissions, design and commissioning documents and reports.

8.5 Before handing-over of any new pipeline system, compressor / booster stations etc., Projects Department shall ensure commissioning of all the major system such as SCADA / DCS, remote operation of valves, permanent cathodic Protection system etc.

8.6 The list of documents and records to be handed over to O&M upon completion of a pipeline project is given at Appendix -5

Typical pipeline codes and standards include:
- ASME B31.4 – Pipeline Transportation Systems For Liquid Hydrocarbon Pipelines (US/International Standard)
- CSA Z662 – Oil And Gas Pipeline Systems (Canadian Standards Association)
- NEN 3650 – Requirements For Pipeline Systems (Dutch Standard)
- AS 2885.1 – Pipelines—Gas And Liquid Petroleum Part 1: Design And Construction (Australian Standard)
- SNIP 2.05.06-85* Trunk Pipelines (Russia, Developed By VNIIST)
- VSN 51-3-85 Design Of Steel Field Pipelines (Russia, Developed By Vniigaz)
- BS EN 1594 - Gas Supply Systems _ Pipelines For Maximum Operating Pressure Over 16bar - Functional Requirements
- BSI PD 8010 - Code Of Practice For Pipelines
- ISO 13623/EN 14161 - Petroleum And Natural Gas Industries — Pipeline Transportation Systems
Appendix-1

Guidelines for Pipeline Surveying
For integration in Pipeline Geographic Information System

With the implementation of PGIS database portal after mapping all pipelines in in GIS platform, it is essential that all on-going and upcoming pipelines are incorporated in the system to keep it up-to-date. In this regard, the following guidelines are proposed for review and incorporation by Project and S&LR groups in the planning and execution phase.

1. Once a project is approved for implementation, S&LR group in Project Department shall provide the tentative pipeline route with other pertinent data on start / intermediate / end stations for incorporation in PGIS as ‘Pipeline under Construction’.

2. Route Planning:
   Preliminary Route Planning can be achieved by maps or satellite imageries already available with GAIL (in O&M / Projects group). For areas where map resources are not available, maps / imageries available in public domain may be adequate.

3. Base Map Preparation:
   The base maps in PGIS have been prepared using photogrammetry processes on High Resolution Satellite Imagery. Accordingly the same may be included in the survey contract for detailed route survey. Essential factors in this work may include:
   - Procurement of HRSI which may be kept in the scope of Contractor to reduce cycle time as this involves procuring imagery through NRSC. Alternatively Drone or other aerial vehicle based imageries can also be considered which may further reduce the cycle and time with much higher quality imageries. The imageries may be required for a width of 3 Km with the proposed alignment in the centre.
   - Ground Control Points are required for further processing of Imagery. Establishing the same in field with vertical control by fly levelling tied to nearest benchmarks, may be included in the scope of survey contractor.
   - Post processing of imageries with GCPs to prepare base maps may either be carried out by the survey contractor or sub-contracted to agencies having this expertise.
   - Digital Terrain Models can be generated from the imageries to provide the contour maps.
• At this stage, areas having known geotechnical issues / concerns may be identified for further verification during field survey.

• During this stage, the villages intersected by the proposed corridor can be identified for collection of village maps and their digitization. These digitized village maps can be superimposed on the base map imagery to align with field boundaries and control points can be selected for acquiring coordinates and ground truth-ing during field survey.

4. Field Survey and Staking Pipeline Alignment

During this stage, the identified corridor from the previous stage is further validated and pipeline centreline is confirmed and staked on ground. Along with staking centreline alignment by fixing start / end points, Intermediate Points (IPs) and Turning Points (TPs), required ROU corridor also shall be demarcated on ground by fixing boundary stones / pillars.

• Though in the past, conventional survey using Total Stations has been in practice, in order to make the data GIS ready, either conventional surveys together with capturing the coordinates of IPs and TPs can be adopted with DSPS or the conventional survey can entirely be done away for the DGPS based or Survey Grade Dual Frequency GPS receiver with Real Time Kinematics (RTK) or post processing for fixing the alignment.

• Due care be exercised to tie / cross verify with the GCPs used for base map preparation for ensuring the required precision.

• Vertical Profile along the centreline alignment shall be taken by fly-levelling and tying back to bench marks and GCPs.

• GPS coordinates of all obstacle crossings such as railway tracks, all type of roads, all topographical features such as boundary fences / walls, mounds, field bunds, water bodies such as channels, drains, rivers, lakes & ponds, trees, powerline alignment parallel or crossing proposed centreline, powerline poles, pylons and other structures etc.

• Foreign Pipeline crossings shall be identified and coordinates of the foreign pipelines shall be collected for atleast 100 m on either side of the proposed centreline. In addition nearest markers of the foreign pipeline shall also be collected along with attributes such as owner of pipeline, name of pipeline, product, size and the concerned agency

• Enquiries shall be made with the local persons for the nearby Points of Interest (POI) such as hospitals, schools, government offices, power & utility stations, railway stations, bus stops etc. and their GPS coordinates shall be collected.
These may be collected on a corridor width of 20 Km (10 Km on either side of centreline).

- This survey shall also collect coordinates of administrative boundaries such as village, taluk, district etc.
- GPS coordinates of all linear features such as administrative boundaries, obstacle crossings etc., shall be collected for a minimum of 100 m on either side of the proposed centreline alignment.

5. Identifying Obstacle Crossing & Detailed Maps

Data of obstacle crossings falling on the proposed centreline are required to be collected with GPS coordinates in detail for deciding appropriate method of pipeline construction in such crossings and aiding preparation of detailed cross section drawings for the same.

- Detailed survey of crossing locations including crossing profiles, extent of ROU or crossing width, markers & features applicable to the obstacle crossing such as KM pillars, culverts etc. in case of roads.
- Collecting details of agencies concerned and their specific jurisdictional office responsible for stretch of railways / roads / canals etc.
- Due consideration shall be given to width of water bodies viz., width at the time of survey, highest water mark and width as per the records of the concerned agencies.

6. Population Density Survey

Population density is a factor considered in the pipeline design for providing appropriate Design Factor.

- As against the mere dwelling count in given Location Class unit, all the dwellings, industrial & office premises, public buildings etc shall be mapped by collecting GPS coordinates of the vertices of the buildings.
- Type of building whether permanent, multi-story (count of stories), evidence of underground utilities, traffic in roads etc shall be collected as attributes of the PDI.
- All the above data shall be collected for a corridor of min. 200 m on either side of the ROU and up to Potential Impact Radius (PIR) given by PIR (r) = 0.00315 \( d \sqrt{p} \); \( d = \) diameter (mm); \( p = \) pressure(KPa)
7. Geotechnical Survey
Geotechnical survey typically covers bore holes survey to examine sub-terrain characteristics such as soil type, underground rock formations, water table etc. and soil resistivity survey. Corrosivity of the soil is also established by chemical and biological analysis of soil samples from bore hole surveys. It is essential that the GPS coordinates of the bore holes and soil resistivity survey shall be collected for incorporation in the database.

8. Data Collection during / post construction:
It is important to collect data as the pipeline is being built so that accurate as-built drawings and maps can be generated without any additional effort.

- GPS coordinates of each weld joint (after lowering)
- GPS coordinates of the SVs and other installations of pipeline
- GPS coordinates of the vertices of installation boundaries
- GPS coordinates of casing extents
- GPS coordinates of bends
- GPS coordinates of cable connections to pipe for CP
- GPS coordinates of Anode ground beds
- GPS coordinates of all markers and boundary pillars
- Geotagged photographs of construction activities

9. The above data shall be incorporated in the Pipe Book such that the same can be completely geo-referenced.

10. The geographic database in GAIL shall be based on the following reference system:
- Coordinate System : Geographic Coordinate System
- Horizontal Datum : World Geodetic System – 1984 (WGS 84)
- Vertical Datum : WGS-84 Geoid

Deliverables at each of the above stages shall be provided to PGIS coordinator in Corporate O&M for updating the geographic database of PGIS regularly.
### Appendix-2

**Thresholds for Corrosive Constituents of Natural gas & LPG for Pipeline Transportation**

#### Natural Gas:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.1 % by Volume – Max</td>
</tr>
<tr>
<td>Hydrogen Sulphide (H₂S)</td>
<td>5.7 mg / SCM – Max</td>
</tr>
<tr>
<td>Mercaptans</td>
<td>5.7 mg / SCM – Max</td>
</tr>
<tr>
<td>Total Sulphur</td>
<td>46 mg / SCM – Max</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>2% by Volume – Max</td>
</tr>
<tr>
<td>Liquids</td>
<td>Gas shall be free of water and other liquids at the temperature &amp; pressure at which gas is delivered. Gas shall not contain hydrocarbons that might condense to free liquids in the pipeline under normal conditions. In no event, the gas shall contain water vapour in excess of 112 Kg / MMSCM</td>
</tr>
<tr>
<td>Dust/Gums/Solid Matter</td>
<td>Gas shall be free of dust, gum-forming constituents and other solid matter</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>3% by Volume – Max</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>400 ppm max</td>
</tr>
<tr>
<td>Temperature</td>
<td>Min: 4.4 deg Centigrade</td>
</tr>
<tr>
<td></td>
<td>Max: 49 deg Centigrade</td>
</tr>
</tbody>
</table>

#### LPG:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Sulphide (H₂S)</td>
<td>5 ppm – Max (EN ISO 8819 / ASTM D2420)</td>
</tr>
<tr>
<td>Total Sulphur after odorizing</td>
<td>50 mg / Kg– Max (EN 24260/ASTM D2784/D3246 / D6667)</td>
</tr>
<tr>
<td>Moisture</td>
<td>No Free water at 0 deg C (EN 15469 / ASTM-D 6304-07 / IS 1448)</td>
</tr>
<tr>
<td>Caustic</td>
<td>Zero</td>
</tr>
<tr>
<td>Copper strip corrosion</td>
<td>Not worse than No.1a (ASTM D1838)</td>
</tr>
</tbody>
</table>

Other parameters will be as per IS 4576.
Corrosion Management- Design Basis

1.0 Design Data and Basis

1.1 For details on Corrosion management during design, construction & commissioning, CIMG guidance document CIMG-FW-5-2017-0001 on GAIL Corrosion Management System shall be referred. The salient features are re-produced here below.

1.2 Planning and Design of a pipeline system begins with collection of data along the pipeline route or at the proposed tie-ins to other pipelines, terrain characteristics, pipeline fluid specifications, hydraulic parameters etc. Evaluating that data allows an upgrade of the Process Design Basis into the Process Design Package once all the intermediate activities of actual site / route survey including corrosion survey has been completed.

1.3 Corrosion Survey shall examine the characteristics of the external and internal environment in which the pipeline system is expected to operate in and gather data for further assessment or analysis. These will typically include corrosivity of the local atmosphere (above ground pipelines and structures), soil characteristics and chemistry & depth of water table. The internal characteristics of the pipelines, the type and concentration of corrosive components and the physical state and volumes of electrolyte (typically, moisture or liquid water) in the pipeline flowing medium specifics such as flow regime, volume, temperature and pressure, are all essential for internal corrosion assessment. They shall form a set of minimum data requirements for the assessment of corrosion risk and the selection of suitable design for the pipeline systems and their appurtenances that ensures integrity.

2.0 Corrosion Assessment

2.1 Preparation of Process Design Package shall be preceded by a Corrosion Assessment that determines the principal external and internal corrosion threats. Such an assessment shall be the basis for selecting material of construction, determination of Corrosion Allowances (CA) and the corrosion protection requirements. The protection requirements typically include primary passive barriers in the form of paintings, coatings and insulations supplemented by active control systems, such as Cathodic Protection (CP).
2.2 Corrosion Assessment is accomplished by Internal Corrosion Prediction Modeling (ICPM) or other assessment tools and methodologies that utilize latest technologies and software packages tailored to specific corrosion mechanisms (or a combination of those) applicable to the GAIL pipeline system.

2.3 Notwithstanding the ICPM findings, the following minimum corrosion protection measures shall be incorporated in the design and construction of a pipeline system.

2.4 Corrosion Allowance for a carbon steel pipelines, fittings and mainline valves shall be calculated from corrosion modelling based on the evaluation of all the potential corrosion mechanisms and their severity levels. Notwithstanding the above, all pipelines shall have a minimum of 1 mm corrosion allowance. If any variation in gas quality is expected at any stage in the operation, the corrosion allowance shall be that calculated by modelling or 2.0 mm, whichever is higher.

2.5 Piping, equipment, vessels and structures exposed to atmosphere shall be provided with a painting / coating / insulation system suitable for the specific local environment (industrial, marine, rural or indoors).

2.6 Piping and pipelines buried underground shall be provided with a Corrosion Protection Coating System in accordance with Guidance Document "Factory & Field Applied Coating on Line Pipes, Field Joints and Appurtenances" Ref.CIMG-GD-5-2017-0002.

2.7 Buried pipelines and structures shall be provided with a properly designed Cathodic Protection system of Impressed Cathodic Current Protection (ICCP) Type, complete with monitoring test posts, coupons & probes as given here with in Appendix-3.

2.8 Pipelines shall be routed and stations shall be sited such that they are not impacted by AC / DC Interference from power lines and other foreign pipelines. A thorough survey to identify such threats shall be carried out, followed by a software model based study and incorporation of mitigation measures during the construction stage.

2.9 Internal Corrosion Monitoring System using combination of ER Probes with provisions for data logging and Mass Loss Coupons at defined locations as given in Guidance document CIMG-GD-5-2016-0006: Internal Corrosion Monitoring of Pipelines.

2.10 Buried pipeline sections shall be isolated from the aboveground sections by a monolithic type of Insulation Joint of appropriate rating with protection.

2.11 Pipeline systems shall be designed to facilitate periodical inspections using in-line tools.
2.12 Preliminary corrosion risk assessments carried out during the design phase of a project shall be subject to ongoing active reviews and updates throughout operation and decommissioning stages. A change in operating conditions identified during the operational phase will require reassessment or a new assessment of a specific corrosion mechanism. Alternatively, a sensitivity analysis to varying pipeline conditions may be required to examine the impact of certain parameter on the corrosion rate. Furthermore, it is essential that the results of any corrosion assessments be used as a benchmark for the field monitoring and inspection data. Consequently, corrosion risk assessment is a periodic ongoing activity throughout the life cycle of the project.

3.0 Planning & Design

3.1 Pipelines shall be designed and constructed in accordance with the PNGRB regulations, OISD standards and the requirements of the PIMS Framework and the Guidance Documents referenced therein.

3.2 The original hydraulic study of the pipeline system typically includes additional capacity for the pipe sizing. However, it is preferable to maintain internal gas velocity at an optimised constant rate. The velocities that are too low will lead to the development of the stratified flow, water drop out, solids deposition inside the pipeline and the associated corrosion risks (TOLC, UDC). If the velocities are too high, corrosion can accelerate due to increased pipe wall shear stresses, solid impingement, erosion and erosion-corrosion.

3.3 Internal Coating used both for corrosion protection and improved flow efficiency shall be considered for the pipelines connecting the small and medium volume onshore gas sources or those sources where gas quality deviates from prescribed tariff specification.

3.4 All new pipelines shall be piggable irrespective of their length and size. All the pipelines carrying fluids not meeting the dry gas quality specifications that traverse urban and populated areas shall invariably be equipped with the full bore valves, long radius bends and pig barrels at either ends or with provisions for connecting temporary scrapper barrels.

3.5 Online analyzers for continuous gas composition monitoring for corrosive constituents shall be installed downstream of the locations where off-spec gas enters the main gas stream.
3.6 A corrosion rate sensitivity analysis to the 50 and 25% turndown gas flow rates should be carried out as part of ICPM while determining the corrosion allowance and finalizing corrosion mitigation and monitoring systems design.

3.7 If the resulting corrosion rate from the ICPM assessment exceeds 0.1 mm / year, mitigation measures shall be incorporated in the design which may include alternate materials or chemical intervention.

3.8 If an injection of corrosion inhibitor is required to control corrosion, the full functional specification of the requisite corrosion inhibitor injection system including metering pumps, CI transfer & storage system, injection quills and connected piping/tubing shall be incorporated in the design of the dispatch terminals and intermediate points.

3.9 Aboveground piping and facilities shall be provided with painting / coating systems in accordance with the codes and specifications applicable to the environment where those systems will be located and operated.

3.10 Buried pipeline sections and facilities shall be provided with an appropriate coating system with the impressed current cathodic protection system (ICCP). A robust monitoring system shall be built into the cathodic protection system comprising isolation joints, CP test posts, coupons etc. The CP system design shall be an integral part of the total pipeline design which comprises temporary CP system for the pipeline during construction and permanent CP system once the pipeline has been commissioned. To achieve the effective CP design of the pipeline system a site survey is required to collect essential information of soil resistivity, geographical factors, likelihood of existence of stray currents. The surveys shall be carried out before and after construction.

3.11 Baseline AC/DC interference surveys shall be undertaken in conjunction with software modelling to develop and implement a mitigation program. The program shall define the monitoring data points for verification during service life and the necessary measures for augmentation / additional mitigation, when necessary.

4.0 Corrosion Management during Construction:

4.1 Line Pipes are required to be stored at intermediate storage yards prior to stringing in ROU. Care shall be taken to prevent corrosion of line pipes in such storage.

4.2 Line Pipes to be stored for more than one year shall be covered with tarps to prevent against UV degradation of the PE outer layer. For details, refer to Guidance Document...
4.3 Preservation of pipes during long term storage and construction is very important aspect for corrosion control of line pipes specifically at ends and hence steps as given in CIMG guidance document CIMG-GD-1-2016-0002 for Long term Preservation of Coated line pipes to be strictly followed up to prevent the line pipe from corrosion at ends.
Design & Engineering of Cathodic Protection System for Buried Pipelines

1.0 Basic Design Requirement

1.1 Impressed Current Cathodic Protection (ICCP) systems shall be used to protect the buried underground pipelines / piping network or sections. The minimum design life of the permanent Cathodic Protection System shall be 35 years.

1.2 Sacrificial anode systems may be used for localized protection for some short portions of the piping system, such as underground sections of normally above ground flow lines at road crossing locations. This has to be identified by the designer of CP system. Proposal to use sacrificial anode systems shall require prior GAIL approval. However, culverts at such locations shall be preferred to isolate the underground piping from soil contact.

1.3 Temporary CP system shall be installed at earliest but not later than one month from the time of lowering of pipeline segments to ensure that all buried steel structures are cathodically protected until the permanent CP facilities are operational. The temporary anode cables shall be terminated in a Test Station (TLP). The minimum design life of the Temporary CP system shall be at least Two (2) years. However, permanent CP system shall be provided within one year from the date of installation of TCP.

1.4 The Contractor shall ensure that the integrity of the existing impressed current cathodic protection (ICCP) system for the pipelines and other buried metallic assets is intact after the installation of the works.

1.5 Each pipeline section shall be provided with a minimum of One (1) separate cathode (negative) connection point. The actual number of connection points shall be considered to control the current flow and to provide protection over the pipeline.

1.6 Junction box / boxes shall be utilized for cable connection, anodes distribution, and current flow control.

1.7 Minimum capacity/ rating of components in each system, including, anodes, shunts, resistors, etc. shall be of suitable rating.

2.0 Cathodic Protection Criteria

2.1 The structure-to-soil potential shall be measured by using high impedance Multimeter and duly Calibrated Copper/Copper Sulphate (Cu/CuSO₄) saturated reference electrode.
2.2 The negative polarized potential (IR corrected, instant OFF) of at least 850 mV with respect to a saturated \( \text{Cu/CuSO}_4 \) reference electrode.

2.3 The maximum negative potential value permissible (IR corrected, instant OFF) shall not exceed \(-1200\text{mV (Cu/CuSO}_4)\). 

2.4 As such there is no limit for maximum "ON" negative potential; however in general, it should not be more negative than \(-2500\text{ mV (Cu/CuSO}_4)\). If any special circumstances exist where an “ON” potential of more than \(-2500\text{ mV (Cu/CuSO}_4)\) is required to be applied, then it shall be brought forward for GAIL approval with proper justification supported by the pipeline coating Manufacturer's recommendations.

3.0 Current Requirements and Density

3.1 For design purposes, the minimum protective current density shall be:

   a) \(0.5\ \text{mA/m}^2\) for buried piping / pipelines where high quality coating systems (e.g. fusion bonded epoxy, high build epoxy, high build polyurethane, or three layers extruded polyethylene) are applied.

   b) \(3.0\ \text{mA/m}^2\) for buried piping / pipelines, where coal tar enamel or tape wraps coating are applied.

   c) \(15\ \mu\text{A/m}^2\) for temporary CP system for buried piping / pipelines.

4.0 Bonding

4.1 The Contractor shall supply and install bonding stations for the new pipeline as a provision for interference mitigation. Bonding Junction box (BJB) shall be installed as a minimum at the following locations

   a) Where the new pipeline runs parallel to the existing pipelines, at start and end of parallelism and at every five (5) km intervals. As a minimum, all existing parallel pipelines laid with a separation distance of 10 m shall be provided with bonding provision.

   b) Where the pipeline crosses or intersects the existing buried pipelines or buried section of pipelines / Piping.

4.2 BJB shall have provision to terminate \(16\ \text{mm}^2\) bonding cables and a \(6\ \text{mm}^2\) potential monitoring cables connected to each foreign pipelines as well as new pipelines. BJB shall be provided with appropriately rated shunts and resistors for each circuit. Minimum rating of resistors in the circuit shall be \(5\Omega, 100\text{ W}\).

4.3 Bonding stations shall limit the drain current from the existing CP unit to be not more than 10% of the rated output current.
5.0 Test Station

5.1 Test Stations shall be provided at both ends of pipeline and at maximum interval of 1 km (1000 m) along the pipeline length. If the pipeline length is less than 1 km (1000 m), three (3) test stations shall be provided as minimum. A Test Station at farthest end from the feeding point in a section shall be installed.

5.2 The Test Stations at vulnerable locations in view of corrosivity shall be provided with dual coupons. One shall be for IR free potential measurement, while the other shall be for native potential measurement. Such Test Stations shall include a magnetic reed switch between the polarized coupon and the pipe connections to facilitate interruption of the coupon.

5.3 Additional Test Stations shall be installed at the following locations:
   a) At Isolating joint locations
   b) At both sides of the valve station
   c) On both sides of cased road crossing locations
   d) At the galvanic / sacrificial anode installation
   e) At the stray current areas
   f) At a location that a change in the pipe wall thickness or diameter occurs
   g) At the feeding & drain points
   h) At Overhead power transmission line crossing or parallelism
   i) On both sides of river crossings

6.0 Line Current Measurement Test Station

6.1 Line Current Test Station (B Type Test Station) shall be provided at drain points and along the pipelines at every Ten km (10 km).

6.2 Current carrying cables on B Type Test station shall be 10 mm², whereas measurement cable shall be 6 mm².

7.0 Road/Rail Crossings

Pipelines and piping systems provided with road crossing casing pipe shall meet the following requirements:

7.1 Casings should be avoided as far as possible.

7.2 Wherever, cased crossings are unavoidable:
7.2.1 Casings pipe shall be designed in accordance with API RP 1102 thickness & Grade, subject to a minimum thickness as given therein.

7.2.2 Minimum extent of the casing shall be governed by the width of ROW of the utility corridor & additional site requirements.

7.2.3 Casing pipe shall be bare at its internal & external surface. Casing vent pipe shall be coated.

7.2.4 Casing pipe sizes shall be selected sufficiently large to avoid the damage to insulators during insertion of Carrier pipe in Casing. The difference between carrier & casing pipe size shall be as follows:

<table>
<thead>
<tr>
<th>Carrier Pipe Size</th>
<th>Min. difference in Casing &amp; Carrier Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 12''</td>
<td>6''</td>
</tr>
<tr>
<td>14 to 24''</td>
<td>8''</td>
</tr>
<tr>
<td>26'' and above</td>
<td>10''</td>
</tr>
</tbody>
</table>

7.2.5 No sacrificial anodes shall be used inside casing annular space.

7.2.6 Annular space of Casing & Carrier shall be left clear without any filler inside.

7.2.7 Post installation, it is to be ensured for sound isolation of Casing & Carrier Pipe and if any Electrolytic coupling or metallic shorting is observed, same shall be rectified during project/construction stage itself.

7.2.8 Utmost care should be taken to avoid any possibility of Coating defect in Carrier pipe while laying the Casing & Carrier pipe. Suitable Insulator supports, without any metallic fasteners should be designed to take care the Carrier pipe load. (In most cases, poor quality of insulators and their poor installation on the carrier pipe leads to breakage / bunching of insulators at the insertion point). Insulators should be fixed on carrier in such manner that they are not easily dislodged (using epoxy adhesives etc.) and also additional insulators need to be installed at either ends. High strength Polyethylene spacers & rollers fixed on carrier pipe should be used for easier insertion.

7.2.9 Casing pipe shall be electrically isolated from the pipe, using Polypropylene or HDPE spacers. The distance between two consecutive spacers shall not be more than 1 meter. In addition, double spacers shall be installed on carrier pipe at both ends of the casing.

7.2.10 Casing pipe shall be sealed at each end to prevent ingress of soil / water. Only pull-on type end seals shall be used for new pipelines. Retrofitting or wrap around type end seals shall only be used for existing pipelines with split casing installations. The end seal
shall be designed such that the end seal material by itself shall form water tight fit on casing as well as carrier pipe.

8.0 Overhead Power Transmission Lines

8.1 Testing shall be carried out in order to evaluate the effects of induced AC current and voltage on the cathodic protection system, pipeline and the effect on safety of personnel during pipeline construction. Remedial measures shall be implemented in accordance with codes & standards to bring down the steady state touch voltage on pipeline below 15V (rms) for safety reasons. In addition, any AC voltage indicating a current density of 30 mA/m² or above (assuming 1 cm² sized area of holiday / defect) shall be mitigated using a solid state DC de-coupling device and sacrificial anodes to mitigate against the probable AC corrosion.

8.2 Wherever Pipeline & power lines are collocating for more than 1 Km in vicinity (separation distance less than 50m from pipeline on either side, a continuous length of Zn Ribbon Anodes/Copper conductors with back fill material shall be laid along the pipeline on both sides to mitigate the interference effect of overhead power transmission pipelines.

9.0 Pre-Design Survey

9.1 Pre-design cathodic protection site survey shall be carried out along the route of pipeline and survey report shall be submitted to Company for review and approval. Site survey findings / results shall be offered for site verification to the Company representatives prior to submission of reports. Site survey report shall include detailed layout drawings of pipeline / facilities, reflecting all foreign pipeline / Overhead power transmission lines crossings & parallelism, existing CP facilities (such as transformer rectifiers, anode ground beds, test facilities etc.), soil resistivity survey locations, road crossing locations, etc.

The following surveys shall be carried out as a minimum along the pipeline route:

9.2 Soil Resistivity Survey

a) The survey procedure shall take into account the surface soil conditions, required survey depth and planned finished grade levels at the Site.

b) Soil Resistivity shall be carried out for subject area and survey results of which shall be made available for optimum design and calculations for the CP system.

c) Soil resistivity / conductivity measurements for deep anode beds are recommended, but not mandatory before the borehole is drilled. In any case, the final borehole depth and anode placement shall be approved by the
Company during construction, based on measurements of drill stem resistance and test anode resistance, taken during drilling of the anode borehole.

d) Soil resistivity data used in CP design calculations shall include the effect of seasonal weather conditions whereby the most onerous data is used.

e) Soil resistivity surveys shall be carried out at following locations as a minimum:

i. Along the pipeline route at every one (1) km interval, temporary sacrificial anode locations, road crossing locations and overhead power transmission lines at 1 m, 2 m and 3 m depths, utilizing Wenner’s 4-pin method as per ASTM G57 or by Electromagnetic method.

ii. Soil resistivity survey shall be carried out at shallow anode ground bed locations for plant areas. Soil resistivity survey shall be carried out at 1m, 2 m, 3 m, 5 m and at every 2 m interval up to the depth of anode, using Wenner 4 pin method as per ASTM G57. Such survey shall be carried out at minimum four (4) locations for each CP system.

9.3 Stray Current Interference

a) Site survey shall be conducted to identify the possible source of DC Stray currents.

b) Survey shall identify the existing anode ground bed and CPTR locations in the vicinity of pipeline route. Entire list of foreign ground bed / CPTR locations including rating and operating parameters of ground bed / CPTR shall be included in the report.

c) Foreign pipeline crossings and parallelism along the pipeline route shall be identified. Site survey report shall include the entire list and details of foreign pipelines along the pipeline route.

9.4 HVAC Line Crossings and Parallelism

Site survey shall be carried out along the pipeline route to identify the HVAC crossing locations and/or HVAC line parallelisms. Site survey report shall include a comprehensive list which includes the HVAC line rating in KV, distance of HVAC line / tower footings from pipelines and length of parallelism. Survey shall also include AC potential measurements of existing pipelines in the same corridor.

10.0 Electrical Continuity / Isolation

10.1 The pipeline / piping shall be electrically continuous over the total length but excluding connections to other pipelines. Where an isolating device is provided, a controllable bonding connection with variable resistors and current shunts shall be provided across the isolating device.
10.2 Electrical isolation of all newly constructed pipelines / piping shall be made via isolating joints, which shall be properly selected to comply with the pipe design parameter.

10.3 Electrical isolation joints shall be installed at the following location(s):
   a) Connection points of new pipe with existing pipelines.
   b) Connection points of new pipe with gathering centers, booster stations, manifolds, tanks, pump stations, and metering stations.
   c) When connecting the pipe to a device, that requires electrical grounding.
   d) Connecting pipes made of dissimilar metals

10.4 Additional isolating flange/dielectric kits, isolating glands and similar equipment shall be installed, as necessary, to prevent shorting of electrical isolation by instrumentation, electrical, and civil requirements. Such isolation points shall be provided with surge diverters.

10.5 Isolating devices shall not be installed in any buried section of a pipeline or piping.

10.6 Each isolating joint shall be fitted with an appropriate device to provide electrical isolation of CP DC voltages and currents, but provide a path for the safe passage of AC fault and lightning currents.

11.0 Cable Connections

11.1 Aboveground Cable Connections
   a) Aboveground cable connections to pipeline / piping and structures shall be by means of bolted cable lug connections to carbon steel plates welded to the structure. Only highly rated pure brass and, bolts and nuts shall be used.
   b) The steel plate and weld method shall be compatible with the structure material. The steel plate coating shall be removed to facilitate the bolted cable connection.
   c) Necessary coating repair / touch up shall be made on the steel plate after completion of cable connection

11.2 Underground Cable Connection
   a) Underground cable connections to piping and pipelines shall be made by means of Thermit welding or by Pin Brazing.
   b) A section of the pipe coating required for connections shall be removed to the minimum area, not more than 100 mm x 100 mm from the top of pipe.
   c) Suitable tools and method shall be used for cutting and peeling back the coating to avoid any damage to bare metal and the surrounding coating (percussion tools or grinders, shall not be used for this purpose).
d) This pipe area shall be thoroughly cleaned to a near white metal finish Sa2½, (NACE 2) surface preparation.

e) Upon completion of the weld, the pipe coating shall be repaired in accordance with the applicable Standard for pipe coating repairs.

f) A holiday detector shall be used to verify that the applied coating and wrapping have no holidays.

g) All cables shall be laid in single runs. No underground cable-to-cable splicing connections shall be made.

11.3 The connection shall be tested for mechanical strength and electrical continuity (Contact resistance between the pipe and cable shall not exceed 0.01 Ohm).

12.0 Anode Ground Beds

12.1 Anode ground beds shall be located such that the nearest cathode structure as well as any foreign structures is not within the anode voltage gradient. A minimum distance of 100 m shall be maintained between new anode ground bed and cathode / foreign structure.

12.2 Where new pipelines / piping run within the calculated voltage gradient of an existing anode ground bed, stray current mitigation shall be provided. On case to case basis, either a bonding station shall be provided between the pipeline and the existing ground bed transformer-rectifier (T/R) unit negative connection or sacrificial anodes may be used at "hot spots". Use of sacrificial anode shall be subjected to the GAIL approval. Bonding stations should limit the drain current from the existing T/R unit to not more than 10% of the T/R rated output current.

12.3 All anode groundbeds shall have ground bed marker posts with the groundbed name, tag number and depth on a stainless steel plate.

12.4 Coated metallic pipe or non-metallic plastic pipe shall be utilized for inactive length of ground bed casing, alternatively, metallic casing pipe at inactive length shall be cased with non-metallic, plastic pipe with adequate di-electric strength.

12.5 The Contractor shall provide GPS Coordinates for the proposed deep ground bed location to the Company prior to Drilling activities for approval.

12.6 The anode material for ICCP system shall be mixed metal oxide coated Titanium. All anodes shall be of tubular configuration.

12.7 Prepackaged (Canister) MMO anodes with carbonaceous backfill as per clause 15.6 of this document shall be used for shallow close distributed type anode ground bed.

12.8 The Vendor shall submit the calculation of quantity of backfill material required, which shall include quantity up to the top of the anode (active length) and spare quantity
above the active column. Coke breeze quantity shall be estimated for specified design life considering consumption rate of coke breeze **1.0 kg per amp year**.

### 13.0 Galvanic / Sacrificial Anode System

13.1 The use of a galvanic / sacrificial anode system shall be subject to the GAIL approval, and may be considered for the following cases:

a) Temporary CP systems during construction periods.

b) Underground road-crossing areas of above ground pipelines for short sections.

c) Stray current areas.

d) Overhead power transmission line crossing or parallelism

13.2 Prior to the selection of cathodic protection by sacrificial anodes, soil resistivity shall be measured to determine, if the resistivity is sufficiently low to allow successful application of sacrificial anodes; and to calculate the required weight of the sacrificial anodes.

13.3 Sacrificial anodes shall be used and supplied in low resistivity chemical backfill package

### 14.0 Cathodic Protection Designer & Installer

14.1 The design and installation of the CP system shall be carried out by a **Cathodic Protection Specialized Contractor**, subject to the GAIL approval.

14.2 The design and commissioning of cathodic protection systems shall be carried out by a Cathodic Protection Specialist Engineer (NACE certified as CP-Specialist or equivalent).

A NACE certified Technician of Level II or equivalent shall present at all time at site to supervise the installation of all the parts of the cathodic protection system.

### 15.0 Materials and Equipment Requirements

All cathodic protection materials shall be procured from PMC approved manufacturers.

#### 15.1 ICCP Anodes

15.1.1 The anode material shall be **catalyzed Titanium anode coated with highly conductive Mixed Metal Oxide (MMO)**.

15.1.2 Anodes shall be installed as a number of discrete strings, each comprising a maximum of two (2) anodes, with each string connected to an anode junction box adjacent to the head of the ground bed.

#### 15.1.3 Mixed Metal Oxides (MMO) Anodes
a) The Mixed metal oxides (MMO) Anodes base metal shall be Titanium conforming to the ASTM B 338 Grade I/II material specifications.

b) MMO coating on the anode shall be mechanically stable and shall have high corrosion resistance to highly acidic medium. In addition, the MMO Coating on the Anode shall have abrasion resistance to sharp rock or sharp metal edges.

c) The consumption rate of MMO coating in fresh water and coke breeze backfill shall be 1 to 6 milligrams/Amp-Yr. and operating current density shall be 100 Amp/m² for 30 Yrs. life which shall be further de-rated for 35 design life (82 A/m² for 35 years).

d) The connection between the cable and the tubular anode shall be centre connected. Both the ends of the tubular anodes shall be sealed over the insulated cables by applying hydraulic pressure or by complete resin sealing with non-shrinkable type epoxy fill.

e) Anode to cable connection resistance shall be less than 500 micro Ohms.

f) MMO tubular anode shall be supplied with GI canister and canister shall be filled with Calcined petroleum coke breeze as specified here in the document. The size of the canister and backfill quantity shall be for suitable for rated current output.

15.1.4 MMO Anode Strings

a) MMO anodes string shall comprise of a group of tubular anodes of maximum of two (2) anodes in each string. The dimension of each anode in the string and spacing between the anodes shall be suitable for specified design life.

b) MMO anode string shall be supplied with suitable Centralizer and vent pipes.

c) The anode tail cable / anode string cable shall be as given here in the document.

15.2 Sacrificial Anodes

15.2.1 Magnesium Alloy Anodes

a) Magnesium anodes shall exhibit an open circuit potential, at ambient temperature, of -1750 mV or more negative with reference to a Cu/CuSO₄ electrode in soil.

b) Magnesium anodes for soil application shall conform to the following Composition:
15.2.2 Zinc Alloy Anodes

a) Zinc anodes shall exhibit an open circuit potential, at ambient temperature, -1100 mV or more negative in reference to a Cu/CuSO₄ electrode.

b) Zinc anodes for Soil and fresh water application shall conform to the following Composition:

- Al 0.005% Maximum
- Cu 0.002% Maximum
- Fe 0.0014% Maximum
- Pb 0.003% Maximum
- Cd 0.003% Maximum
- Zn Balance

c) Zinc anodes for Sea water and brackish water application shall conform to the following Composition:

- Al 0.10 – 0.50% Maximum
- Cu 0.005% Maximum
- Fe 0.005% Maximum
- Pb 0.006% Maximum
- Cd 0.025 – 0.07% Maximum
- Zn Balance

d) Zinc anode shall have an electrochemical capacity of 738 amp-hrs /kg.

15.3 Cables

15.3.1 CP Cables shall be single core, stranded copper conductor, double insulated, voltage grade 600 / 1000V and shall conform to ICEA-S-95-658 (NEMA WC 70) or IEC 60502-1.

15.3.2 Cable conductors shall be annealed copper as per ASTM B3 or IEC 60228 and shall be concentric-lay stranded as per ASTM B8 class B or C or as per IEC 60228 class 2.
15.3.3 Positive main cable shall be armoured in accordance with Table 1 & 2 of this Standard. The armour wires shall be galvanized steel.

15.3.4 Cables for onshore application shall be Cross Linked Poly Ethylene (XLPE) / Poly Vinyl Chloride (PVC) double insulated except anode tail and string cables. Anode string or anode tail cables for onshore application shall be Poly Vinlydene Fluoride (PVDF) / High molecular Weight Polyethylene (HMWPE) double insulation.

15.3.5 Cables for offshore application shall be Poly Vinlydene Fluoride (PVDF)/High molecular Weight Poly Ethylene (HMWPE) PVDF / HMWPE double insulated.

15.3.6 Cables for both onshore and offshore applications with PVDF / HMWPE insulation shall conform to the ASTM D1248, Type 1, Class A and Category 5, grade E04 & E05.

15.3.7 Positive and negative cables shall be of RED and BLACK colour respectively. Reference electrode cable shall be of different colour.

### Table 1: Cable sizes, Stranding and Insulation

<table>
<thead>
<tr>
<th>Cable Size</th>
<th>No. of Strands</th>
<th>Type of insulation for onshore</th>
<th>Type of insulation for offshore</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 (6)</td>
<td>7</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>8 (10)</td>
<td>7</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>6 (16)</td>
<td>7</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>4 (25)</td>
<td>7</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>2 (35)</td>
<td>19</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>1 (50)</td>
<td>19</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
<tr>
<td>2/0 (70)</td>
<td>19</td>
<td>XLPE/PVC</td>
<td>PVDF/HMWPE</td>
</tr>
</tbody>
</table>

15.3.8 The cable sizes shall be determined to suit the current rating and voltage drop requirements of the CP design. However, the following types with minimum sizes shall be used:

### Table 2: Cable Sizes

<table>
<thead>
<tr>
<th>Cables Types</th>
<th>Cable Size AWG (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive main cables</td>
<td>1 (50)</td>
</tr>
<tr>
<td>Anode string cables</td>
<td>4 (25)</td>
</tr>
<tr>
<td>Anode Tail Cables</td>
<td>6 (16)</td>
</tr>
</tbody>
</table>
Cables Types | Cable Size AWG (mm²)
---|---
Negative main cables | 1 (50)
Bonding / Negative drain cables / AC mitigation | 4 (16)
Monitoring / Test cables | 8 (10)
Reference electrode Cables | 10 (6)
Sacrificial Anode tail cables | 8 (10)
Line Current Test Station Cables:
a) Measurement Cable | 6 mm²
b) Current Cable | 10 mm²

15.3.9 Cable Marking: The cable outer insulation layer or jacket for impressed current cathodic protection cables shall be permanently marked at intervals of no greater than one meter with the Manufacturer's name or trademark, the conductor size, and the type of insulation.

15.4 Transformer Rectifier Unit (TRU)/CPPSM - Automatic Type

15.4.1 Description
Transformer Rectifier Unit/CPPSM suitable to operate as DC variable power supply source for cathodic protection systems.

15.4.2 Service Conditions
a) The Transformer Rectifier Unit (TRU)/CPPSM shall be suitable for continuous operation in environmental
b) The TRU/CPPSM shall be rated for continuous operation at full load under the temperature from -3°C to 55°C & 100% humidity.
c) TRU/CPPSM shall be located in non-hazardous areas.

15.4.3 Basic Design
The Transformer Rectifier Unit (TRU)/CPPSM components shall be housed in enclosures, constructed from folded sheet steel of not less than 2mm thick and cable access shall be using suitably sized, removable undrilled gland plates. While designing the TRU/CPPSM, the following shall be considered, unless otherwise specified in the project document:

a) In case of TRU, A.C. Input Voltage: Single Phase (240V± 20 %) /Three phase four wire power supply of 415 V ± 20 %, 50 Hz ± 2.5 % frequency. In case of CPPSM, DC input supply shall be 24 Volts (+ 25 %/-15%)
b) D.C. Output Voltage: 0 to 25 V or designed voltage whichever is higher.
c) D.C. Output Current: 0 to 25 Amp or designed current whichever is higher.
d) Full load efficiency of rectifier: 85 % (min.)
e) Ripple Factor: 5 % (max.) of the DC output current between 5 % and 100 % of the rated current output.

15.4.4 Construction

a) Rectification:

The following shall be taken into consideration while designing Rectification unit:

i. The DC output shall be controlled using latest solid state Silicon Controlled Rectifiers (SCR). These SCRs shall be controlled by the commands from the control circuits. All the electronic circuits shall be assembled on plug-in type control cards. Three phase full bridge connection of SCR with peak inverse voltage above 1200 Volts shall conforms to IEC 60146 “Semiconductor Converters”.

ii. Power rectifying elements shall be mounted on anodized aluminum heat sinks suitably sized for max. case temperature 90°C at 55°C ambient and rated load conforming to component data sheets.

iii. The SCRs shall be rated for 200 % (min.) of the rectifier full load output.

iv. Filtering circuit shall be using L-C filters with wheel diode to limit the ripple to 10% (max.) between 10 % & 100 % of rated current output.

b) Protection:

Transformer Rectifier unit shall be provided with various protections, which shall include but not limited to:

i. Freewheeling diode protection in Output


iii. Lightning Arrestor at both input and output side of the unit of RMS voltage rating 500 Volts and RMS current Rating 5 kA.

iv. MCBs with HRC fuse in input and output.

v. Glass cartridge fuses in the live line of all lamps.

vi. Auxiliary power lines to control circuit.

c) Mode of Operation:

i. The operation of the unit shall be fully automatic and shall be controlled by the reference electrode feedback. The unit shall automatically maintain reference voltage or Pipe to Soil Potential (PSP) within ± 15 mV of the set value under all conditions. It should also have the facility to operate in Manual Mode (AVCC). Unit can operate either in constant voltage mode or constant current mode. In constant voltage mode, the output voltage is adjustable from 0 V to rated value by means of a stepless voltage setter. In constant current mode, the output current is adjustable from 0 A to rated value by means of a stepless current setter.

ii. Facility shall be provided to select one out of three (3) reference electrodes by means of a manually operated reference selector switch.

iii. In the event of failure of the reference electrode, while the unit is working in auto reference mode, the DC output voltage of the unit shall get set to a pre-set value. This pre-set voltage shall be adjustable from Zero to rated value.

d) Meters / Instruments:

Digital meters shall be provided for measurement of incoming AC /DC voltage & Current with phase selector facility, DC output current with precision shunt (of accuracy of at least ±0.25 %) and DC output voltage with 10 MΩ impedance for structure to electrolyte Potential range 0 to ±20 V.

e) Current Interruption Facility:

GPS based Current Interruption facility shall be provided by interrupting the output side (Positive side) of the transformer rectifier.

f) Earthing:

Two (2) Nos. ½” earthing bolts and One (1) No. Nickel plated Copper earth bus bar of 25 mm x 3 mm size shall be provided.

g) Other Accessories:

The TRU/CPPSM shall be equipped with suitably rated Transducers, facility for connectivity for communicating with RTU-SCADA for CP unit data transfer, digital counter for measuring the CP unit availability.

15.4.5 Enclosures
The Transformer Rectifier Unit (TRU) shall comprise of the following enclosures (separated from each other):

a) Control Cabinet:
Consisting of metering and control devices. Devices such as Control cards, DC Voltmeter, DC Ammeter, incoming AC Voltmeter, signal Lamps, Metering fuses, controls for Current Interrupter & System Monitor Unit, etc. shall be provided on an internal hinged door with viewing window of toughened glass to facilitate reading of the meters without opening the door. The design shall allow the user easy access to all the controls and metering devices.

b) The AC Terminal Cabinet:
The AC Terminal Cabinet shall be provided to terminate incoming cables and protections for incoming AC supply line.

c) The DC Terminal Cabinet:
DC Terminal Cabinet comprises of DC terminals with protection & auxiliary devices. The DC Terminal Box shall be provided with termination facility of DC outgoing cables and permanent reference electrode. Two (2) Negative & two (2) Positive Terminals DC Output Terminals shall be provided.

d) Maintenance Cabinet:
An enclosure for special tools & documents with a single-phase 240 V AC power socket for maintenance purpose.

e) Transformer Rectifier/CPPSM Enclosure:
The enclosure shall have ingress protection IP55 (min.) in accordance with IEC 60529.

f) Transformer Rectifier Unit (TRU)/CPPSM shall be Plinth mounted and be free standing. Support shall be provided for unit, via welding two (2) Nos. 5 mm thick structural channels under the Oil Tank. A minimum of 100 mm steel channel shall be used for underside clearance. All the units shall have suitable lifting arrangements.

g) The TRU/CPPSM shall be suitably constructed to facilitate inspection, cleaning, repair & maintenance and ensure absolute safety during operation, inspection and maintenance.

h) The phase sequence of the AC supply and polarity of DC supply shall be clearly marked.
15.4.6 Painting of Enclosure

Painting shall be applied on SA2.5 blasted surface on enclosure with either 70 micron Zinc Rich Epoxy followed by 80 micron Epoxy Polyamide and finished with top coat of 40 micron modified Polyurethane paint of colour RAL7033 or 100 micron thickness baked epoxy powder coating of colour RAL 7033.

15.4.7 Name Plate and Labels

a) Transformer Rectifier /CPPSM Unit shall be provided with a bolted or riveted series 300 stainless steel engraved or stamped nameplate. The nameplate shall have minimum information of Manufacturer, Serial Number, Project No., Date of Manufacture, Power Supply Rating data (Voltage, Current, Frequency etc. of incoming power supply and voltage, Current etc. of secondary of Transformer).

b) Warning labels shall be provided in all locations, as required, to warn personnel of potentially dangerous situations.

c) All instruments, selector switches, indicators etc. shall be provided with descriptive labels.

15.4.8 Following spares shall be supplied for each Transformer Rectifier Unit (TRU)/CPPSM panel as a minimum:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COMPONENT DESCRIPTION</th>
<th>QUANTITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fuses of different types and rated currents according to quantities installed</td>
<td>Five (5) in each</td>
</tr>
<tr>
<td>2</td>
<td>MCBs of different ratings according to quantities installed</td>
<td>Two (2) in each</td>
</tr>
<tr>
<td>3</td>
<td>Indicating lamps</td>
<td>Two (2) in each</td>
</tr>
<tr>
<td>4</td>
<td>Lamp holders with dropping resistance and cap</td>
<td>Two (2) sets</td>
</tr>
<tr>
<td>5</td>
<td>Coloured caps for indicating lamps of diff. colours in proportion to the installed quantities</td>
<td>One (1) set</td>
</tr>
<tr>
<td>6</td>
<td>Control push buttons for any type</td>
<td>One (1) No.</td>
</tr>
<tr>
<td>7</td>
<td>Measuring instruments (AC / DC) in the panel.</td>
<td>One (1) in each</td>
</tr>
<tr>
<td>8</td>
<td>Control Cards (all type)</td>
<td>One (1) Set</td>
</tr>
</tbody>
</table>
15.4.9 Packaging & Shipping

The method of packaging and shipping for domestic and overseas vendor shall comply with Company Packaging Specification for Export Shipment. Transformer Oil shall be shipped separately.

15.4.10 Testing of Transformer / Rectifier for TRU (Automatic Type)

Routine test shall be carried out at Manufactures works for each Transformer Rectifier unit in accordance with the requirements of IEC 60076 and IEC 60146 as applicable, which shall include, but not limited to the following:

- **a)** Dielectric Test: The insulation between primary circuits to secondary circuits, primary circuits to dead metal parts and secondary circuits to dead metal parts shall withstand 2000 Volts, 50 Hertz signal applied for one (1) minute as per IEC 60076. Leakage current shall be less than five (5) mA and no amount of arcing is acceptable.
- **b)** Rectifier Efficiency Test at various loads 25%, 50% & 100%.
- **c)** Ripple Test at various loads 25%, 50% & 100%.
- **d)** Air Test: Each rectifier enclosure shall be tested for absence of leakage before galvanizing or coating. After galvanizing or coating, the enclosure lid and the appropriate gasket shall be installed and the test shall be conducted to confirm that a dust tight seal has been achieved.
- **e)** Component functionality, overall operation test and load test shall be carried out at various loads at 25 %, 50 %, 75 % and 100 %.
- **f)** Visual inspection, meter calibration, dimensional check, foundation dimension check etc. shall be carried out.
- **g)** Temperature Rise (heat run) test shall be conducted for 24 hours of the following components. Temperature measurement shall be made by thermocouple or resistance change method. Minimum ambient air / oil temperature shall be 20 ºC to conduct this test. The rectifier shall be tested with the AC line voltage set to 20 % above nominal at rated output.
- **h)** Perform the functional test in Automatic/Manual Mode operation.
- **i)** The Vendor shall submit test certificates and type test certificate as specified in Sub-Clause 7.4.10 for the GAIL approval prior to dispatch of material.

15.5 Junction Boxes

15.5.1 Junction Box and test posts shall be suitable for outdoor application and shall have a minimum degree of protection as NEMA-4X or IP 56.
15.5.2 All internal components used for junction boxes and test posts shall be corrosion resistant.

15.5.3 Engraved Stainless steel labelling shall be screwed/ riveted to identify the junction box / test post name, type, tag number, protected structure details & service, etc. For JBs and test points installed on pipelines, Diameter, km reference points, origin and destination shall also be provided.

15.5.4 Engraved Stainless steel schematic layout drawing shall be screwed / riveted inside all test post and JBs. The drawing shall reflect the arrangement of coupons, permanent reference electrodes, sacrificial anodes, cable connections to each structure/pipeline, impressed current anode & power feed orientations, orientation of zinc ribbon anode, details of diodes/resistors/shunts, etc. as applicable.

15.5.5 All Test station posts shall be of nomenclature as directed by company.

15.6 Carbon Backfill

Carbonaceous backfill shall be suitable for use with cathodic protection anodes, comprising hard round grain carbon to pass sieve No. 16; and shall be dust free, with appropriate carbon lubricant added to bulk density around 900 kg/m³. The recommended backfill is **Loresco SC-3 or approved equivalent**.

Carbonaceous backfill shall be dust free Calcined petroleum coke and suitable for impressed current anodes. Calcined petroleum coke backfill shall have following composition.

- Fixed Carbon content: 99.35 % (Min)
- Volatile content: 0.3 % (Max.)
- Bulk density: 900 kg/m³ (Min.)
- Particle size: 1.0 mm (Max.)
- Particle Shape: Spherical

15.7 Surge Diverter

Surge diverters shall be installed at isolation flanges and shall be designed such that the impulse breakdown voltage of the surge diverter is lower than that of the isolating joint across which they are mounted. In addition the surge diverter shall be capable of discharging the expected lightning currents without sustaining damage.

15.7.1 All Isolation Joints shall be protected from voltage transients by surge diversion devices. Solid-state over voltage protectors shall be installed at all joints and be capable of providing over-voltage protection from both lighting and AC fault currents.
15.7.2 Surge diverters shall be solid-state type, encapsulated in a waterproof fitting and in accordance with the following general requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to AC 50 Hz Voltage (spark-over)</td>
<td>800 V</td>
</tr>
<tr>
<td>Impulse spark-over voltage 100% (1.2/50 µs)</td>
<td>2.2 kV</td>
</tr>
<tr>
<td>Nominal discharge current (8/20 µs)</td>
<td>100 kA</td>
</tr>
<tr>
<td>Degree of protection (IEC 60529)</td>
<td>IP 54 min.</td>
</tr>
<tr>
<td>Explosion-proof protection</td>
<td>EExn IIB T3 Zone 2</td>
</tr>
</tbody>
</table>

15.8 Solid State Polarization Cell

Solid state polarization cells shall be installed as a DC decoupling device at the AC mitigating locations. Solid state polarization cells shall be suitably rated for specified design life.

15.8.1 Polarization cells shall be Solid state type and shall be designed to provide DC decoupling and AC continuity / grounding when used with cathodically protected structures.

15.8.2 Solid state polarization Cells (SSPC) shall be used for AC mitigation, lightning over-voltage protection and grounding of electrical equipment that are connected to the cathodically protected structures.

15.8.3 SSPC shall have very high AC fault and lightning surge current ratings.

15.8.4 Design of the SSPC shall comply with following specifications:
   a) Threshold Voltage: -3 to +1 V DC
   b) AC Steady-State Current (amperes – rms) 50 Hz: 40 A min.
   c) Lightning Surge Current: 100 kA crest (8 x 20 µs waveform)

15.8.5 Material of construction for enclosure shall have minimum degree of protection shall be NEMA 4X or IP56 for non-classified areas.

15.8.6 Enclosure shall be certified for EExn IIB T3, Zone 1 & 2 and with minimum degree of protection shall be NEMA 4X or IP56 of for hazardous classified areas.

15.9 Polarization/Test Coupons

15.9.1 Polarisation coupons are connected to the CP system on the structure, thus simulating a similar-sized bare area of the structure’s surface, such as at a holiday in the coating. The polarisation coupon may be disconnected from the circuit during periodic testing and it’s instant-disconnect potential measured. These measurements represent the polarized potentials of the structure in the vicinity of the polarisation coupon.
15.9.2 Polarization coupon shall be installed such that it receives the same current density as the structure in that area and does not shield cathodic current from the structure. For a flat coupon with one coated surface, the bare/holiday surface should face away from the structure.

15.9.3 The typical locations for installation of Polarization Coupons, should be at the following locations:

- AT CP Stations
- Midpoint of two CP Station / Far end of pipeline from CP Station.
- Foreign pipeline crossings OR Foreign CP interference exists.
- Stray current sources include DC traction systems, foreign rectifiers, telluric earth currents, and high-voltage direct-current (HVDC) electrodes
- AC Interference area
- The pipeline is protected by Sacrificial anode.
- Long-line or telluric currents that result in IR-drop errors that interruption cannot eliminate.
- In areas in which multiple impressed-current sources influence the structure-to-electrolyte potential, interruption of all current sources is not always practical.
- Low-lying wet / marshy area

15.9.4 Coupon shall be constructed using same pipe material and size of the coupon shall be 9 cm² in area. Each coupon shall have two wires (12 AWG) soldered to it. The bottom of the coupon shall be exposed while the top is sealed with epoxy to avoid the entry of soil inside the tube. Where installed at post, one pair of coupon shall be provided at the respective test station, one for representative potential measurement and other for native potential.

15.9.5 A magnetic reed switch of suitable size shall be supplied for interrupting the coupon circuit. Reed switch shall have contact resistance 150 milli ohms, switching current 0.25 Amp and shall be suitable for Temperature -20 to + 70 °C.

15.10 **External ER Probes:**

15.10.1 External ER Probes are used to monitor the corrosivity of the Electrolyte (Soil). External ER probes shall be installed at Test stations along the pipeline as given below:
16.0 Installation of CP System

16.1 General

16.1.1 Prior to installations, all materials including transformers, rectifiers, cables, anodes, backfill, and junction boxes shall be inspected to ensure that they are in good condition.

16.1.2 All electrical connections shall be made safe and secured.

16.1.3 The integrity of cable connections shall be ensured prior to energization of CP system by suitable testing, to ensure positive feeder cable from AJB and negative cable from NJB are connected to positive and negative terminals of Transformer.

16.1.4 For pipelines / piping installed at areas with existing bare copper grounding network, the following modifications shall be made as below:

   a) The buried copper cables shall be insulated minimum of 10.0 m to each side of pipeline / piping crossing location.

   b) Copper conductors parallel to new pipe at a distance of 3.0 m shall be insulated.

   c) Relocate grounding rods to 10.0 m away from the piping.

16.1.5 Samples of installation check lists are attached herewith in the document. The Contractor shall make suitable additions or changes for the particular job.

16.1.6 Any damages caused to existing Cathodic Protection equipment during construction activities of new pipeline shall be rectified on urgent basis by coordinating with owner representatives.

16.2 Installation of Transformer Rectifier (T/R)

16.2.1 All T/R units shall be installed outside the main fence of plant area, such as, GC’s, Booster stations, manifolds, etc.

16.2.2 External AC cut-off switch shall be provided near the TR unit and within the TR fence.

16.2.3 The transformer / rectifier body and fence shall be grounded in accordance with this document.
16.3 Installation of Deep Anode Ground Bed

16.3.1 Holiday test shall be conducted for anode tail cables prior installation, if any insulation damages found during holiday testing the whole anode assembly shall be rejected.

16.3.2 Anodes shall be installed with centralizers in low resistivity carbonaceous backfill in such a way that the anode is in the center of the bore hole. Two (2) Nos. of centralizers shall be used for anodes of length 1.0 m and more.

16.3.3 A perforated vent pipe shall be installed alongside the anode string(s) and covered by a geo-textile woven fabric to avoid backfill blocking the perforations.

16.3.4 The backfill material shall be specially formulated to facilitate pumping from bottom with the minimum risk of air entrapment. Settling and compaction can be used to improve ground bed performance and life.

16.4 Installation of Shallow Ground Bed

16.4.1 Close Distributed type Shallow Vertical or Shallow Horizontal Anode Installation.

   a) The location of the anodes shall be marked.
   b) Anode tail cable shall be holiday tested prior to lower the anode. If any holiday is detected the anode assembly shall be rejected.
   c) The depth and diameter of anode bore hole or trench shall be as per the approved design. Upon completion of anode bore hole or trench, canister anode shall be lowered to the design depth. During the anode lowering care should be taken that there is no damage to the cable connection.
   d) Quantity of anodes for each CP system shall be installed as per the approved design. After the completion of anode installation anode tail cables shall be laid in a trench and shall be terminated in anode junction box.
   e) All the anode tail cable shall be terminated using suitable variable resistor and shunt inside the anode junction box. Anode tail cable shall be properly tagged for easy identification.

16.5 Installation of Test Station and Junction Boxes

16.5.1 Test Station / Junction box shall be installed on a suitable concrete foundation.

16.5.2 The cable entry pipe inside the Test Station/junction box shall be properly sealed.

16.5.3 The cable shall be terminated inside the junction box with proper tagging for identification.
16.6 **Installation of Solid State Polarization Cell**

16.6.1 Solid state polarization Cells be installed inside a suitable junction box at AC mitigation locations.

16.6.2 Grounding anode tail cable, pipe bonding and test cable shall be terminated inside the junction boxes mounted with suitable support frame and foundation.

16.7 **Installation of Test Coupons**

16.7.1 Test coupon shall be constructed and installed according to NACE RP 0104.

16.7.2 Coupon cable shall be terminated inside the Test Station. A magnetic reed switch shall be installed between pipeline and one coupon.

16.8 **Cable Laying**

16.8.1 The CP cables shall laid at 750 mm depth.

16.8.2 The cable laying shall include provision of cable identification tags, backfilling of cable with sifted sand, provision of cable tile and warning tape.

16.8.3 Aboveground cable markers inscribed in English shall be installed to identify cable routes. Cable route markers shall be provided at every 30.0 m and every turning point.

16.9 **Galvanic / Sacrificial Anode Installations**

16.9.1 Prior to installation, the waterproof container shall be removed and the anode package shall be inspected to confirm its good condition.

16.9.2 The anode lead wire shall be inspected to ensure that it is securely connected to the anode.

16.9.3 Prior to backfilling, it shall be confirmed that the anode is centered in the backfill package.

16.9.4 The anode shall be connected to the cathode structure through test station / junction boxes, installed aboveground.

17.0 **Pre-Commissioning and Final Commissioning**

17.1 **General**

17.1.1 Pre-commissioning shall be carried out by CP Engineer to ensure high quality performance.

17.1.2 All terminations inside the junction boxes, test boxes and T/R shall be checked.

17.1.3 Individual anode/ anode string resistance and total anode bed resistance shall be measured using 3 - Pin method.
17.1.4 All buried cathodic protection main cables shall be tested for insulation damages prior to and/or during commissioning. The insulation resistance shall be measured between the cable conductor and a temporary grounding arrangement by applying a test voltage of 500 Vdc and minimum acceptable insulation resistance value shall be 100 M Ohm.

17.1.5 Pipe shall be protected by temporary CP system immediately within two (2) weeks after the pipe burial in soil. For temporary CP with sacrificial anodes and where installation of junction/test boxes are delayed, pipe and sacrificial anode cables may be allowed to be temporarily connected by crimping together both cables in order to provide protection immediately. In addition, temporary CP system shall be monitored and maintained on monthly basis until permanent CP system is commissioned. The monthly report shall be submitted to Company for review and approval.

17.1.6 Impressed current CP System commissioning shall be carried out as per the approved procedure.

17.2 Natural Potential

17.2.1 Prior to performing the natural potential survey, contractor shall confirm the subjected pipeline is disconnected from all the sacrificial anodes and foreign pipelines/structures.

17.2.2 The subjected pipeline shall be disconnected for minimum 72 hours for depolarization.

17.2.3 Natural potentials shall be measured and verified at the Test Stations and Junction Boxes. If higher or lower natural potentials are observed then the location shall be investigated.

17.2.4 The natural structure to soil potential shall be measured and recorded at all the measuring points on the pipeline, both sides of isolating joints, foreign structures, road crossing casing, test coupons, etc..

17.2.5 The survey results shall be witnessed and approved by Company representatives.

17.3 Preliminary Adjustment

The T/R output shall be kept at 10% of design current output. After 48 hours, potential shall be measured and the transformer/rectifier output shall be increased or decreased, if required, in order to meet the protection criteria indicated in this document.

17.4 Coating Conductance Test

Line current measurement shall be carried out at all current measurement test stations. Line current measurement shall be carried out using calibrated digital millivolt meter.
Prior bonding the new pipeline with foreign pipelines or structures, coating conductance test shall be performed by injecting a test current.

17.5 **Interference Testing**

17.5.1 The Contractor shall perform all AC & DC interference testing; and shall be responsible to contact all relevant authorities and arrange for their presence at all the required tests.

17.5.2 AC & DC Interference Survey shall be conducted on the identified pipeline section with suspected interference, including modelling / simulation in case of AC or HVDC interference. Mitigation measures shall be designed, implemented and validated on a case to case basis for its type and extent.

17.5.3 A positive swing of PSP of more than 50 mV shall be considered as DC interference. A 15 V induced AC voltage on the pipeline or AC Current density more than 30 A/m² measured on an AC corrosion coupon with 1 cm² holiday during steady state condition shall be considered as AC Interference.

17.5.4 DC Interference survey shall be carried out at the locations of foreign pipeline crossings, in the vicinity of foreign anode bed, where the new pipeline diverge or converge with existing pipelines and run parallel with existing pipelines. Other interference prone areas shall also be selected for the survey.

17.5.5 The DC interference survey shall be carried out as per the approved procedures. The DC interference survey shall be carried out by interrupting the new and existing TR(s) independently.

17.5.6 If any DC interference test results show a positive change in the potential of new / foreign installation or structure, then the Contractor shall take remedial action to eliminate the interaction.

17.5.7 Mitigations shall be carried out based on the survey results and with consultation with new pipeline and foreign pipeline Owner.

17.5.8 Post mitigation survey shall be carried out to ensure that DC interference is mitigated.

17.5.9 Preferably, DC interference should be overcome by the use of adjustable resistors and diodes installed inside a bond station junction box, between the bonding cable from the pipeline and the foreign structure.

17.5.10 AC interference survey shall be carried out as per the approved procedure. Induced AC potentials and AC Current density shall be measured at the locations where HVAC overhead transmission (greater than 11kV) lines crossing, parallel to the pipeline and locations where converges / diverges. Continuous AC potential
17.5.11 If induced AC potential found above the safety limits, mitigation measures to be carried out. Further, measured AC current density shall be investigated for any probable metal loss due to AC induction and mitigation measures shall be taken accordingly.

17.5.12 Post mitigation survey shall be carried out to ensure that interference due to AC is mitigated.

17.6 Potential Measurement

17.6.1 Following the adjustment of CP station outputs to meet the structure to soil potentials and after allowing sufficient time for structure polarization, a complete set of ON/OFF potentials shall be recorded at all the measuring points and other positions measured earlier. During the ON/OFF survey all the rectifiers connected and affecting the structure shall be interrupted with GPS synchronized interrupters.

17.6.2 Should the potential of metallic casings be more negative than their natural potential previously recorded or if any potential swing occur on casing potentials during ON/OFF survey, then the Contractor shall investigate the reason for the low resistance between casing and carrier pipe.

17.7 Final Commissioning

Final commissioning shall consist of the following:

a) Measuring structure to soil potentials at all measuring points by an approved method and as specified in clause 18.6.1.

b) Measuring total current output from each CP station and the current in each direction where current measurements are possible.

c) Measuring settings of power sources: transformer / rectifiers.

d) Measuring current and resistance, if remedial bond fitted.

e) Calibrating all current measurement points.

f) Measurement of AC potentials at test stations.

17.8 Post Commissioning Surveys

17.8.1 Close interval potential survey (CIPS), Current Attenuation Test (CAT) and direct current voltage gradient (DCVG) surveys shall be carried out after all adjustments to the CP system are made.
17.8.2 Prior to any CAT, DCVG and CIPS surveys, the Contractor shall develop a Survey Plan and Procedures and submit the same for GAIL approval.

17.8.3 For piggable pipelines, CIPS shall be carried out for whole length of line, at every 1 meter, CAT at every 50 meter & DCVG at identified location from CIPS & Cat data outcome.

17.8.4 For un-piggable pipelines, CIPS & DCVG shall be carried out for whole length of line with CAT at every 10 meter with its elevation profile measurement.

17.8.5 The results of CIPS and DCVG surveys shall be analyzed, and the Contractor’s proposal for proper remedial actions shall be recommended and carried out after GAIL approval.

17.8.6 Any coating defects identified during DCVG survey shall be investigated and further exposed for direct examination. Defects shall be repaired or rectified with approved procedures.

18.0 Quality Assurance / Quality Control

18.1 The Manufacturer / Contractor shall operate a quality system to ensure that the requirements of this Standard are achieved. The quality system shall be preferably based on ISO 9000 series of standards; and the Manufacturer / Contractor shall demonstrate compliance by providing a copy of the accredited certificate or the Manufacturer’s / Contractor’s quality manual.

18.2 Verification of the Manufacturer’s / Contractor’s quality system is normally part of the pre-qualification procedure, and it is therefore not detailed in the core text of this Standard.

18.3 The Contractor shall submit their Quality System Manual & Quality Assurance Plan that includes all the activities in chronological order with responsibilities. Inspection & Test Plan (ITP) for CP system design, procurement, installation and commissioning shall be submitted for the GAIL approval.

18.4 A typical ITP is attached in here in the Standard. The Contractor shall make suitable additions or changes for the particular job work.

19.0 Deliverables

19.1 General

19.1.1 All correspondence, drawings, instructions, data sheets, design calculations, or any other written information shall be in English Language.

19.1.2 All dimensions, units or measurements, physical constant, etc. shall be in SI units, unless otherwise specified.
19.2 **Calculations and Documentation**

19.2.1 The following documentation, drawings, inspection and test plans and check lists shall be submitted for the Company review and approval:

a) Design Calculations;
b) Schematic drawings of the entire structure and the CP systems;
c) Anode ground bed detail drawings;
d) T/R unit electrical schematic diagrams;
e) T/R unit general arrangement and mounting detail drawings;
f) Ground bed layout drawing;
g) Anode material;
h) CP cable schedule & layout drawing reflecting, type, size, colour, origin & destination;
i) Test facility detail drawings;
j) Junction boxes and support stands construction drawings;
k) Junction boxes termination drawings;
l) Piping cable connection detail drawings;
m) A detailed area layout drawing reflecting the GIS Co-ordinates and Locations of following:
   i. Complete pipeline and piping with connections to other pipelines, manifold, plants, etc. including location of all insulation flanges / joints and cased road crossing locations.
   ii. Installation of all CP equipment’s such as Transformer Rectifier, anode
   iii. Ground beds, test & Junction boxes, etc.
   iv. Cathodic Protection cable routing including start, end and turning points.
   v. Overhead / Underground AC power lines.
   vi. Foreign metallic structures close to the piping/ pipeline, including all
   vii. crossing and parallel foreign pipelines
n) Piping interactions survey report and remedial measures required;
o) CP electrical installation specification;
p) Installation procedure;
q) Pre-commissioning and Final Commissioning procedures;
r) Operation and maintenance procedures;

s) CP material data sheet

t) List of foreign pipeline CP system and anode ground beds in the pipeline vicinity

u) List of Cased crossings

v) Technical data sheet for all major CP equipment’s

w) AC & DC Interference survey & mitigation Procedures and Reports

x) QAP/ITP for material procurement

y) QAP /ITP for CP installation activities

19.2.2 CP calculations shall include:

a) Protected structure surface area;

b) Anode ground bed resistance, output current, anode mass and number;

c) Protected structure CP current demand;

d) Foreign structure CP drain current;

e) CP T/R unit voltage including both the anode and cathode circuit;

f) CP T/R unit current rating;

g) Soil resistivity calculations.

h) Line current Test Station calibration factor

i) Coating conductance

j) Anode bed Remoteness calculation

k) Attenuation calculation for cross country pipelines

l) Earth potential rise calculation for optimum distribution of close distributed anodes

20.0 As-Built Drawings

20.1 Construction / design drawings shall be updated to reflect field modifications to the original design, showing the as-built cathodic protection system.

20.2 The as-built drawings shall establish the coordinate in “WGS 84 Geographic Information System- GIS, locations of the following and shall be integrated with GAIL PGIS system:

a) The pipeline route.

b) Casings.

c) Test Stations.

d) Electrical bonding.
e) Interference locations.
f) Electrical isolation locations.
g) Cables.
h) Junction boxes.
i) Ground beds.
j) Transformer / Rectifiers.
k) Overhead / underground AC power lines.

20.3 The Contractor shall also update the existing CP drawings of the particular facility / area incorporating the new system.

21.0 Annexures

Annexure - A:
Typical Inspection and Test Plan for Cathodic Protection System

Appendix - B:
Typical Check Lists for
1. Pipe to Cable Connection by Thermite Welding or Pin Brazing
2. Deep Ground Bed Protection System
3. Road Crossing Cathodic Protection System Boxes (JB and Test Box)
4. TR / Rectifier
5. Pre-commissioning Checklist for Impressed Current Cathodic Protection System (Pipelines)
### ANNEXURE- A

**TYPICAL INSPECTION AND TEST PLAN FOR CP SYSTEM**

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<td>Installation of Anode, Cable and Vent pipe</td>
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<td>Installation of Temporary CP installation and monthly monitoring</td>
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<td>Testing and energisation of Transformer Rectifier</td>
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<td>28</td>
<td>Protective potential survey</td>
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<td>29</td>
<td>AC/ DC interference Survey and mitigation</td>
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<td>Line Current measurements</td>
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<td>31</td>
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**R**: Review  **S**: Surveillance  **W**: Witness
ANNEXURE- B

TYPICAL CHECK LISTS

1. Pipe to Cable Connection by Thermite Welding or Pin Brazing
2. Deep Ground Bed Protection System
3. Road Crossing Cathodic Protection System
4. Boxes (J.B and Test Box)
5. TR / Rectifier
6. Pre-commissioning Checklist for Impressed Current Cathodic Protection System (Pipelines).
1. PIPE TO CABLE CONNECTION: TYPICAL CHECK LIST

Test / Junction Box no.:  Date:

No. of connections & cable conductor sizes:

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<td>Location as Per approved Drawing / procedure</td>
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<tr>
<td>2</td>
<td>Connection areas cleaned to bright metal</td>
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<tr>
<td>3</td>
<td>Pipe to Cable connection acceptable (Pin Brazing / Thermite Welding)</td>
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<td>4</td>
<td>Cable conductor size and distance between connection points as per approved drawing / procedure.</td>
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<td>5</td>
<td>Graphite weld mould size and condition</td>
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<td>6</td>
<td>Pin brazing equipment and method suitable</td>
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<td>7</td>
<td>Mechanical integrity (pull test)</td>
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<td>8</td>
<td>Electrical continuity (less than 0.01 Ohm)</td>
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<td>9</td>
<td>Coating Encapsulation and holiday tested.</td>
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<td>Cable ends tagged</td>
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Comments:

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Note: Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.

Abbreviations: Acc.: Accepted; Rej.: Rejected; NA: Not Applicable
## 2. TYPICAL DEEP GROUND BED CATHODIC PROTECTION SYSTEM CHECK LIST

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<td>1</td>
<td>Location of Deep Ground Bed</td>
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<td>Sufficient distance maintained from nearest foreign structure, protected structure &amp; other GBs.</td>
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<td>3</td>
<td>Distance from foreign structure (M)</td>
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<tr>
<td>4</td>
<td>Distance from protected structure (M)</td>
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<td>5</td>
<td>Distance from other anode GB (M)</td>
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<td>6</td>
<td>Depth Borehole to the required length (M)</td>
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<td>7</td>
<td>Drill stem resistance measurement at every 10 m interval</td>
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<td>8</td>
<td>Drilling stopped at / before “Dammam formation”</td>
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<td>Welding of Casing and Installation</td>
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<td>Non-metallic Casing at Inactive length (M)</td>
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<td>13</td>
<td>Welding of Support Pipe Plate, Centralizers and Anodes Support Shoe</td>
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<td>Support Pipe Length (M)</td>
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Pipeline Design, Engineering, Construction & Commissioning in GAIL

### Type
GUIDANCE

### Reference No.
CIMG-GD-1-2016-0001

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**Note:** Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.

**Abbreviations:** Acc.: Accepted; Rej.: Rejected; NA: Not Applicable
### 3. ROAD CROSSING CATHODIC PROTECTION SYSTEM: TYPICAL CHECK LIST

**Road Crossing No.:** [Required]

**Date:** [Required]

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<tr>
<td>3</td>
<td>Check discontinuity between Carrier Pipe and Casing Pipe during and after insertion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Check discontinuity between Carrier Pipe and Casing Pipe after completion of carrier pipe tie-in works</td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>Check discontinuity between Carrier Pipe and Casing Pipe after backfilling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Check Installation of End Seal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**

---

**Sub-Contractor**

**Contractor**

**GAIL**

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
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</thead>
</table>

**Note:** Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.

**Abbreviations:**

- Acc.: Accepted
- Rej.: Rejected
- NA: Not Applicable
### 4. BOXES (J.B AND TEST BOX) : TYPICAL CHECK LIST

#### Junction box / Test Station & Identification Number :  

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>Results</th>
<th>Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location as per Drawing</td>
<td>Acc./ Rej./ NA</td>
<td>Sub-Contractor</td>
</tr>
<tr>
<td>2</td>
<td>Support as per detail drawings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Foundation Location and Details correct</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Installation as per detailed drawing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cable connections as per Termination Diagram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cables installed &amp; Termination complete.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Schematic diagram provided inside the JB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>All Cables clearly identified with tags</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>JB tagged according to approved drawing / procedure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**

**Sub-Contractor**   **Contractor**   **GAIL**

**Name**

**Signature**

**Date**

**Note:** Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.

**Abbreviations:**  
Acc. : Accepted  ;  Rej. : Rejected  ;  NA : Not Applicable
## 5 TR / RECTIFIER: TYPICAL CHECK LIST

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<th>Sl. No.</th>
<th>Description</th>
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<td></td>
<td><strong>Equipment Undamaged</strong></td>
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<tr>
<td>1</td>
<td><strong>Orientation and Alignment Correct</strong></td>
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</tr>
<tr>
<td>2</td>
<td><strong>Accessories Installed / Sun Shade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>Earth as per detail drawing</strong></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td><strong>T/R Foundation</strong></td>
<td></td>
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<tr>
<td>5</td>
<td><strong>Insulation resistance</strong></td>
<td></td>
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<tr>
<td>6</td>
<td><strong>Primary Winding – Earth</strong></td>
<td></td>
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</tr>
<tr>
<td>6.1</td>
<td><strong>Secondary Winding – Earth</strong></td>
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<tr>
<td>6.3</td>
<td><strong>Primary Winding - Secondary winding</strong></td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td><strong>Oil filling complete and no leakage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><strong>Condition of Silica Gel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td><strong>AC Supply</strong></td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td><strong>AC setting</strong></td>
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<tr>
<td>11</td>
<td><strong>MCB operation for input</strong></td>
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<td></td>
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<tr>
<td>12</td>
<td><strong>MCB operation for output</strong></td>
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<td>13</td>
<td><strong>DC output voltage</strong></td>
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<td>14</td>
<td><strong>DC output current</strong></td>
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<td>15</td>
<td><strong>Negative cable connection</strong></td>
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<td>16</td>
<td><strong>Positive cable connection</strong></td>
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<td></td>
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<td>17</td>
<td><strong>External AC isolator provided</strong></td>
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<tr>
<td>18</td>
<td><strong>Schematic &amp; operating manual inside T/R</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td><strong>T/R Fence</strong></td>
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**Comments:**

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<thead>
<tr>
<th>Sub-Contractor</th>
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<tbody>
<tr>
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<td>Signature</td>
<td>Date</td>
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**Report No.:** CIMG-GD-1-2016-0001

**Issue Date:**

---
### Title
Pipeline Design, Engineering, Construction & Commissioning in GAIL

### Type
GUIDANCE

### Reference No.
CIMG-GD-1-2016-0001

**Note:** Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.

**Abbreviations:** Acc.: Accepted; Rej.: Rejected; NA: Not Applicable
## 6. PRE-COMMISSIONING CHECKLIST FOR IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM (PIPELINES): TYPICAL INSPECTION AND TEST SHEET

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Inspector</th>
<th>Date</th>
<th>Remark</th>
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<tbody>
<tr>
<td>1.0</td>
<td>Pre-Commissioning</td>
<td>□</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Check if number and location of the anode are as per drawing</td>
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<tr>
<td></td>
<td>Check if all anodes cable are terminated and labelled with schematic drawings in the anode Junction Box (AJB).</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Check if the negative cable (from structure) is terminated in a junction box with appropriate cable tagging and schematic drawing inside the J/B.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if all J/B’s and Test Stations are marked and labelled inside and outside with schematic drawings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if all J/B’s shunt and resistor rating as per specification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if all T/Rs capacity, location, labelling, oil level, silica gel are as per specification.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if the T/R positive cable is connected to anode J/B and negative cable is connected to Structure J/B.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if all coupons are installed as per drawings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verify that no short circuit exists between the casing and carrier pipe at road crossing locations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check if the isolation flange (IF) are installed and there is no short circuit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check If all bonding cables to foreign pipelines are not connected.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check If all temporary cathodic protection system is disconnected.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Witness potential natural reading for all Test Stations before energizing the T/Rs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Witness Calibration of pipeline at line current Test Station</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Cable insulation resistance test of buried main CP cables by “Megger”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>After energizing the T/Rs.</td>
<td>□</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verify if T/Rs meters are functioning.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conduct Coating Conductance test</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Witness if potential &quot;On/Off&quot; readings are meeting the protection criterion for all Test Stations, J/B &amp; IF.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>After bonding cables to foreign pipelines are connected, Mg anode is connected to the casing and Zn anode is connected to the carrier pipe, witness if potential &quot;On/Off&quot; readings are meeting the protection criterion for all Test Station J/B &amp; IF.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Check for any interference.
Interference Mitigation
CIPS & DCVG Survey

Notes:

Reviewed By.................................  Approved By............................

Note: Additional items may be added by GAIL at any stage of the work and shall be implemented by the Contractor.
**PROJECT DOCUMENTS UPLOADED IN GAIL’S EDMS SYSTEM & HANDED OVER TO O&M DEPTT.**

**Appendix-5**

**FINAL HOTO (R- 3)**

<table>
<thead>
<tr>
<th>Tick Appropriate Level:</th>
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<tbody>
<tr>
<td>DOCUMENTS LEVEL-1 (DOCUMENTS UPTO MECHANICAL COMPLETION) ( )</td>
</tr>
<tr>
<td>DOCUMENTS LEVEL-2 (DOCUMENTS UPTO PIPELINE COMMISSIONING) ( )</td>
</tr>
</tbody>
</table>

**NAME OF PROJECT :**

**DATE OF PROJECT COMPLETION :**

**DATE OF COMMISSIONING/ GAS IN :**

**DATE OF CAPITALIZATION :**

**DATE OF HANDING OVER TO O&M :**

<table>
<thead>
<tr>
<th>BASE LINE DOCUMENTS</th>
<th>INDICATIVE RECORDS TYPES</th>
<th>DOCUMENTS APPLICABILITY YES/ NO</th>
<th>DOCUMENT STATUS &amp; EDMS No.</th>
<th>FURTHER DOCUMENT DETAILS/ NO. OF PAGES/ VOLUME/ PACKAGES ETC</th>
<th>PHYSICAL STORAGE LOCATION</th>
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<tbody>
<tr>
<td>1. PROJECT CHARTER</td>
<td>1.1 Project approval</td>
<td></td>
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</tr>
<tr>
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<td>1.2 PNGRB approval</td>
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<td></td>
<td>1.3 DFR</td>
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<td>1.4 EMP / EIA/RRA Report</td>
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<tr>
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<td>1.5 (i) Process Design</td>
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<tr>
<td></td>
<td>Package</td>
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<tr>
<td></td>
<td>(ii) Design Basis</td>
<td></td>
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<tr>
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<td>(iii) Design Audit</td>
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<td></td>
<td>1.6 HAZOP/Operation</td>
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<td></td>
<td>Philosophy</td>
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<tr>
<td></td>
<td>1.7 Miscellaneous</td>
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### BASE LINE DOCUMENTS

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</tbody>
</table>

### 2. FINAL DOCUMENTS

#### 2.1 AS BUILT DOCUMENTS (VKPL-II Section C1 CH 00.000 TO CH 24.990)

- **As-Built construction Drawings particularly**
  - **2.1.1** Alignment sheets
  - **2.1.2** Crossing drawings
  - **2.1.3** P&IDs
  - **2.1.4** Logic ladder diagrams/ Process Flow Diagram
  - **2.1.5** SLD of control & lighting in SV stations
  - **2.1.6** As built/final drawing documents of TCP & PCP
  - **2.1.7** Final Interference & Mitigation of PCP system
  - **2.1.8** Data on Sheet of HT
<table>
<thead>
<tr>
<th>BASE LINE DOCUMENTS</th>
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<tr>
<td></td>
<td>Line from the Agency in Line with NACE RP 0177</td>
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<td>2.1.10 CP &amp; Coating design Philosophy</td>
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<tr>
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<td>2.1.11 SAT of all Instruments including Calibration &amp; loop Testing Certificate</td>
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<tr>
<td>2.2 FINAL TECHNICAL FILE PACKAGE/ PO WISE</td>
<td>Final Technical File including below (as applicable)</td>
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<td>2.2.1 (i) Schedule of Projects (duly signed)</td>
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<td>(ii) Schedule of Package (duly signed)</td>
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<td>2.2.2 Pipe tally sheets</td>
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<td>2.2.4 Inspection and QA/QC documents</td>
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<td>2.2.5 Electronic Geomentry Pigging EGP</td>
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<td>2.2.6 Pipeline Markers</td>
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<td>2.2.7 Warranty / guarantee certificates</td>
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<td>2.2.8 Calibration certificates</td>
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<tr>
<td>and traceability certificates</td>
<td>2.2.9 Vendor manuals</td>
<td>2.2.10O&amp;M manuals</td>
<td>2.2.11Equipment commissioing documents</td>
<td>2.2.12List of mandatory spares</td>
<td>2.2.13List of commissioing spares</td>
</tr>
<tr>
<td>3. SURVEY &amp; LAND RECORDS</td>
<td>3.1.1 Survey &amp; Soil investigation reports</td>
<td>3.1.2 RoU Village file</td>
<td>3.1.3 Corrosion Survey Report &amp; Data</td>
<td>3.1.4 Tree &amp; crop Survey compensation reports</td>
<td>3.1.5 RoU Cadestral maps</td>
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<td>3.1.9 List of Disputes / pending complaints with detailed status.</td>
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<td>4.1.2 CCoE Laying</td>
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<td>4.1.3 CCoE Commissioning</td>
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<td>4.2.3 Others</td>
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<td>4.3.1 Crossings Permissions</td>
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<td>4.3.2 Railways</td>
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<td>4.3.4 Forest / Wildlife / sanctuary</td>
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<td>4.3.5 NH / SH</td>
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<td>4.3.6 Others</td>
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<td>Electricity Authority Permissions</td>
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<td>4.4.2 Factory Licenses As per Factory act 1948</td>
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<td>4.4.3 Clearance for Frequency in case of Radio set, Walky Talky/VHF/UHF.</td>
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<td>4.4.4 Storage Licenses from CCOE/Dist Collectore incase of Diesel of any Hydro carbon storages.</td>
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<td>4.4.5 Authorization for hazardous waste rule (Management &amp; Handling-1989)</td>
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5. PROJECT CLOSURE

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<td>5.3 Completion Documents</td>
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<td>Mechanical completion</td>
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<td>(VKPL-II Section C1 CH 00.000 TO CH 24.990)</td>
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<td>5.3.3 Commissioning certificate and Commissioning history</td>
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<td>5.3.4 Construction QA/QC records, Procedure &amp; Inspection Records.</td>
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<td>5.3.5 Radiography Films &amp; Reports</td>
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<td>5.3.6 Drawing such as Plot Plan, HAC Drawing, cable route drawings &amp; P&amp;ID.</td>
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<td>5.3.7 Tie-in Joint Inspection Reports</td>
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<td>5.3.8 Pre Commissioning Inspection Reports</td>
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<td>5.4 MOUs and agreements</td>
<td>5.4.1 MOUs &amp; Agreements with Product suppliers &amp; Customers (i.e. GSA &amp; CT with customers)</td>
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**NOTE:** EDMS nos. mentioned in “Bold Letters” in the above HOTO format have been currently uploaded in the system

(Signature of O&M)             (Signature of Project Deptt.)

Name           :                                                                 Name          :
Designation:                                                                    Designation: