ETHEKWINI WATER AND SANITATION

WATER DESIGN & NON-REVENUE WATER BRANCH

CATHODIC PROTECTION AND ALTERNATING CURRENT MITIGATION TECHNICAL SPECIFICATION

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FOREWORD

This document will undergo continuous change and revisions will follow on a regular basis. The eThekwini Water and Sanitation Department (EWS) appreciates that the corrosion industry may be defined in a far broader sense to include, but not be limited to, coatings, linings, metallurgy, cathodic protection and alternating current related safety and corrosion issues amongst others. For purposes of this document the word “corrosion” is an all-encompassing term for the various areas stated above. In this regard EWS identifies the following types of service providers:

1. Corrosion consulting engineers / advisors.
2. Corrosion construction / implementation contractors.
3. Corrosion quality control and assurance providers.
4. Manufacturers of corrosion related materials, equipment and systems.
5. Suppliers of corrosion related materials, equipment and systems.
6. Third party corrosion review / audit providers.
7. International corrosion review specialists.
8. Main civil/mechanical contractor/s.
9. Main civil/mechanical design engineer/s or project manager/s.

Service providers 1 to 7 in the above list are likely to be engaged at various stages of a typical project life cycle with EWS and as such the onus of having the latest revision of this document, drawings and stipulated national and international standards, rests with the individual service providers. When service providers 1 to 7 are quoting, tendering or contractually engaged by EWS, this responsibility is accepted by the service provider.

Services providers 1 to 3 are expected to have the requisite technical skills, engineering nous and practical experience to engage on complex corrosion related matters. EWS expects service providers 1 to 3 to understand the intricacies of a corrosion project to the extent that inherent safety considerations, notices and warnings form part of the duty of every discipline and not purely service providers 8 and 9 identified in the list above.

The failure of service providers 1 to 3, 6 and 7 to notify EWS and service providers 8 and 9 of inherent project risks associated with their area of specialist knowledge will be interpreted as dereliction of their duties.

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1. GENERAL PREAMBLE

1.1. Scope

This Specification defines the minimum and mandatory requirements governing the design, application, installation and commissioning of both Sacrificial Anode Cathodic Protection (SACP) and Impressed Current Cathodic Protection (ICCP) and AC mitigation (ACM) systems for the following:

- Pipelines, fire water and utility piping, as well as pipes located inside chambers;
- Pipeline casings (cased crossings);
- The internal surface of water storage tanks
- Any buried or submerged steel structure

Unless otherwise agreed by the purchaser's Engineer in writing, the materials and specifications used shall strictly follow the clauses of this specification.

The requirements of this specification may not necessarily be repeated in the bill of quantities or typical drawings issued. Thus this specification must be strictly adhered to.

The “Client” shall refer to the asset owner’s Corrosion Engineer or his designated representative.

The “Engineer” shall refer to the CP design engineer or his designated representative.

The “Contractor” shall refer to the supply and/or installation contractor.

The “Corrosion Engineer” be appointed by The Client and shall have discretion and authority in the following:

- Agreeing corrosion protection system and specification
- Approval of Protection System and procedures
- Specific Materials for both corrosion protection and materials of construction
- Quality Control systems
- Approval of qualifications

In the event of any detail that is not fully addressed in this specification and that is warranted to be carried out by The Contractor, the work shall be performed in accordance with the relevant applicable codes and best recognised engineering practices in the cathodic protection (CP/Corrosion) industry. The Consultant shall develop detailed specifications, procedures and method statements required to perform the CP design and/or corrosion engineering during

The Engineering phase of work and this shall be submitted to The Client for review and approval prior to construction, supply and/or installation work by an appointed Contractor.

AC interference mitigation may be achieved through the use of pipeline-earth grounding systems, in conjunction with solid state DC decoupling devices. It must not adversely affect or interfere with the CP system, or others.

The details and extent of the plant or structure equipment required to be cathodically protected, the site / locality and the meteorological data shall be both specified and supplied by The Client.

1.2. Legal Requirements

All works shall be conducted in compliance with the relevant sections of the OHS Act. The Consultant / Contractor is responsible for ensuring that all personnel are equipped with appropriate PPE.

All materials, plant and equipment shall be the best of their respective kinds and spare parts, replacements and servicing facilities shall be readily available from local sources.

The following sections represent general specifications that shall be adhered to. Specific sizes and descriptions are detailed in the Bill of Quantities.

All work shall be carried out by qualified personnel and correctly supervised.

The Contractor shall be required to backfill and compact all excavations and ensure that all waste products and materials are removed from site and safely disposed of. All civil works are to be accepted/rejected by an approved competent civil professional.

Should any requirement of the project specification conflict with any requirements of the standardised or particular specifications listed in the list of specifications, the requirement of the project specification shall prevail.

1.3. Alternative Materials, Equipment and Work

If alternatives pertaining to materials, equipment and work method are submitted, the Supplier / Contractor shall supply with their quotation/proposal all detailed specifications, designs, calculations, drawings and a fully priced Bill of Quantities as per the original quotation and/or any alterations and any further information that may be required by The Client for the proper evaluation of the offer.

The attention of the Supplier / Contractor is particularly drawn to the high standard of materials, workmanship, testing and performance applicable to the Contract as a whole.

The Client reserves the right to carry out a factory inspection at their discretion.

Should any requirement or provision of the Project Specification conflict with any requirement of any standardized (SANS 1200) specifications or any drawings, the order of precedence, unless otherwise specified, are:

- Project Specification
- Drawings
- SANS 1200
- Bill of Quantities

Any discrepancies will be brought to the attention of the Corrosion Engineer or designated representative.

When all tests have been successfully completed to the satisfaction of The Client, an Operational Acceptance Period shall commence and shall consist of a continuous period of operation of 12 months free from trouble.

During the operational acceptance period The Contractor shall carry out all necessary servicing and any adjustments required at their expense.

1.4. Guarantee Period

* The Contractor is required to supply a written guarantee on the items supplied by them for a period of 2 years from date of site acceptance testing under continuous working conditions after the successful completion of the abovementioned Operational Acceptance Period.

*** NOTE**: Where the CP and AC Mitigation Contractor is employed as a sub-contractor to the main construction contractor, the guarantee period for all manufactured, supplied and installed equipment shall reflect the main construction contractor's guarantee and performance bond durations.

The only exceptions shall be for damages arising from vandalism, mechanical damage, and external fire and/or flooding.

Any faults as may be certified by The Client due to poor materials, workmanship or The Contractor's design (where applicable), shall be remedied and faulty goods replaced entirely at the Installation Contractor's cost.

The Contractor is responsible for the guarantee of all items under the terms of the tender and for the safe delivery and installation of the equipment and materials, as called for in the Bill of Quantities, unless otherwise instructed in writing by The Client.

Where the Contractor is required to manufacture, supply and deliver materials and/or equipment to The Client's stores, or a suitably designated depot, the guarantee period shall commence from the time of delivery and sign off at the stores, by the Client, that the materials and/or equipment was received in good order. The guarantee for manufacture, supply and delivery type contracts shall be issued in writing for 2 years from the delivery date.

All materials and/or equipment delivered to The Client's stores, or a designated depot, (only under a manufacture, supply and delivery type contract) shall be delivered in a rugged crate with suitable solid impact resistant walls, unless otherwise specified. The enclosure shall be marked with black 50mm high lettering stating the purchase order number (PO No. XYZ) and a single line description of the contents ie. TRU, Anodes,

1.5. Safety and Work Procedures

The Contractor shall ensure that a competent person is assigned to the works at all times in terms of OHS Act. The Contractor shall ensure that he complies with all statutory regulations, municipal by-laws, etc. concerning pollution and the health and safety of his personnel and members of the public who may be affected by his work. The Contractor shall provide for all necessary safety precautions and risk assessments and the loss control or safety officer shall prepare a safety plan for the area to be worked in. The Contractor shall advise The Engineer of all hazardous materials to be brought on site.

All electrical commissioning works and tie in to Eskom or the relevant power supplier shall be carried out by a qualified Electrician registered with the Electrical Contracting Board of South Africa. All excavation and construction work shall be carried out strictly in accordance with the relevant Health and Safety regulations of local authorities or relevant departments within the Relevant Metropolitan Area.

Oily or solvent rags shall be kept segregated in closed containers and in minimum quantity. Any spillage of volatile material shall be wiped up immediately. Solvents and volatile materials shall be stored in designated areas. The Contractor shall provide and erect such scaffolds and rigging as may be required. All scaffolds and rigging shall comply with the requirements of the OHSA. Temporary welded support elements are not permitted except where written approval has been granted by The Engineer.

The Contractor shall ensure that the relevant electrical, civil, roads, rail or other departments are timeously informed of proposed project works. The necessary wayleave approval for each aspect of the work shall be kept on file for inspection during the project.

On completion of the works, The Contractor shall include the wayleave forms with the documentation to be handed over to The Client.

Furthermore, The Contractor shall ensure that the relevant departments are approached to determine:

- Specific requirements according to the SAECC
- Specific department safety regulations.
- Specific construction restrictions and timing.
- Notification of work requirements.
- Procedures for work approval.
- Location of services that may be affected during construction.
- Public notification requirements to inform residents or business owners of potential disruptions.

The Contractor shall inform The Client of the requirements and ensure that the relevant minutes of meetings with departments are kept of record for the duration of the works. The relevant project information and minutes of meetings with third parties shall be copied to The Client at the end of the project. The Contractor shall prepare typical Hazard Identification and Risk Assessment forms for each of the major aspects of a construction project namely:

- Working near or under High Voltage Power Lines.
- Step and touch potential mitigation measures when approaching, working under or exiting High Voltage Power Line areas.
- Handling, storage and installation of anodes, cables, TRU/SMU/NDU and other electrical equipment to minimize theft and vandalism.
- Excavation, backfilling and compaction.
- Lifting and moving of heavy equipment on site.
- Operation of machinery on site.
- Road traffic management.
- Working in trenches deeper than 1.5m.
- Managing pedestrian traffic nears construction works.
- Electrical testing, connections and commissioning.

- Locking out and securing of sensitive areas during normal work hours and after hours.
- Entry into pipes of 800mm diameter or less.

1.6. Handling and Storage

The following precautions shall be taken for the site storage and handling of supplied items:

- All coated components shall be handled using soft slings and/or acceptable methods that will not cause damage.
- All components to be transported shall be loaded with support blocks, packaging and packing between pieces and tight lashing to avoid chafing.
- Off-loading at site shall be conducted using the same care and precautions for on-loading. Components shall not be tipped off the transportation.
- Coated corrosion protection items shall be stored under cover where possible.
- Items not stored under cover shall be stored in such a manner as to avoid retention of water and allow good air circulation.
- Items shall be stored on baulks of timber to raise the lowest level above the rain splash zone.
- Items shall be stacked using timber packing or other approved means to avoid item-to-item contact. Sufficient bearing area of packing shall be used to avoid damage to items.
- Storage of anodes, cables, TRU / SMU / NDU and other related electrical equipment shall be in a secure location that is fenced off, inside a locked/secure building or enclosure and adequate security measures should be in place for 24 hour guarding and armed response.
- Handling of all anodes, cables, TRU / SMU / NDU and other related electrical equipment up to the point of installation and backfilling shall be managed in such a manner that the maximum security is in place to minimize theft and vandalism before the equipment is tested, commissioned and handed over.

1.7. CP Design Requirements

The CP system requirements i.e. design life, type, materials, supply and installation method shall be as specified by The Engineer. The buried / immersed steel components should be designed to be accessible for the purposes of supplying, installing, applying, inspecting and maintaining the CP system.

The guidelines to ensure accessibility and suitability for maintenance and upkeep of the complete CP system shall be drawn from SANS 15589 “Cathodic Protection of Pipeline Transportation systems: Part 1 On-Land pipelines”.

1.8. Qualified Staff

The Contractor/Consultant shall ensure that there are at all times sufficient suitably qualified, experienced and skilled staff to carry out and supervise all activities.

1.8.1. CP Design Engineer

The CP Design Engineer must:

- Hold an engineering degree or a technical diploma.
- Have a NACE CP Specialist Certification with a minimum 8 years corrosion related work experience or a NACE CP Specialist with a Professional Engineer’s License and 4 years CP related work experience.
- Alternatively, hold an engineering degree or a technical diploma and have a minimum of 20 years post qualification engineering work experience, of which 15 years are CP design related with verifiable references.

1.8.2. CP Engineer

The CP Engineer must:

- Hold an engineering degree or technical diploma.
- Have a minimum of 15 years corrosion related experience or hold a NACE CP Level 3 Certification with a minimum 6 years corrosion related experience.
- Alternatively, hold an engineering degree or a technical diploma and have a minimum of 15 years post qualification engineering work experience, of which 10 years are CP trouble shooting, construction and design related with verifiable references.

1.8.3. AC Mitigation Engineer

The AC Engineer must:

- Hold an engineering degree or technical diploma and have a minimum of 5 years post qualification Cathodic Protection experience
- Have a minimum of 10 years corrosion related experience or hold a NACE CP Level 3 Certification with a minimum of 3 years corrosion related experience.

- Have a minimum of 5 years AC Mitigation experience and have suitably been trained on AC mitigation modelling software (Certificates to be provided) or be able to demonstrate sound engineering practice in the design development with detailed calculations and estimations.
- Have a Professional Engineer's License.

1.8.4. Senior CP Technician

The Technician must:

- Hold a minimum of a 3 year diploma or be a trade tested electrician.
- Have a minimum of 8 years Cathodic Protection experience or hold a NACE CP Level 2 Certification with 8 years corrosion related experience.
- Have the ability to sign off and verify all maintenance records that the system is safe for operation.

1.8.5. CP Field Technician

The CP Field Technician must:

- Hold a minimum of a 3 year diploma.
- Have a minimum of 3 years Cathodic Protection experience or hold a NACE CP Level 2 Certification with 3 years corrosion related experience.

1.8.6. Pipe Coatings Inspector

The Inspector must:

- Hold a N3 Technical with English or Grade 12 certificate.
- Hold a minimum NACE CIP 1 Certification with two year post qualification experience or a SAQCC (Corrosion) Inspector certification with a two year post qualification experience or have a minimum of 7 years' experience in Inspecting Coating Systems.
- The inspector's CV should reflect all experience relevant to the job.
- Have the ability to sign off and verify all maintenance records that the system is safe for operation.

1.8.7. CP Field Assistant

The CP Field Assistant must:

- Have 3 years electrical or electronics practical experience.
- Have a NACE CP Level 1 Certification or 5 years CP related field experience.

- Be a permanent employee of the company.
- Be properly trained for the work that needs to be executed.

1.8.8. Semi-skilled CP Hands (Labourer)

The Labourer must:

- Have relevant experience in the discipline of Cathodic Protection of Pipelines.
- Be a permanent employee of the company.
- Be properly trained for the work that needs to be executed.

1.9. Quality Assurance

1.9.1. Contractor Qualification

All material, certification and records of the Contractor will be subject to examination by the Engineer. This shall include the checking and testing of the equipment. If any deviation to the approved QCP or product quality is found, the Contractor may be instructed to perform additional testing and quality surveillance, at no additional cost to the Client. The Engineer may, at his discretion, require a Quality Audit of The Contractor's facility to ensure that he has the management, facilities and skilled staff to carry out the work in accordance with the specification.

The Contractor shall accept full responsibility for the quality of his work and of materials used, irrespective of any quality surveillance that may be carried out by The Engineer.

1.9.2. Quality Control

The Contractor shall have the necessary equipment and qualified staff to carry out the quality control required to ensure compliance with the specification.

Quality control shall be carried out by a qualified inspector who is independent of the application activities. Quality control cannot be carried out by the site supervisor or any member of staff involved in production and programming.
The Contractor shall keep at least the following records:

- Material batch records
- Site Data Sheets
- Records
- Records of specific tests as required by The Engineer

These records shall be kept in a format that meets the approval of The Engineer.

The cost of quality control shall be included in The Contractor's tender price.

Before the commencement of the contract, The Contractor shall prepare a Quality Plan detailing each activity to be carried out during the execution of the works. Each activity shall be supported by a detailed Works Procedure for that activity. The Quality Plan will also detail the inspection requirements of each specific activity, listing whether it be a review, witness or hold point, and define the responsibilities of the various parties at each stage of the works.

The Contractor shall provide the necessary documentation to be used during these inspections. Such documentation shall be reviewed and approved by The Engineer beforehand.

1.9.3. Quality Surveillance

A third party specialist corrosion consultant may be appointed by The Client to perform independent quality assurance inspections.

For the purpose of carrying out quality surveillance, the Specialist shall be granted access to any part of The Contractor's premises relevant to the work being carried out, at any reasonable time. The Contractor shall provide, at his own cost, any equipment or labour necessary to gain access to the works that are in progress.

The Specialist may remove any reasonable samples of materials to be used in the application. Rejection of the samples will place a hold on the use of material of the same batch number and may lead to rejection of all that batch of material and the reworking of any components that have already been worked on with rejected material.

The Specialist may carry out reasonable destructive tests to ascertain compliance with the specification. Areas thus damaged shall be repaired by The Contractor to the satisfaction of The Engineer at no additional cost.

A report shall be compiled by the Specialist for each visit. A copy of the report will be given to The Contractor on completion of each surveillance visit.

2. RELEVANT SPECIFICATIONS

Below is a list of typical relevant specifications that may be used in the execution of a project. Where applicable, items specified in this document shall comply with the latest revision of the stated specifications and other specifications quoted or referred to within these documents:

NOTE: Where there is a contradiction, the project specification takes preference. The exact specifications to be used will be specified by The Corrosion Engineer at the Pre-Job Conference ("kick-off" meeting).

2.1. American Society for the Testing Of Materials (ASTM)

ASTM B265	Standard specification for titanium and titanium alloy strip, sheet and plate
ASTM B338	Titanium Alloy for Heat Exchangers
ASTM A518	Specification for corrosion resistant high silicon iron castings
ASTM G57	Method for field measurement of soil resistivity using the Wenner Four Electrode method
ASTM G95-87	Standard Test Method for Cathodic Disbondment Test of the Pipeline Coatings
ASTM 3418	Method of measuring transition temperatures by Differential Scanning Calorimetry (DSC)
ASTM D293	Standard Test Method for the Sieve Analysis of Coke
ASTM B418	Standard Specification for Cast and Wrought Galvanic Zinc Anodes

2.2. British Standards Institution (BS) Specifications

BS 171	Specification for power transformers
BS 1016	Method for analysing and testing of coal and coke
BS 1872	Specification of electroplated coatings on tin
BS 6001	Sampling Procedures for Inspection by Attributes
BS EN 15280	Evaluation of AC Corrosion Likelihood of Buried Pipelines Applicable to Cathodically Protected Pipelines

2.3. Canadian Standards Association (CSA)

CAN/CSA –C22.3 No.6-M91	Principles and practices of electrical coordination between pipelines and electric supply lines

2.4. International Electrotechnical Commission (IEC) Publications

IEC 60038	Standard voltages
IEC 60028	Copper wire.
IEC 60051	Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories.
IEC 60071	Co-ordination of insulation.
IEC 60076	Parts 1-5 Power Transformers.
IEC 60144	Degree of protection of enclosures for low voltage switchgear and control gear
IEC 60146	Semiconductor Converters.
IEC 60189	PVC Insulation and PVC Sheath.
IEC 60269	Low voltage fuses – Fuses mainly for Industrial applications.
IEC 60445	Identification of equipment terminals and of Terminations of certain designated Conductors, including general rules for Alphanumeric system.
IEC 60616	Terminal and tapping markings for power transformers.

2.5. National Association of Corrosion Engineers (NACE)

NACE SP0169	Control of External Corrosion on Underground or Submerged, Metallic Piping Systems
NACE SP0177	Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
NACE SP0188	Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.
NACE SP 0207	Performing close-interval DC pipe-to-electrolyte potential surveys on buried or submerged metallic pipelines
NACE SP0286	Electrical Isolation of Cathodically Protected Pipelines
NACE SP0502	Pipeline External Corrosion Direct Assessment Methodology
NACE SP0572	Design, Installation, Operation and Maintenance of Impressed Current Deep Groundbeds
NACE RP 0104	The Use of Coupons for Cathodic Protection Monitoring Applications
NACE TM 0102	Measurement of protective coating electrical conductance for underground pipeline
NACE TM 0109	Techniques for aboveground evaluation of the coating condition of underground metallic pipelines

NACE TM 0497	Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
NACE Pub	Measurement Techniques Related to Criteria for 10A190 Cathodic Protection of Underground or Submerged Steel Piping Systems
NACE Pub	Impressed Current Anodes for Underground 10A196 Cathodic Protection Systems

2.6. South African National Standards (SANS)

SANS 10142-1	The wiring of premises Part 1: Low-voltage installations
SANS 1091	National colour standards for paint
SANS 10129	Plastic tape wrapping of steel pipelines.
SANS 10140	Parts 1 to 3: Identification - Colour Marking.
SANS 10064	Preparation of steel surfaces for coating.
SANS 121	Hot dip galvanised coatings on fabricated iron and steel articles.
SANS 1700 SET/ ISO 1461	Fasteners
SANS 122-1975	Pressure-sensitive adhesive tapes for electrical purposes (Metric Units)
SANS 10199	The design and installation of an earth electrode specifications
SANS 10313	Protection against lightning – Physical damage to structures and life hazard
SANS 1063	Earth rods, couplers and connection
SANS 1411-1	Materials of insulated electric cables and flexible cords Part 1: Conductors
SANS 1411-2	Materials of insulated electric cables and flexible cords Part 2: Poly-Vinyl- Chloride (PVC)
SANS 1411-3	Materials of insulated electric cables and flexible cords Part 3: Elastomers
SANS 1411-4	Materials of insulated electric cables and flexible cords Part 4: Cross-linked Polyethylene (XLPE)
SANS 1411-5	Materials of insulated electric cables and flexible cords Part 5: Halogen free, flame-retardant materials
SANS 1411-6	Materials of insulated electric cables and flexible cords Part 6: Armour
SANS 1507-1	Electric cables with extruded solid dielectric insulation for fixed installations (300 / 500 V to 1900 / 3300 V) Part 1: General
SANS 1507-2	Electric cables with extruded solid dielectric insulation for fixed installations (300 / 500 V to 1900 / 3300 V) Part 2: Wiring cables

SANS 1507-3	Electric cables with extruded solid dielectric insulation for fixed installations (300 / 500 V to 1900 / 3300 V) Part 3: PVC distribution cables
SANS 1507-4	Electric cables with extruded solid dielectric insulation for fixed installations (300 / 500 V to 1900 / 3300 V) Part 4: XLPE distribution cables
SANS 1507-6	Electric cables with extruded solid dielectric insulation for fixed installations (300 / 500 V to 1900 / 3300 V) Part 6: Service cables
SANS 15589 Part 1	Petroleum and natural gas Industries – Cathodic Protection of pipeline transportation systems. Part 1: On-land pipelines.
SANS 50162	Protection against corrosion by stray current from direct current systems.
SANS 53509	Cathodic Protection measurement techniques
SABS 10142	Wiring of Premises - LV Installations
SANS/IEC 79&10108	The classification of hazardous locations and the selection of apparatus for use in such locations
SANS 1222`	Enclosures for electrical equipment classified by IP code
SANS 121/ISO1461	Hot dip galvanized coatings on fabricated iron and steel articles: specifications and test methods.
SANS 1091 H40	national colour standard
SANS 15589	Petroleum And Natural Gas Industries - Cathodic Protection of Pipeline Transportation System.
SANS 089	The installation of underground storage tanks, pumps/dispensers and pipework at service stations and consumer installations
SANS 086	Code of practice for the installation and maintenance of electrical equipment used in explosive atmospheres

The relevant SANS Standardised Specifications for Civil Construction shall apply.

It shall be the responsibility of The Contractor to obtain at his own expense, copies of the relevant editions of the documents referred to above. Subsequent amendments or revisions to these documents that have direct bearing on the project specification shall be clarified in writing with The Engineer before construction commences.

In addition to this all elements of the Contract Documents shall be available for inspection on Site at all times.

SANS 1200	A General
SANS 1200	AB Clients Office
SANS 1200	C Site Clearance
SANS 1200	D Earthworks
SANS 1200	DB Earthworks small works
SANS 1200	GA Concrete – small works
SANS 1200	H Corrosion Protection of structural steelwork
SANS 1200	M Roads – General
SANS 1200	MF Base
SANS 1200	MH Asphalt base and surfacing
SANS 1200	MK Kerbing and Channelling

3. GLOSSARY OF TERMS / DEFINITIONS

AC: Alternating Current

ACM: Alternating Current Mitigation

Anode: The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the solution at the anode.

Anode Backfill: Carbonaceous material placed in a hole to fill the space around the anodes, vent pipe and buried components of an anode groundbed.

Anode Groundbed: One or more anodes installed below the Earth's surface for the purpose of providing a long-lasting, corrosion-resistant, positive connection to earth in a cathodic protection system, that enables the required current to pass into and through the electrolyte to the steel surface to be protected. A sacrificial anode groundbed sacrifices itself in favour of the steel structure being protected.

Anode Groundbed Survey: This survey involves the measurement of soil resistance values at regular spacing intervals of 2m up to a spacing of 50m or more. Results are analysed to determine the suitability of a location to install a low resistance anode groundbed.

Bill of Quantities (BOQ): The pricing instructions that are in the tender document that contains the quantities to be supplied or installed.

Bonding: A method of connecting metal surfaces to each other by cable using exothermic or pin brazing techniques; often used to establish electrical continuity along pipelines coupled with mechanical joints.

Bonding Cabinet:	A cabinet used to house cable that establishes a connection between metal structures.
Bonding Stations:	A station used to facilitate connection of metal structures to each other.
Cathode:	An electrode of an electrochemical cell at which reduction (gain of electrons) is the principal reaction. Electrons flow toward the cathode in the external circuit.
Cathodic Protection:	The process to reduce or prevent corrosion of metal structures in contact with an electrolyte by the flow of direct current from the electrolyte into the structure surface.
Cathodic Protection Station:	A combination of equipment installed to provide cathodic protection to the pipeline.
Chamber Bonding:	Continuity bonding of all pipe work within a chamber.
Client:	The “Client” shall refer to the asset owner’s Corrosion Engineer or his designated representative.
Continuity Bonding:	A suitable electrical connection, usually metal, that provides electrical continuity between structures that can conduct electricity.
Copper Sulphate Reference Electrode:	See reference electrode
C and I:	Control and Instrumentation
Contractor:	The supply and/or installation contractor.
Corrosion Engineer:	The individual appointed by the Water Authority
Current Drainage Survey:	Survey aimed at determining the amount of DC current required to render a particular structure cathodic to accepted criteria.

Data Logger:	A digital instrument used to measure the potential of a structure over a period of time. This data is then downloaded on to a computer, processed and graphed.
DC:	Direct Current
Digital Multi Meter:	Digital instrument used to measure current, voltage and resistance. For example: a "Fluke™" meter.
Drain Point:	The point on the pipeline where the connection of the negative terminal of the cathodic protection voltage source is made to conduct (drain) the returning current from the pipeline to the foreign voltage source.
Electrolyte:	A conductive liquid or material such as soil or water in which an electric current can flow.
Earth Spike:	16 mm diameter, threaded type, 1.5 m long electroplated SANS 1063.
Earth Cable:	70 mm^2 bare stranded copper
Engineer:	The CP design engineer or his designated representative.
Exothermic Welding:	An exothermic welding process that makes use of copper oxide and aluminium powder to weld copper cables to a pipe or other steel structure.
Flange:	A mechanical joint comprising two flush steel faces, usually at pipe ends, used to join pipe lengths.
Forced Drainage Unit (FDU):	A unit comprising of a TRU and a bypass diode connected between pipe and rail.
Foreign Structures/Pipelines:	Metal structures or pipelines other than that under consideration in contact with the same electrolyte as the structure/pipeline and which are or may become under the influence of the structure/pipeline's cathodic

	protection system. Foreign structures /pipelines may be owned by The Client and/or other companies and may or may not be equipped with cathodic protection.
Impressed Current:	A DC electric current supplied by a device employing a power source that is external to the electrode system. Current that flows as a result of an impressed voltage between anode and cathode components of a cathodic protection system.
Isolation Flange:	An isolation flange typically comprises a gasket of phenol resin with isolating sleeves over high tensile bolts fitted with isolating washers .The purpose of the isolating flange is to stop current flow between a pipe and structural steel or earthing systems.
"IR Free" potential:	The pipe-to-soil potential measured immediately after the cathodic protection system is switched off and the applied electrical current stops flowing to the pipeline surface, but before polarisation of the pipeline has decreased.
Marker Stations:	Typical stations of concrete construction to mark out cable and pipe routes.
Megger:	A meter used to measure resistance values.
Midpoint:	The point on a pipeline between two cathodic protection stations where the influence of the two cathodic protection stations is expected to be equal and the protection levels are usually expected to be at their lowest depending on the design overlap that has been included.
Monitoring Cabinet:	A metal cabinet designed to house recording equipment for monitoring purposes.
Natural Drainage Unit (NDU):	An electrical device comprising a diode and surge protection units linked between pipe and rail to allow

	the flow of current back to the rail under certain conditions.
Natural Potential:	The pipe-to-soil potential measured shortly after installation of the pipe when the soil has been backfilled and compacted. No cathodic protection is applied, polarisation caused by cathodic protection is absent and no significant stray current is present.
OEM:	Original Equipment Manufacturer
"OFF" Potential:	The pipe-to-soil potential measured immediately after the cathodic protection system is switched off and the applied cathodic protection electrical current stops flowing to the pipeline surface, but may still include stray current or foreign service interference in the measured value.
"ON" potential:	The pipe-to-soil potential measured while the cathodic protection system is continuously operating.
O and M:	Operations and Maintenance Manual (also OMM)
Pipe-to-Soil Potential:	The difference in electrochemical potential between a pipeline or foreign structure/pipeline and a specified reference electrode in contact with the electrolyte. Similar terms such as structure-to-soil potential, pipe to electrolyte potential are sometimes used as applicable in the particular context.
Polarisation:	The change of the pipe-to-soil potential caused by the flow of DC current between an electrolyte and a steel surface.
PRE:	See SRE
Reference Electrode:	An electrode with an open circuit potential that is constant under similar conditions of measurement, which is used for measuring the relative potential of

other electrodes or metals under varying electrolyte environments.

Sacrificial Anode System: Anodes manufactured from materials that are sacrificed preferentially when placed in a galvanic couple with another metal i.e. Magnesium coupled to steel in soil.

SCADA: Supervisory Control and Data Aquisition

Sealer: Mastic putty, rubber tape and PVC insulation tape.

Soil Resistivity: An indication of the soil resistance at a certain depth measured using a Megger and the Wenner four-pin technique.

SRE: Stationary Reference electrode

Stray Current: Current that flows through paths other than an intended circuit i.e. current flow though the soil that originated from a DC traction railway line. The current may cause interaction with the cathodic protection system and often acts upon foreign structures and/or pipelines.

Test Station: A point, often of concrete or steel construction, where regular measurements of structure-to-soil potentials may be taken. Test cables are connected directly to the structure being monitored. This term can be used interchangeable with Test Post, Test Point, Test Chamber, Test Cubicle etc.
There are several types of Test Station namely:

- Type A – monitoring station
- Type B – SRE monitoring station
- Type C – Cross bonding test station
- Type E – 4 wire current span test station
- Type F – Test station with ACM

- Each test station type (A, B, C, E or F) may have optional temporary CP in the form of a suitable galvanic anode that may be disconnected.

Transformer Rectifier Unit (TRU): An electrical device designed with the purpose of stepping down either single or three phase power to a suitable voltage and then rectifying the power supply to provide a suitable DC output.

Viking-Johnson Type Coupling: A coupling that uses a rubber seal on both sides of the coupling barrel, allowing flexibility of the joint, but also electrically isolating one length of pipe from another.

4. CABLING FOR CATHODIC PROTECTION

4.1. General Properties of Isolating Compounds

Cable insulation properties are based on environmental, physical and performance requirements. All three requirements are key factors to consider for CP design purposes, however the cables insulation performance with respect to the environmental conditions is more critical. Cable insulation properties should be based on the environmental requirement and the best isolating material for this requirement should be selected. These insulation materials can generally be split into thermoplastic and thermoset materials.

Thermoplastic materials soften and flow when heated and usually possess a definitive melting point. The material will become firm again upon cooling. These materials can be moulded and shaped with a heating and cooling process and the process can be repeated.

Thermoset materials are soft and pliable during one stage of the processing, can be moulded and extruded at this state after which they are set or cured, usually at a higher temperature. After the setting or curing process (cross linking) is complete, they cannot be softened by reheating.

Some of the insulation compounds available include, but are also not limited to:

- Polyvinyl Chloride (PVC)
- Polyolefins
- Polyethylene (low (LMPE), medium (MMPE) and high density (HMWPE)) (PE)
- Polypropylene
- Cellular Polyolefins
- Non-Halogen compounds
- Fluorocarbons (PTFE, PVDF (Kynar™), ECTFE (Halar™), ETFE (Tefzel™))

The primary insulation material (i.e. outer cable insulation) is the most important of the cable material for overall performance reasons. The key requirements that should also be considered include, but are not limited to:

- Voltage dielectric properties for higher voltage charge at the conductor surface.
- Low loss material for high frequency signal cables,
- Heat resistance in high temperature environments,
- Low temperature flexibility,

- Toughness for cut-through, abrasion and burial (crush) resistance.
- Fire resistance
- Ultra violet (UV) resistance (weatherability)
- Chemical resistance (i.e. acids and alkalis, pH resistance)

4.2. Cable and Cable Insulation Compliance

Cathodic Protection cables shall be insulated and rated for voltages up to 600V/1000V and shall have stranded copper conductors in accordance with SABS 1507 or ASTM Specification B-8. The cable conductor and cable voltage drop shall be calculated in accordance with SANS 10142.

All cable suppliers are to ensure that they are familiar and possess the latest SABS specifications herein referred to (refer to section 1.3). Alternative cabling solutions are to adhere to the requirements as stipulated Preamble “Alternative CP Materials”.

4.3. Cathodic Protection Cable Requirements

The following table shall be used when selecting DC cables for Cathodic Protection. The insulation layers are specified as inner/outer layer. All cables are to be embossed or otherwise identified on the outer insulation.

The specific labelling requirements are outlined in Section 4.4. The material certification will be available upon inspection and/or delivery**.**

Cathodic Protection Single Core Cable Insulation Requirements

Cable Detail	Installation Environment	Insulation Layers* and Type	Insulation Colour
Positive DC	Direct Sun	HMWPE/PVC	Red
	Partial Sunlight	PVC/PVC	Red
	Soil (Non Polluted)	PVC/PVC	Red
	Soil (Polluted)	PVDF/ HMWPE/PVC	Red
Negative DC	Direct Sun	HMWPE/ PVC	Black
	Partial Sunlight	PVC/PVC	Black
	Soil (Non Polluted)	PVC/PVC	Black
	Soil (Polluted)	PVD/ HMWPE/PVC	Black
Continuity / Cross Bonding DC	Direct Sun	HMWPE/PVC	Black
	Partial Sunlight	PVC/PVC	Black
	Soil (Non Polluted)	PVC/PVC	Black
	Soil (Polluted)	PVDF/HMWPE/PVC	Black
Earthing	Direct Sun	PVC	Green-Yellow
	Partial Sunlight	PVC	Green-Yellow
	Soil (Non Polluted)	PVC	Green-Yellow
	Soil (Polluted)	PVC	Green-Yellow
Sacrificial Anodes	Soil (Non Polluted)	PVC/PVC	Red / Blue
	Soil (Polluted)	PVDF/HMWPE/PVC	Red / Blue
Pipe Monitor	Soil (Non Polluted)	PVC/PVC	Black
	Soil (Polluted)	PVDF/HMWPE/PVC	Black
Reference Electrode	Soil (Non Polluted)	PVC/PVC	Red
	Soil (Polluted)	PVDF/HMWPE/PVC	Red
Corrosion Coupons	Soil (Non Polluted)	PVC/PVC	Black
	Soil (Polluted)	PVDF/HMWPE/PVC	Black
AC Mitigation Grounding	Soil (Non Polluted)	PVC	Green-Yellow
	Soil (Polluted)	PVC	Green-Yellow

*Insulation layers are defined inside layer to outer layer.

In exceptionally corrosive environments, fluorocarbon insulation shall be provided, as detailed by The Client. The cable and associated cable warning tape burial depth will be specified in the Bill of Quantities. No chevron or bunting tape will be allowed. Warning tape is to stipulate live electrical cables and/or CP cables.

Furthermore, negative cables to pipe and positive cables to the anode groundbed may require additional protection against vandalism i.e. concrete encasement.

In certain instances, multi-core power cabling might be required, such as: 4 Core PVCI/PVCS/SWA/PVCS, as per the Bill of Quantities.

4.4. Cable Identification

Cables are to be labelled by means of permanently marked plastic ferrules with black lettering on a white background. Ferrules shall be the slip-on type and matched to the size of the cable.The ferrules are to be fastened to the cable with cable ties. Ferrules shall be situated so as to read the right way up on horizontal cables and from lug to insulation on vertical cables. All labels of this type shall be supplied in “made-up” condition ready for fixing.

4.5. Cable Weld Attachments

4.5.1. General

The cable weld attachment method to be used shall ensure that metallurgical contact is achieved between the cable and the pipe substrate surface.

The Contractor shall submit detailed QCP’s of the preferred system for approval listing the equipment and staff. In addition a detailed QCP for the coating repair and re-instatement thereof is to be submitted for approval.
Unless otherwise specified, all cable connections to the pipe are to be by means of thermit (exothermic) welding. This applies equally to the cable for the following CP installations:

- Main negative cable,
- Continuity cables,
- Cross Bonding Cables,
- Test station Monitoring cables,
- DC Decoupling device cables, etc.

Where cables are attached to the overt of the pipe, these attachments should be made at field joints to minimise the number of repairs required. The minimum amount of pipe coating shall be removed in preparation for the weld. Where ever possible, cable connections should be made onto the pipe outside of chambers as vandalism and theft in many instances renders the chambers accessible and the connections are removed.

Thermit welding may not be used on the barrel of epoxy lined pipes unless weld pads have been provided. Solder pads many be use subject to satisfactory prequalification trial. Charge size, cleanliness and fluxing are critical aspects of solder pad use.

All welding on epoxy lined pipes must be preceded by a trial on spare pipe or reference pipe piece and the epoxy subjected to visual and holiday detection testing after welding.

Exothermic welding is not permitted on a pipeline where the wall thickness is less than 3.0mm or severe corrosion i.e. metal loss has occurred and the pipe wall thickness is unknown.

In these instances, cables shall be connected by means of pin brazing / Stud welding / Capacitive Discharge Welding. The proposed method of attachment shall be detailed with adequate substantiation to address the relevant concerns set out previously, thereby allowing The Engineer to make an informed decision.

4.5.2. Surface Preparation

The area where the welding is to take place shall be thoroughly cleaned to provide an area slightly larger than that of a typical graphite mould (approximately 75 x 75mm). The welding surface area must be brushed with a steel wire brush and all traces of petroleum mastic, concrete, bitumen coating, primer material or any other matter shall be removed.

Prior to making the weld the area shall be roughened using a coarse file or an angle grinder fitted with a flapper disc.

Always ensure that the steel surface is dry prior to welding.

4.5.3. Exothermic Welding (Thermit Welding)

A detailed QCP procedure is to be submitted by the contractor for approval. A guideline procedure for thermit welding is as follows:

- Bare the end of the insulated cable for a distance of 25mm.
- Select the correct size and type of mould for the weld application.
- Place the supplied retaining cap in the bottom of the mould and pour the correctly sized weld metal powder into the mould.
- Pour the starting/igniter powder over the weld metal, close the lid and sprinkle some on the lip of the mould.
- Place the cable on the pipe and the mould squarely over the cable, pressing down firmly. Ensure that the mouth of the mould is turned away from the welding operator.

- Ignite the starting powder with a flint gun and allow the weld to solidify, the mould is to be kept still during the entire procedure.
- Remove the mould and clean out the residue in preparation for the next weld.

The cables and charges as well as types of joins will be suitably matched as follows (the list below is not considered exhaustive and the manufacturer's guidelines should be adhered to):

Cable (mm^2)	No. of Welds	Entry	Charge Size (g)
10	One	Single	15
16	One	Single	15
35	Two	Single	15
70	Four	Single	15

For multicore cables, each core will require its own thermit weld as per the table above.

A ferrule is required on any 10mm^2 cable.

4.5.4. Stud Welding/Pin Brazing

A detailed QCP procedure is to be submitted by the contractor for approval. Equipment and rating thereof to be identified, ensuring that the welding unit is suitable for the studs and pipe to be welded. After successful trials and reference samples have been signed, all works will be performed in strict accordance with this QCP and adhered to for all further work.
A guideline procedure to be followed when stud welding is as follows:

- Bare the end of the double insulated cable and crimp into the appropriate sized lug using an approved OEM crimping tool. Insert the stud in the welding mechanism (gun) i.e. Mandrel and place against the cleaned steel surface. Ensure all pins have pipe contact.
- Select the appropriate power setting and press the trigger of the stud welding gun, pressing down firmly. Ensure that the correct setting, stud welding consumables, studs, and lugs have been selected prior to welding.
- Remove the stud welding from the cable connection and clean any residue from the brazed connection.

Stud welded connections shall be tested as above, but the stud will be protected using a nut in order to prevent damage to the thread. Should any movement occur the cable shall be re-welded and re-tested.

4.5.5. Testing

After the above procedure(s) have been carried out, a number of welds shall be tested by an approved inspector as appointed by The Client. The test will be performed by striking the weld with a 2kg hammer. Should any movement occur the cable shall be re-welded and re-tested.

4.5.6. Safety Precautions

In addition to all OSH Act requirements and relevant safety procedures, the following precautions should be exercised when welding (stud or exothermic):

a. Ensure that the weld-metal and starting powders, mould and surface to be welded is perfectly dry.
b. Do not attempt to weld in areas where the water level is close to the area to be welded on.
c. Ensure that the correct mould and consumables are used. Do not use moulds past their design life or force a cable into an incorrect mould.
d. Use correct PPE and safety shoes which may be readily removed or shoe spats are to be used.
e. Wear appropriate eye protection, welding gloves and protective clothing. Always ensure that the mouth of the mould face away from the body of the operator. Centre the mould over the pipe, holding it steady during welding. Use special exothermic putty on small bore pipes, in order to prevent the hot liquid weld-metal from escaping between the base and the pipe damaging the coating system and/or possibly cause harm to the operator.
f. Use only a pistol type flint igniter, matches and/or cigarette lighters are not permitted.
g. Follow all permit conditions required by the pipeline owner prior to and during the exothermic and/or stud welding operation.

4.6. Coating Make-Good

All coating repairs associated with CP connections shall be made in accordance with the repair procedures relevant to the coating system applied to the pipe. The Contractor is to submit detailed QCP for the coating repair and re-instatement thereof is to be submitted for approval.

After connecting the cable the entire exposed area shall be encapsulated. Remaining coating to at least 50mm beyond the final repair limits shall be removed and the outer edges suitably feathered.

All cable to pipe connection and coating repairs shall be witnessed by The Engineer or The Client's nominated representative.

Any buried attachments to the exterior of the pipe will require repair using circumferential wrapping. Patch repairs may not be used in buried applications.

Cable connections to epoxy coated specials in valve chambers will require a different coating make good application. A surface tolerant high-build epoxy shall be applied adequately covering the weld and cable area and overlap onto the existing pipe coating by at least 25mm. Epoxy is to be given time to fully cure.

5. CONTINUITY AND CROSS BONDING

Continuity and cross bonding shall include excavation, cable connections, make-good of the coating system, QA/QC test and back filling.

Make good of the coating system where necessary is to be carried out in accordance with the relevant specifications.

5.1. Cross bonding

Cross bonding facilities are to accommodate cable facilities that will enable the following:

- Bonding if a common cathode approach is required
- Current bond is required
- Interference bond is required
- Facilitate breaking of the bond to allow for fault finding and pipe utility tracing

Each cross bond cable shall be clearly identified and labelled, indicating to which pipe it is connected.

Cables shall be identified in accordance with Section 4.4 above.

Cross bonding facilities will be required where buried pipeline systems run parallel to each other or to other foreign services.

Where sections of buried piping of varying diameter run parallel for some distance, frequent cross bonding facilities are required.

Bonding is required from one pipeline to another, i.e. upstream feed and downstream supply of a pump station, or a current carrying bond is required from one system to another that cross or run parallel to each other.

All cross bonding will be done through approved cross bonding facilities i.e. galvanised test posts, concrete bunkers adjacent to valve chambers using bonding links mounted in the enclosure.

One 4-core 16mm^2 SWA cable shall be installed between foreign pipeline and the bunker.

5.2. Continuity Bonding of Buried Joints

Examples of buried pipe joints are as follows:

- Flanged joint
- Bolted flanges
- Viking Johnson type Type Couplings
- Victaulic pipe joints
- Spiggot and socket
- Piping within valve chambers
- Flexible couplings

Buried pipe joints shall be continuity bonded by means of two double insulated single core copper cable connected to either side of the joint on the pipe using either of the approved CP connection methods as described in Section 4.5. Cable insulation and compliance is to be in accordance with the requirements as stipulated in Section 4.2.

Guidelines on the cable size to pipe diameter for continuity bonding is given as follows:

Buried pipes Ø < 700mm → 2 x 16mm²

Buried pipes Ø ≥ 700mm → 2 x 35mm²

In the case of Viking Johnson type couplings, at least one cable shall be bonded to the body of the coupling.

5.3. Continuity Bonding of Buried/Below Grade Bolted Flanges (Alternative System)

Continuity bonding will be required on all buried/below grade bolted flanges, preferably at the pipe overt.

Continuity bonding by means 25mm x 6mm steel flat bar is to be welded across the flanges (flange centre to flange centre).

Flat bar to have a minimum thickness of 6mm.

Guidelines on the number of flat bars size to pipe diameter for continuity bonding is given as follows:

Buried pipes with Ø < 700mm → 2 x flat bar

Buried pipes with Ø ≥ 700mm → 3 x flat bar

The weld shall be a full depth fillet weld across the end of the flat bar.

Weld approval will be in accordance with the weld test as given in Section 4.5.
Coating make good of the flat bar is to be in accordance with one of the options referred to section 4.6.

5.4. Continuity Bonding Inside Valve Chambers

This method of establishing electrical continuity along a pipeline is not the first choice solution and every effort should be made to establish electrical continuity by installing a continuity bond outside the chamber. The reason behind this is vandalism and theft. Only under exceptional circumstances will an internal continuity bond be considered by the Engineer and approval must be in writing.

Valve chambers shall be continuity bonded by means of insulated copper cable connected to either side of the valve chamber. Cable shall be run through a 20mm diameter PVC conduit mounted with saddles 200mm above the top of pipeline along inside wall of the chamber.

Where there are aboveground sections of piping on a buried pipeline network that section of aboveground piping is also to be electrically continuous. Continuity bonding will be required on all above ground dismantling flanges or couplings (i.e. Viking Johnson type Couplings).

Continuity bonding is by way of double insulated single core copper cable. The cable size to pipe diameter relationship for continuity bonding is given as follows:

Pipes with Ø < 700mm → 1 x 16mm^2

Pipes with Ø ≥ 700mm → 1 x 35mm^2

5.5. Continuity Bonding Outside Valve Chambers

Continuity bonding will be required around all valve chambers where bolted flanges, dismantling flanges or couplings are found. Bonding cables will be attached to the pipe(s), each side of the valve chamber wall. Weld should be placed approximately 300mm from the valve chamber wall to accommodate ease of coating make-good. The cables are to be laid around the outside of the valve chamber walls at a nominal depth of 2000mm below final grade level. All cabling to be concrete encased to a thickness of 300mm x 300mm for the full length of cable.

Continuity bonding by means of 2 off black single core, double insulated copper cables which are to be welded on the pipe overt on either side of the valve chamber.

The bonding cable is to be independent from any monitoring cables.

The cable size to pipe diameter relationship for continuity bonding is given as follows:

Pipes with Ø < 700mm -> = 1 x 16mm²

Pipes with Ø > 700mm -> = 1 x 35mm²

The bonding cables are to be independent from any monitoring cables.

6. TERMINAL BLOCKS

Din rail mount bolt connection terminal blocks for cable lugs up to 35 mm² in accordance with DIN 46234 and DIN 46237 shall be supplied.

The type of modular terminal block will be specified on the drawing as follows.

1. The terminal block shall be either:
   1.1. CLIPLINE™ RT Bolt connection terminal blocks, 35mm², 125A, feed-through type. Type RTO- 8-TC, Order No. 305002 as supplied by Phoenix Contact or approved equivalent OR
   1.2. CLIPLINE™ RT Bolt connection terminal blocks, 50mm², 150A, bolt connection terminal blocks. Type HV M8/2, Order No. 3049550 as supplied by Phoenix Contact or approved equivalent.
2. Tenderers to price for whichever terminal block module type costs more as The Engineer shall specify either type at the time of placing an order to the successful tenderer and it will be accepted that the Tenderer made adequate provision while pricing the tender to accommodate either type of connector block.

The Bill of Quantities shall specify the minimum number of terminals blocks to be supplied on a particular length of DIN rail. The manufacturer / supplier shall inform The Engineer at the time of tender whether or not the specified DIN rail length shall be adequate to hold the specified number of terminal blocks and recommend an alternative DIN rail length if so required.

The terminal blocks shall be rated for 125A continuous use and a maximum voltage of 1000V. The minimum terminal bolt size shall be M8. The manufacturer / supplier shall ensure that the terminal blocks fit securely onto the DIN rail and that the end terminal blocks prevent sliding off the DIN rail. At the time of tender full details of proposed DIN rail mount type terminal blocks shall be provided.

7. ELECTRICAL ISOLATION OF CATHODICALLY PROTECTED PIPELINES

Cathodic Protection (CP) is most effectively, efficiently and uniformly applied when the primary structure requiring CP is electrically isolated from those structures not requiring CP.

Electrical isolation implies that all metallic/electrical contacts with foreign metallic structures are completely eliminated.
Electrical isolation provides three major benefits:

- Restriction of the required protective current to the surface of the primary structure to produce a uniform polarised level of protection.
- Minimising stray current influence (AC and/or DC).
- Prevention of unwanted galvanic current flowing between metallic structures.

Best practice guidelines are to be followed here, and Isolating joints are to be installed as above ground and housed in a well-drained and ventilated chamber with inspection access.

IF are typically required at:

- Pump stations
- Reservoirs
- Pressure break tanks
- Electromagnetic flow meters
- Valve actuators
- At points of dissimilar metal contact
- Any earthed instrumentation
- Any other place indicated by the Corrosion Engineer

7.1. Isolating Flanges

Pipeline electrical Isolating Flange (IF) materials shall be selected with consideration given to quality and standard material availability.

The chosen material shall be suitable for the following pipe conditions:

- Gasket material must be drinking water approved
- Flange type
- Flange face
- Dielectric properties
- Line temperature maximum and minimum
- Surrounding Temperature maximum and minimum
- Pressure
- Medium
- Cyclic loading
- Predicted line movement
- Installation of IF's is to be conducted by accredited and competent joint integrity bolting practitioners.

IF materials shall be cross referenced to the manufacturer's specifications to ensure compatibility between materials, service and the environment.

The materials required per IF, shall be supplied as one complete set.

The IF kit shall consist of an isolating non-metallic central gasket, non-metallic bolt sleeves and non-metallic washers and steel thrust washers, as well as the associated studs, nut and bolts.

A detailed QCP procedure is to be submitted by the contractor for approval.

Equipment and rating thereof to be identified, ensuring that the IF kit and surge protection device used is acceptable.

Type of gasket, thickness and whether the gasket is raised face or full face must be specified, together with material certification and approvals.

7.2. Isolating Gasket

The contractor shall provide full details of the manufacturer's specifications and recommended application procedures for approval and sign off by the engineer.

The isolating gasket between flanges is to be in accordance with following table based on pipe diameter and pressure rating.

The internal diameter of the pipe and gasket shall be equal in all instances.

Field Test Pressure MPa	Nominal Pipe Dia. (mm)	Isolating Gasket Material
Lower or equal to 2.5	All diameters	3.2mm Thick High Density Polyethylene to PEH Hostalen GM5010 Specification, full face gasket in one piece.
Lower or equal to 4.6	Smaller or equal to 1200	3.2mm Thick Fabric Reinforced Phenolic (BS EN 60893-3-4) full faced gasket in one piece with neoprene or nitrile rubber faces 0.8mm thick.
Greater than 4.6	Smaller or equal to 1200	3.2mm Thick Fabric Reinforced Phenolic (BS EN 60893-3-4) full faced gasket in one piece with neoprene or nitrile rubber faces 0.8mm thick with a composite gasket.

Isolating gasket shall be tested to BS5102 Appendices A-M: type III, with not more than 3 factory made lap joints and with Neoprene or Nitrile faces 0.8mm thick. The gasket's internal diameter (ID) is to be 6mm smaller than the pipe ID.

The non-metallic central gasket and non-metallic washers shall conform to the following materials specification:

Material Property	ASTM Test Method	SI Value	Imperial Value
Dielectric Strength (Min.)	D149	21 kV/mm	540V/mil
Compressive Strength (Min.)	D625	340 MPA	49,000 psi
Water Absorption (Max)	D229	0.1%	0.1%
Operating Temp (Min)	----	-17℃	0℉
Operating Temp (Max)	----	+93℃	200℉
Hardness, Rockwell M (Min)	D785	115	115
Shear Strength (Min)	D732	150 MPA	22,000 psi

7.3. Isolating Bolt/Stud Sleeves

The insulating sleeve shall be made-up of a glass reinforced epoxy (GRE) material with high resistance to damages associated with thread pinch, cracking, breaking and crushing. The total length of sleeves is to be 2-3mm less than the length between the inside faces of IF washers. The insulating sleeves shall fit completely inside the insulating washers and extend partially within the IF washers.

A lead free, non-metallic, non-conductive and lubricating heavy-duty anti seize compound shall be applied as a lubricant on the bolt within the sleeve. It must contain a blend of water-resistant properties, corrosion inhibitors in high extreme (environmental and pressure) conditions to provide protection to in excess of 1000ºC. It shall have no hazardous ingredients, complete with reduced torque capabilities and low friction effects.

The contractor shall provide full details of the manufacturer's specifications and recommended application procedures for approval and sign off by The Engineer.

7.4. Isolating Washers

Isolating Flange (IF) - washers shall be machined with diameter and thickness to SABS 1149, Table 3, and be:

- 3.2mm thick Glass Reinforced Epoxy * (GRE) and,
- 3.2mm thick Hardened Coated Steel (Coated with resin bonded modified PTFE).

  * **Note:** the preferred washer type shall be specified by The Client.

A double washer configuration shall be used and shall include the following components for each Bolt:

- Two (2) – 3.2mm thick hardened coated steel washers (located against the nut).
- Two (2) – glass reinforced epoxy washers (located against the flange face).
- One (1) – Full length isolating sleeve.

Double washer configuration is highly recommended as an additional protection against the potential electrical ‘shorting out’ of nuts and bolts. Furthermore, the double washer sets acts as an electrical isolator of both nuts and bolts from the main metal flanges.

The inner diameter of the isolating washer shall be a sliding fit over the OD of isolating sleeves.

The contractor shall provide full details of the manufacturer’s specifications and recommended application procedures for approval and sign off by The Engineer. The manufacturer shall provide recommended torque values to ensure that the washers are not damaged during the tightening process.

7.5. Steel Washers

Steel washers shall be machined with diameter and thickness to SANS6149:1989. Stud bolts shall be to SANS 1700 and nuts to SANS 1700.

7.6. Studs, Nuts And Bolts

All studs, nuts and bolts supplied are to be of the same material grade as the pipe flange to mitigate any galvanic effect, unless otherwise stated.

Stud bolts and studs shall be grade 8.8 and nuts grade 8 to SANS 1700.

Stud bolt diameters shall be selected to the next smaller size for installation in standard drilled flanges. Stud bodies shall be machined down to the next smaller standard size and suitable smaller nut to be used.

Stepped stud bolts shall be sized on the one end to fit the tapped blind bolt holes in the valve flanges, the other end shall be of the same diameter as the normal stud bolt.

7.7. Surge Protection

The Contractor is to ensure that compliance with electrical surge requirements is maintained and that approval and sign off by a professional electrical engineer is obtained. The following are best practice guidelines that the contractor can follow providing the mechanical compliance of the joint is maintained:

The explosion-proof Spark Gap Type ExFS (minimum acceptable shall be according to EN62561-3 or IEC 62561-3) shall be installed across the flange faces complete with hot-dip galvanized mild steel mounting brackets to suit the flange bolt. The width of the holding bracket of the explosion-proof spark gap shall be the same as the steel insulating washers and the bottom end be rounded off to fit into the spot faced area of the valve and/or steel flange.

If required for AC mitigation, a steady-state DC decoupler (SS-DCD) device or technically compliant equivalent shall be installed across the flange faces complete with surge rated non-corroding metal mounting brackets to suit the flange bolt. The DCD shall be located in a suitably rated enclosure as stipulated in SANS/IEC 79 and SANS 0108.

In the absence of a DCD, a spark gap device (as specified above) or technically compliant equivalent shall be installed across the flange faces complete with hot-dip galvanising mild steel mounting brackets to suit the flange bolt.

Installation of the brackets is to be in strict requirements with the OEM requirements ensuring that there is adequate mechanical, metal, electrical contact to the metal surface with minimal coating damage to the surface.

7.8. Identification and Protection of Isolating Flange

Visual, physical and insulation testing is required at IF installations. Positive visual identification in the form of an approved paint system, aluminium punched tag (minimum 12mm punch die) (and ID) is required for traceability and routine testing requirements. The identification of IF installations using paints, tags or labels shall be submitted to the engineer for approval.

7.8.1. Protection of IF Installations

- All IF testing is to be completed and signed off together with the installed surge protection device before protection of the IF can be supplied and installed.
- No painting over the studs, nuts, bolts and washers.
- Protection of the IF installation is to be installed to cover the gap between the flange faces only. If possible an opaque covering should be used to allow for visual inspection of the sleeves and/or gap.
- Flange protection devices and/or tape wrap systems approved by the engineer shall be installed.
- Nuts are to be protected against corrosion and rust, nut protection covers are to be installed.

7.8.2. Wrapping of the IF Installation

The engineer shall specify whether or not the IF installation shall be wrapped and will be determined by the following environmental considerations:

- Likelihood of flooding.
- Likelihood of conductive material build up on the exposed surface of the flanges.

The entire isolating flange shall be wrapped circumferentially with a 1.5 to 2.0mm thick white plastic backed polymer modified bituminous tape, or similar approved. The latter shall have a minimum overlap of 25mm. In the case of surface irregularities, i.e. stepped flanges, etc. A CLIENT approved Petrolatum mastic material shall be used to provide a smooth contour for subsequent tape application.

The isolating flange shall be wrapped circumferentially with a 1.5 to 2.0mm thick white plastic backed polymer bituminous tape, or similar approved. The latter shall have a minimum overlap of 25%. In the case of surface irregularities, an approved Petrolatum mastic material shall be used to provide a smooth contour for subsequent tape application.

The entire isolating flange should be wrapped circumferentially with a white plastic backed polymer modified bituminous tape, or similar approved, 1.5 to 2.0mm thick with a minimum 25mm overlap.

In case of surface irregularities, i.e. stepped flanges, etc., an approved mastic material shall be used to provide a smooth contour for subsequent tape application.

The entire isolating flange should be wrapped circumferentially with a white plastic backed polymer modified bituminous tape, or similar approved, 1.5 to 2.0mm thick with a minimum 25mm overlap.

In case of surface irregularities, i.e. stepped flanges, etc., an approved mastic material shall be used to provide a smooth contour for subsequent tape application.

7.8.3. Visual Identification of IF Installations

For coding, a red colour band of 30mm width shall be applied in the centre on the horizontal surface. The tape shall be a plastic backed electrical tape to SANS 1222. A 2mm thick aluminium plate shall be fixed to the isolating flange with stainless steel strapping. The following shall be stamped thereon in 20mm high characters filled with black indelible ink:

- "OPERATING ISOLATING FLANGE"
- "NO ATTACHMENT TO PIPEWORK PERMITTED"
- "VALVE CHAMBER TO BE KEPT DRY"
- "DO NOT PAINT"

7.9. Electrical Insulation Testing Of Isolating Flanges

Electrical insulation testing of the joint (IF and surge protection) must be conducted after installation confirming that the isolating joints are in compliance with the specifications and drawings.

The Contractor is to submit a detailed QCP of their IF insulation testing procedure together with test report formats for approval by the engineer. Once joint integrity has been confirmed a data book for each IF must be prepared for sign off once:

- All material certifications for the IF kit and surge protection device are on hand and signed off
- Joint integrity has been tested and confirmed including torque tightness and pressure tests
- Visual inspection has confirmed that all isolating sleeves, washers, steel washers etc. are in place
- Surge protection device has been installed.

The IF inspection shall be witnessed by The Client, the CP Design Engineer and the IF installation contractor.

The procedures for the electrical insulation tests on the IFs to be performed as a minimum are detailed below:

OPTION 1

- Switch off Transformer Rectifier.
- A free-floating compass shall be placed on top of the isolating flange. The needle normally aligns itself along the pipeline axis. If strong stray currents are present the needle may align at an angle to the pipeline.
- A 12 Volt heavy-duty car battery or DC welding generator should then be used to bridge this isolating flange. If the isolating flange is functioning correctly, no significant deflection of the needle will be observed. If the isolating flange is not functioning, the compass needle will deflect to a position orthogonal to the pipeline.
- The current drawn from the battery is an additional indicator of flange integrity. A short circuited IF will typically draw in excess of 200A.
- Before changing a faulty isolating flange assembly, a bolt by bolt continuity check should be carried out to determine if the problem is not a faulty bolt, isolating sleeve or isolating washer.
- Re-testing must be carried out upon replacing faulty components.

OPTION 2

- Short wave radio frequency testing device such as the Tinker and Rasor IF™ tester or equivalent shall be used.
- Testing across the flange face and across the stud to flange interface of each stud is to be tested, recorded and verified.

7.10. IF Installation Guidelines

Guidelines pertaining to ordering, installation, torqueing and electrical protection of IF installations is given under Annexure E: Isolating Flange Guidelines.

8. CATHODIC PROTECTION TEST STATIONS

8.1. Potential Criteria for Cathodic Protection

There are several techniques used to verify the levels of efficacy of the Cathodic Protection (CP) system to ensure that the minimum specification guidelines are adhered to. For buried steel coated pipelines, the pipe-to-soil potential measured with respect to a calibrated copper to copper sulphate reference electrode (CSE) will be used as the criterion for corrosion protection.

In general, the natural potential of steel (i.e. iron) in soil with respect to CSE is in the region of -0.4 to -0.5 Volts (DC).

The buried water pipeline shall be regarded as being under effective CP when a negative (Cathodic) potential of at least -0.95V (with reference to a CSE) with the Cathodic Protection applied is measured. Voltage drops across the structure-to-electrolyte boundary must be considered for valid interpretation of the voltage measurement. This additional negative potential i.e. more negative than -0.85V is required for mitigation against microbe induced corrosion and effects.

A 100mV (0.1V) minimum polarisation obtained between the carbon steel surface of the pipeline and a stable reference electrode contacting the electrolyte can be used as an alternative measure. The formation or decay of polarisation may be measured to satisfy this criterion.

8.2. Locations

The test station location and positioning shall be selected based on a number of considerations, such as:

- On the pipeline servitude and pipeline right of way (ROW),
- Risk of vandalism, theft and/or general damage;
- Access relating to operation, maintenance and monitoring;
- Possible damage by agricultural vehicles, plant vehicles, etc.

Test stations are to be constructed over the pipeline within the servitude. Locations where test Stations are to be installed are listed as follows:

- Pipeline crossings (Client and foreign) which are cathodically protected and major pipeline (> 200mm OD) crossings which are not cathodically protected.
- Other utility crossings which are cathodically protected and major pipeline (>200mm OD) crossings which are not cathodically protected.
- Sacrificial anode locations, unless otherwise specified by the Pipeline owner.
- Either side of electrified and non-electrified railway lines.
- AC power line utility corridors as a minimum at the crossing point, parallel sections at the start middle and end of these parallelisms.
- Either side of all national, provincial and major roads.
- At all cased, directional drilled and/or pipe jacked crossings.
- On one side of all frequently used (greater than 50 vehicles per day) roads and/or heavy haul sand / dirt roads.
- AC mitigation stations.
- Major water crossings (on both sides) where water flows for at least 6 months of the year on a continuous basis and the river crossing exceeds 3m in length.
- Reservoirs.
- In stray current environments, TP are to include IR-Free reference electrodes as and where The Client specifies.
- Every 1 km (maximum separation between any two TPs).
- Other locations The Client considers important.

8.3. Test Station Installation Options

Test stations will fulfil various roles as follows and can be located as follows:

- Free standing test stations (concrete, galvanised construction or material specified by The Client).
- Valve chambers.
- Buried test stations are test station facilities designed with burial or below ground construction in mind.

8.4. Types Of Test Stations

Type	Description	With AC
A	Monitoring Test Station	FA
B	IR Free Station (SRE installed)	FB
C	Cross Bonding Station	FC
E	4 Wire Current Span Station	FE
F	AC mitigation installed	F
Note: Temporary CP test posts will be variations of the A, B, C, E and F type test posts with the addition of sacrificial anode/s as set out in the Bill of Quantities or as directed on site by the Engineer.		

8.4.1. Pipe-to-soil Potential Monitoring Test Station (MTS) (Type A)

These are to be located nominally every 1000m over a given pipeline route or as specified by The Client.

Preferably MTS are to be installed adjacent to valve chambers and/or at other significant locations as detailed in the MTS listing and installation schedule.

This standard monitoring test station comprises two single core 16 mm² black double insulated cables exothermically welded to the pipe.

MTSs will have a DC coupon installed. Refer to Section 8.5 for details.

8.4.2. IR-Free Test Station (Type B)

These test stations will be used to measure "IR-free" potential readings. They will be located as specified or at minimum every 5 km. These test stations will contain two 16 mm² black double insulated cables exothermically welded to the pipe.

In addition, a separate buried stationary reference electrode (SRE) and a separate steel coupon are to be installed. The SRE will be connected to the test station with 6 mm² yellow cable and the coupon will have one 2-core 2.5mm² blue PVC/PVC cable. The construction of the IR-Free Test Station shall be specified by The Engineer.

Each coupon shall be connected via a reed switch or a fuse link (10A slow-blow).

8.4.3. Cross Bonding Test Station (Type C)

Cross bonding test stations allow current to pass from one buried structure to another. Caution should be exercised when testing or maintaining the system at these stations due to the current flowing. The pipe shall be cross bonded as follows:

- To other “foreign” pipelines,
- To other foreign utility structures
- To parallel pipelines where a common cathode is required,
- Current bond required for Cathodic Protection requirements

Bonding cables from the foreign pipe to the test station shall be one 2-core 16mm² SWA cable or as specified by The Engineer.

Bonding test stations are to be constructed of reinforced concrete, galvanized steel or material specified by The Client.

The Test stations are to be installed over the pipeline.

The contractor shall supply and install a ceramic wire wound resistor with the resistance range and wattage as specified in the Bill of Quanitites. If not specified in the Bill of Quantities the minimum ceramic wire wound resistor shall be adjustable from 0 to 5 Ohms and rated at 500 Watts. These resistors shall be wound in such a manner so that they can fit comfortably into a standard galvanised test post of concrete type bunker.

8.4.4. CP Test Stations with Temporary CP

Temporary CP may be specified during upfront pipeline construction or at times when there are prolonged outages on impressed current CP (ICCP) systems. This will be provided using sacrificial anodes.

For upfront pipeline construction, this will be used for short lengths of pipeline. However, once the pipeline sections reach a longer length and start becoming subjected to stray currents, the temporary protection will be provided with impressed current systems.

The temporary CP station will comprise a standard MTS with facilities to connect and dis-connect the associated sacrificial anodes as and when required. The MTS will be connected to bagged magnesium anodes (as the need arises). Once the sacrificial protection is no longer required, the magnesium anodes will be disconnected from the test station and the test station will therefore function as a MTS. The type of test post to which the magnesium anode is temporarily attached will be specified in the Bill of Quanities or the Engineer will direct the Contractor on site to install anodes where deemed necessary.

8.4.5. 4-Wire Current Span Test Station (Type E)

These test stations will be used to measure the magnitude and direction of current flow at selected locations along the route to monitor stray current activity.

One 2-core 16 mm^2 SWA PVC/PVC cable (upstream) and two single core 16 mm^2 SWA PVC/PVC cables (downstream) will be used for each test station. The first cable will be connected to the pipeline 1m downstream of the test station (yellow), the second cable will be located 1m away from the first cable (blue), in the upstream direction, the third cable will be located between 90 -125 m away from the second cable (black), in the upstream direction and the last cable (red) will be 1m away from the third, in the upstream direction.

One test station will be located within 1km from each cathodic protection rectifier.

8.4.6. Test Station with AC Mitigation Hardware (Type F)

Any test station that has AC mitigation hardware and/or gradient control installed.

8.5. Coupons

The design life of the coupon should be such that it will be able to operate continuously for 20 years under conditions of full cathodic protection. The coupons shall be used in conjunction with either Copper Sulphate or Silver Chloride reference electrodes to achieve essentially IR-free or instant “off” potentials in terms of NACE RP0169, NACE RP0104 and BS EN 13509. The coupon shall be designed to operate in a temperature range between 0℃ and 50℃. Each coupon shall have a unique identification number and sizing certificate to suit.

The Engineer shall specify the construction layout of the coupon, particularly if this is to form part of the IR-Free test station.

Coupon suppliers/manufacturers shall provide the following information with their QCP for approval by The Client:

- Record of manufacturing coupons with a 10 year, or longer, intended design life.
- QA/QC documentation of coupons previously supplied to industry with verifiable track record i.e. contact persons and names.

- Coupons previously supplied should have a service life of more than 10 years with traceable records.
- Substantial evidence of product performance comprising a mixture of local and/or international customers that may be verified by The Client.

The coupon shall comprise a round steel elements that is flush mounted into a suitable acid, alkali and chemically resistant epoxy. The coupon material shall be similar to the pipe material. Details of the proposed coupon material shall be approved in writing by The Engineer before manufacturing commences. The coupon shall be connected to a standard 2 core 2.5mm^2 cabtyre cable with all the connections encapsulated in epoxy. The cabtyre shall exit the coupon assembly via a suitably sized cable gland. The cabtyre cable length i.e. tail, shall be specified by The Engineer.

For AC measurements the coupon shall be machined from an 11 mm diameter steel rod. Each AC coupon shall be connected via a resistor only if specifically requested in the Bill of Quantities.

For DC measurements the coupon shall be machined from a 36 mm diameter steel rod.

Random testing will be carried out on 10% of the coupons manufactured and supplied. The random testing shall be carried out as follows:

- Select coupons.
- Check coupon dimensions.
- Check assembly and physical appearance for compliance in terms of the specification.
- Sign off.

8.6. Stationary Reference Electrodes (SRE)

The SRE design life should exceed 15 years' active use and will be used in conjunction with bare steel coupons to allow for "IR-free" potential measurement in terms of NACE RP0169, NACE RP0104 and BS EN 13509.

The SRE installation position (3 or 9 o'clock) shall be determined by The Engineer on site and shall be placed in the same soil as the pipeline adjacent to the coupon station or independent coupon at a distance from the pipe as specifed in the approved typical construction drawings or as directed by the Engineer on site.

SRE suppliers/manufacturers shall provide the following information with their QCP for approval:

i. Record of manufacturing SRE with a 20 year intended design life.
ii. QA/QC documentation of reference electrodes previously supplied to industry with verifiable track record i.e. contact persons and names.
iii. SRE previously supplied should have a service life of more than 10 years with traceable records.
iv. Substantial evidence of product performance comprising a mixture of local and/or international customers that may be verified by The Engineer.

The SRE should be commercially available from a reputable supplier with a proven track record. The Contractor must supply full details of the intended manufacturer.

The Client shall determine whether or not the SRE shall be used to monitor coupons complete with and approved PC Board. The shunt shall be rated at 20W and 0.1Ω as a minimum and a Reed Switch shall be used to interrupt the coupon during testing. Push button and toggle switches are not permissible.

Note: The Contractor shall price for a PC Board that allows for simultaneous monitoring of two coupon feeds, whether or not the BoQ states the specific details of a PC board being used at test stations that have coupons installed.

The permanent burial type SRE shall consist of an encapsulated ceramic tube with protective end caps.

Stability to be <10 milli-volts (mV) with 3 micro-amp load in a temperature range of 0°C to 57.2°C.

8.6.1. SRE Manufacture Specifications

Full data packs of the design detail of the proposed reference cell must be submitted. Failure to do so may disqualify the bid. A standard drawing detailing the reference cell is included in this technical specification.

The SRE shall display high stability under conditions of continuous measurement and when inactive or not attached to an external measuring circuit.

The reference cell stability shall be tested before shipping and shall comply with the following limits:

- 2mV potential shift after application of 0.1µA for 30 seconds,
- 12mV potential shift after application of 1.0µA for 30 seconds.

The SRE shall be designed to operate in a temperature range between 0℃ and 50℃. Full details pertaining to the chemical composition, calibration procedures, manufacture process and drawings of the SRE shall be submitted at the time of tender. Each SRE shall have a unique identification number and calibration certificate to suit.

Random testing will be carried out on up to 10% of the reference cells manufactured and supplied.

9. ICCP ANODE GROUNDBEDS

9.1. General Description

The actual length of each groundbed is presented in the CP design report. However, each groundbed has the following common features:

- Anodes.
- Canisters.
- Spacer canisters.
- Coke breeze backfill.
- Sand fill.
- Bentonite.
- Positive header or ring main cable.
- Watering system.
- Cable warning tape.
- The watering system will be installed during the groundbed construction.
- Cable warning tape (yellow on black) will be installed at a depth of 600 mm below surface along the entire length of the groundbed.
- Anode junction box and concrete markers (markers to be installed only if so specified in the Bill of Quantities).

The Contractor shall await The Client's instruction to proceed with groundbed construction. The Contractor is to supply detailed QCP for approval. All materials are to be pre-inspected and signed off with the material certification data book.

9.2. Groundbed Components

9.2.1. Watering System

Watering systems shall be provided to enable groundbed hydration during dry seasonal periods.

The watering system shall consist of a ribbed and slotted, double walled PVC drainex pipe, 110mm in diameter, typically 6m in length. The pipes should be coupled together suitably and the end of the pipe must be closed with an end cap. The pipe along its full length is to be covered by one layer of flow net and then by one layer of Bidim cloth A2.

Note: The Contractor shall ascertain at the time of tender which of the following options The Client wishes to implement:

- The pipe shall be fed using a 50mm HDPE pipe from the closest valve chamber. The pipe shall be laid in the same trench as the groundbed header cable.
- Terminate the pipe in small manhole at ground level (at highest point) and charge pipe via water tanker when required.

9.2.2. Anode Cabling

No cable joints are permitted in these systems. The outer insulation of the anode cables shall be fluorocarbon based e.g. PTFE, PVDF (Kynar™), ECTFE (Halar™), ETFE (Tefzel™). The anodes will be supplied with certification to this effect.

The cable size to be used for the anode positive cable connection shall be stipulated by The Client. All positive anode cable insulation shall be PVC / HMWPE / PVDF or PVC / PVC / Halar insulation. The minimum thickness of each layer of the insulation shall be 2mm. No cable joints will be permitted under any circumstances in the buried or submerged portions of the positive anode cable. The minimum cable to anode breaking strength shall be greater than the cable breaking strength.

The anode tails shall be sufficiently long to terminate directly into a suitably rated DC distribution cabinet / enclosure, cognisance shall be taken of the area classification, environment, type (concrete, galvanised steel or as specified) and rating of enclosure required.

Anodes may be connected in pairs.

Cable warning tape will be inserted above the groundbed, at a depth of 600 mm below grade.

The positive cable from the groundbed to the TRU shall be encased in concrete as shall the power supply cable.

Cable warning tape (yellow skull and bones with associated wording) shall be placed along the entire length of the horizontal anode bed at typically 500mm below grade.

9.2.3. Anode Junction Box

A concrete bunker shall be installed on top of the anode groundbed in the case of a deep well and at a position indicated by The Engineer in the case of shallow vertical groundbeds. The anode tails as well as positive cables from the TRU shall enter the anode junction box via an HDPE conduit.

The anode tails and the TRU positive cables shall be terminated in the standard terminal blocks.

9.2.4. Anode Canisters

Anodes shall be pre-packed in spirally welded galvanised steel canisters that are thick enough such that each canister is self-supporting, as per Bill of Quantities. Both ends are to be sealed off with galvanised steel end caps and have a side gland conduit for the exit of the anode cable. The anodes will be centrally located within the canister and the annular space between the anode and the canister will be filled with coke breeze.

Care shall be taken in the storage of these anode canisters to ensure they are stored in controlled areas.

Anode canisters filled with coke breeze shall be used as spacer anodes, in order to ensure that the correct anode separation is achieved, in horizontal anode beds. This is not required in vertical distributive systems.

Each anode shall be centralised inside its canister and encapsulated in coke breeze. Cable glands are to be used for exit of the tail cable as to avoid damage that can be caused by the sheet metal.

9.2.5. Cable Warning Tape

Cable warning tape shall be placed along the entire length of the horizontal anode bed at the required depth below grade at 600mm.

9.3. Anodes

9.3.1. Mixed Metal Oxide Anodes (MMO)

The MMO and PMO (precious metal oxide) anode operating voltage shall not exceed 50V for soil and 9V for sea water and halogen polluted applications. The latter assumes that no Halide pollutants are present such as Fluorine (F) or Bromine (Br). Where deleterious pollutants are to be expected, the precise soil and ground water chemistry shall be determined, prior to the use of any MMO/PMO anodes. The anode manufacturers maximum current output for the various anode configurations and dimensions shall not be exceeded under any circumstances. The anode current output and other parameters shall be submitted during the quotation or proposal stage.

In addition to the certification provided by the manufacturer, two anodes from each batch will be subjected to the following range of destructive tests at an independent laboratory:

Test	Minimum requirements/Test Method
Test solution	10% by volume sulphuric acid
Test temperature	Less than 50 ºC for duration of test
Test Current Density	20 kA/m^2 min
Test Duration	Minimum 35 days at the specified current density
Coating adhesion test	ASTM B 571
X-Ray/NDT	The tubular anode shall be X-Ray'ed in order to ensure that bubbles are not contained within the epoxy sealant
Metallurgical and SEM analysis	Anodes will be sectioned and the MMO/PMO coating verified

The anode tails will be 10 mm^2 PVDF/ HMWPE/ PVC.

All anodes, regardless of type shall be rated for at least 2A, 60Ayr and 25y life.

Anode dimensions and loading parameters shall be specified in the CP design document and the Bill of Quantities.

9.3.2. Chemical and Performance Testing of Anodes

A specified number of anodes will be randomly selected from the batch to be supplied and tested as detailed below. The anodes for testing will be selected as per BS 6001/ISO 2859- "Specification for sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection".

The anodes will be tested by an accredited third party laboratory, such as MINTEK, in order to confirm compliance with the specification. Details of the third party laboratory must be approved by The Client prior to testing.

The maximum cable to anode resistance shall be 10 mΩ. The cable shall be pulled or tugged initially as a test after making the cable to anode connection.

9.3.3. Carbonaceous Backfill

Carbonaceous backfills include various coke products produced from coal, tar (pitch cokes) and bitumen (petroleum cokes) and graphite granules. The coke is in essence the solid residue left from coal after its volatile constituents have been driven off by heating in the absence of air and as such, coke is amorphous. This also implies that any metallurgical coke, contains significant amounts of sulphur, ash and volatiles. The ash also generally entraps the heavy metals, such as lead, cadmium, mercury, copper, zinc, etc, which would not be environmentally acceptable.

The effective resistivity of the soil surrounding an electrode (anode) is confined to the immediate region of the anode, it is therefore common practice to reduce the local resistance by using these so-called backfill materials. The backfill being a conductor, "carries" a measure of the current, reducing to some extent, the consumption rate of the anode. Therefore, the essential purpose of the carbonaceous backfill, is to lower the anode/soil interface resistance, increase the current capacity by increasing the effective anode area and thus prolonging the anode's life. The backfill must also allow for the egress of anodic gases during its normal operation and be as environmentally safe and friendly, as possible.

Preference shall be given to pitch coke, however, calcined petroleum cokes may be permitted, providing that it is fully compliant with the technical specification. The supplier must be an ISO 9002 or equivalent accredited organisation. Alternatives will only be permitted to be used upon written approval from The Client.

Coke breeze with the following chemical composition shall be used:

Element/Compound	Specification	Test Method
Fixed Carbon	99.5% min	By calculation – 100% minus (%ash + VCM)
Sulphur	0.25% max	ASTM D 4239
Ash and volatiles	0.50% max	Ash – ASTM D 4422 Volatiles – BS 1016: Part 4
Moisture	0.15% max	ASTM D 3173
Bulk density	1000 kg/m3 max	ASTM D 527
Resistivity	55 Ωm max	Alusuisse C-109

The particle size distribution (PSD) of the impressed current anode backfill material is a very important variable and shall vary according to the anode material and burial depth. The PSD shall be determined in accordance with the following specifications ASTM D293-69, BS.

Anode Type	Environment	Burial Depth	Max. PSD	Min. PSD
MMO/PMO	Soil / Brackish	< 15m	100% < 1.0mm	5% < 0.5mm
MMO/PMO	Soil / Brackish	> 15m	100% < 1.5mm	5% < 0.5mm
MMO/PMO	Soil / Brackish	> 50m	100% < 2.0mm	5% < 0.5mm
Silicon Iron Anode	All	All	100% < 3mm	5% < 0.5mm

Technical motivations for the use of other PSD will be considered by The Client, should the above values not suffice.

The particle size distribution shall be a maximum of 100% < 1.0 mm and a min of 5% < 0.5 mm.

The backfill material shall be supplied in 25kg polypropylene bags, or suitable size that may be available, that are to be packed on palettes to a safe height and weight.

The Contractor shall make provision in the quotation for adequate testing by an approved third part laboratory. At the time of quotation the Contractor shall nominate a suitable laboratory capable of carrying out the tests required to assess compliance with the standards of this section of the quotation document.

2 weeks prior to delivery 10 randomly selected 500g samples drawn by the Engineer from the materials at the Contractor's premises will be sent to the nominated laboratory for testing to confirm compliance with the standards set in this section of the quotation document. Should any of the randomly selected samples fail to comply with the said standards the Contractor shall then conduct further tests at his own expense to verify the compliance of the remaining materials. Should compliance not be achieved the materials shall be rejected by the Engineer. The rejected materials shall be replaced at the Contractor's expense.

9.4. Groundbed Installation Types

9.4.1. Shallow Horizontal Anode Ground Beds

The contractors shall supply Anodes as specified in the bill of quantities. Shallow horizontal groundbeds will contain mixed metal oxide (MMO), encased in galvanised steel canisters, with each canister spliced alternatively to the positive ring main cable. The anode canisters will be 2 m in length, 200 mm diameter, while the spacer canisters will be 1 m long, 200 mm diameter.

The groundbed shall consist of a number of anodes installed horizontally at a specified distance away from the pipeline and shall have a spacing of 1 x anode or anode canister length between them .

The depth of the anode trench shall be at depths as specified but care should be taken when exceeding 2 meters below natural grade level.

The bottom part or third of the groundbed shall be filled with calcined petroleum coke covering the anodes with at least 300mm of coke.

The second third with selected backfill and the last third with backfill to grade level.

All depths are to be verified and signed off by The Contractor and The Engineer.

Watering systems will be provided to enable the groundbed hydration during dry seasonal periods and to prevent groundbeds from drying out.

9.4.2. Vertical Anode Ground Beds

Anode centralisers shall be employed in order to locate the anodes in the centre of the coke column / groundbed. Centralisers shall be designed as such that they do not cause bridging of the coke backfill. Coke is then to be poured/pumped into the borehole in order to ensure that the anode is surrounded by pitch coke. The coke must be pumped as a wet mixture when MMO / PMO anodes are used.

The Groundbed shall consist of a number of shallow vertical holes drilled or augured to a maximum depth and diameter as specified with a minimum spacing of 3m at positions as indicated by the Engineer and a 165mm nominal diameter steel casing shall be installed where the stability of the hole above is doubtful. The exact numbers of holes, spacing and dimensions as well as quantities of coke are given in the Bill of Quantities.

Anode strings shall be installed centrally inside the coke bed with individual tails being brought to the level of the positive cable trench from where they shall be run to the position of the anode junction box.

The vertical position of the anodes in each hole shall be given in the Bill of Quantities.

The Engineer shall witness the entire anode Groundbed installation.

9.4.3. Vertical AGB Anode Installation

The bore holes shall be drilled by an approved professional drilling contractor registered with the Borehole Water Association. Contractors are to submit details of the company they intend to use for this activity.

Relevant deep soil resistivity tests shall be carried out as directed by The Engineer.
The main borehole shall be drilled as follows (unless stated otherwise in the Bill of Quantities):

- The Engineer shall specify the dimensions of the AGB and may vary from those provided in this specification.
- A 36cm diameter hole shall be drilled to the depth of the inactive zone.
- A hole of 25cm diameter shall be drilled to accommodate the active zone.
- A 25cm diameter steel casing (schedule 20) with a closed bottom (welded closed) shall be inserted for the full borehole length.
- A 30cm diameter PVC casing shall then be installed on the outside of the steel casing for the length of the inactive zone.

- Drilling depths as well as quantities of coke and river sand are given in the Bill of Quantities and/or drawing.
- The Engineer shall witness the entire anode Groundbed installation.

Graded washed river sand with a particle size distribution of 0.5 mm to 3.5 mm shall be poured into the anode bed to a depth of 1.5 m below grade level. The remaining 1.5 m to grade level shall be sealed with Bentonite.

Note: The Bill of Quantities may state different dimensions, quantities and types of materials and shall be read in conjunction with the specification. The BoQ shall be used as the measure for pricing and installation purposes. Where a significant conflict arises the details should be presented to the Engineer in writing for a final determination.

The anode tails shall be terminated into a suitably rated DC distribution cabinet / enclosure. Inside process plant areas, cognisance shall be taken of the area classification, environment, type and rating of enclosure required.

10. SACRIFICIAL ANODES

10.1. Magnesium Anodes

The performance characteristics of the 1.75V high potential magnesium alloy, is detailed below. The high potential alloy is specially formulated from pure virgin magnesium and other elements to produce a higher voltage. The advantages of the high potential anode versus its 1.55 V counterpart, is as follows:

The higher driving potential permits fewer anodes in this specific application;

The capacity of a high potential anode is some 4 % greater than that of the other anodes, improving the overall life of the anode;

The anodes shall be manufactured in accordance with ISO 9002. The contractor shall submit written confirmation from the relevant standards authority, confirming complete registration in this regard.

The anode shall be free of blow holes, cold laps, porosity seams and any other imperfection which may impair its performance. Extruded anodes shall be used and cast anodes may be used if approved by The Client.

A 5mm diameter pre-galvanised steel threaded stud or rod shall be centrally located within the anode. The latter shall extend for at least 95% of the anode length and shall be extruded or cast into it. The pre-galvanised threaded steel stud or rod shall be suitable for the electrical connection of the anode to anode cable, which shall terminate in a recess at the one end. The connection shall be suitable for 20 years under submerged conditions.

In all instances a suitable hole will be drilled into the end of the thread or rod and the cable shall be brazed / soldered into the hole.

The insulation of the cable shall be removed for a length such that at least 25mm of the copper is inserted into the drilled galvanised steel rod hole.

The cable shall then be brazed / soldered into the hole. At least 25mm of insulation shall extend into the anode recess.

Mechanical connections between the anode cable and the pre-galvanised steel rod or thread shall not be permitted under any circumstances.

The anode recess shall be completely flooded with hydrochloric acid (10% solution) resistant epoxy. All proposed epoxies shall be submitted to The Client for review, prior to their use. The epoxy shall completely fill the recess without spilling over onto the external surface of the anode.

No bare copper cable shall extend outside the epoxy; the insulation shall extend at least 25 mm into the epoxy as stipulated above.

The maximum cable to anode resistance shall be 10 mΩ. The cable shall be pulled or tugged initially as a test after making the cable to anode connection.

Magnesium anode locations will be designated by The Engineer. The hi-potential anodes, manufactured from virgin material, shall have the following composition:

Element	Composition (%)
Al	0.01 max
Mn	0.5 – 1.3
Cu	0.02 max
Ni	0.001 max
Fe	0.03 max
Zn	-
Other	0.05 max each or 0.3 total
Mg	Balance
Potential (V)	-1.7
Capacity (Ahrs/kg)	1100

The anodes will be pre-packaged in a cotton bag with a backfill containing 70% gypsum, 25% bentonite and 5% sodium sulphate. The volume of the backfill shall be such that there is a minimum of 35mm surrounding each anode.

The anodes will contain a steel core, onto which the anode cable connection will be soldered and the connection will be covered in an appropriate epoxy. No mechanical connections between the cable and the steel core are allowed.

10.2. Typical Installation Details

All anodes shall be installed at a minimum depth of 2.5m or pipe invert depth, whichever is the deeper. The anodes shall be located a minimum of 3.5m from the pipe or as determined by the CP Design. The anode / pipe separation distance shall be stipulated in the bill of quantities of the RFQ document.

The distribution of the anodes shall also be stipulated in the in the bill of quantities of the RFQ document.

The cable connection, installation and backfilling / reinstatement shall be witnessed by The Client.

10.3. Chemical and Performance Testing of Anodes

A complete set of both chemical and metallurgical tests shall be conducted on a number of randomly selected anodes, as determined in accordance with BS 6001, Part 1, prior to installation of the anodes. All of these costs shall be borne by the supplier/installation contractor Anodes may only be installed subsequent to testing and review from The Client.

Complete chemical and metallurgical compliance shall be ensured prior to their installation and a detailed report shall be submitted to The Client for review. Testing shall be carried out at the contractor’s expense.

The anodes will be tested by an accredited third party laboratory, such as MINTEK, in order to confirm compliance with the specification. Details of the third party laboratory must be approved by The Client prior to testing.

The solution potential of the anode when fully submerged in the test chamber, shall be more negative than -1,65 V with respect to a saturated copper / copper sulphate reference electrode.

The anode shall maintain this potential at a 100 mA output and shall possess a capacity of 1200 A.hrs/kg.

The natural anode potential and current drawn shall be measured prior to permanently connecting the anode to the pipe / structure. This data shall be submitted with the commissioning report.

11. TRANSFORMER RECTIFIER UNITS (TRUs)

11.1. Introduction

All powered units (TRU or FDU) will be standard / modular construction in order to minimise the carrying of spares.

The general details of the sites are as follows:

Ambient Temperature:	10° to 40° C
Relative Humidity:	30% to 90%
Lightning risk:	severe

The TRU's may be used in environments where metallic dust, soot and grit may be present.

All structure bolts, washers and nuts shall be stainless steel. Bolts with spring washers are preferred and "Nylock" nuts are permissible where devices being secured remain at ambient temperature.

Where no TRU/FDU cabinet is specified the components shall be mounted on one free-standing frame and access to all components, especially in regard to replacement of diodes shall be possible without excessive dismantling. The frame shall be capable of being located inside a reinforced concrete / brick or other specified enclosure.

Suitable lifting lugs (capable of carrying the total mass of the frame and all its components) shall be incorporated onto the frame (or cabinet if specified) to allow safe handling and installation on site.

11.2. Housing

The TRU's are to be installed in reinforced concrete, coated steel, reinforced brick structures or other structure types as specified. All components must be treated so as to provide satisfactory service under the corrosive conditions of the proposed installation sites.

11.3. Power Supply

Input

400V, 3 phase, 50Hz or

230V, 1 phase, 50Hz

Typical Outputs (refer to Bill of Quanities)

0 - 50V DC

0 - 50A

11.4. Control

Selection of constant pipeline potential, constant current and manual voltage control for over line surveys. Each selection must be controllable from zero to full output.

Facilities are required on rectifiers for switching in order to undertake over line surveying and site commissioning testing.

11.5. Test Switch Facility

The rectifier must have a facility to plug in a switch on the output circuit for over line testing on the protected pipelines. This requirement is irrespective of any built in timer which may be provided.

Manual output voltage and current adjustment facility:

Over line surveying testing requires a "manual mode" to adjust to a constant voltage range from zero to full output voltage, similarly the current depending on load resistance. This is to enable over line testing at a pre-set output current.

- Ideally the thyristor firing circuit of the rectifier can be switched with a switch through a timer socket.
- Firing cards must provide 100% balanced firing over all phases.
- The adjustment of the firing card must be such that the rectifier attains full set output current within 100ms of switching.

Irrespective of control mode, the TRU control equipment must be capable of output voltage, output current and potential pre-set limits.

When the control equipment is changed from one control mode to another control mode, all user programmable parameters must be automatically restored to minimum values to prevent an instantaneous application of output voltage or output current to the load.

Note: Should the electronic PCB, automatic control or LCD display fail, the "manual mode" shall allow the user to switch over to this mode and manually adjust the output voltage and current to pre-set limits within the operating range of the TRU.

11.6. Rectification

The rectifier shall provide single phase bridge or 3 phase full wave six pulse (minimum) rectification.

Control shall be provided by one of the following techniques, as set out in the Bill of Quantities:

- matched thyristors in the primary circuit of the main transformer
- control of the saturation current in a magnetic amplifier incorporated in the primary circuit of the main transformer
- fully controlled secondary thyristor bridge
- switch mode

All semiconductors shall be rated at twice full load current and 1600V PIV. Forced cooling of thyristors and semiconductor devices is not permitted. The efficiency of the transformer rectifier unit must be not less than 85% at maximum rating.

Control stability must be within 3% of set point over the whole range, irrespective of control mode selected.

11.7. Transformers and Chokes

Transformers must be continuously rated, double wound air cooled.

The transformer must have suitable windings on the secondary of the transformer to facilitate coarse selection of the voltage. The windings must be so wound to provide coarse adjustment of 33%, 66% and 100% of the step down voltage.

All transformers and chokes shall be earth screened.

Aluminium wound chokes are not permitted.

The Contractor shall comply with Annexure F: Local Content Requirements for Transformers and submit the necessary contractual documentation to demonstrate compliance with this tender requirement.

11.8. Instrumentation

11.8.1. Multifunction Digital Display

Note: Output indication may be by means of a multifunction digital display.

- DC Output current (Analogue millivoltmeter with shunt located on load side of smoothing devices)
- Pipeline reference potential (Cu/CuSO4) (high impedance digital meter) Note: the input impedance of the monitoring/feedback control circuit shall be a minimum of 10 megohms in order to prevent polarisation of the stationary reference electrode.
- Mains on indication
- DC fuse fail indication
- AC fuse fail indication
- kWh meter

11.8.2. Additional Displays

The TRU will include high quality stand-alone analogue and digital display elements to indicate the following;

i. Output Voltage – Analog, (display min. 75mm x 75mm).
ii. Output Current – Analog, (display min. 75mm x 75mm).
iii. Reference Potential DC – Digital, (display height minimum 12mm to 15mm readable in sunlight).
iv. kWhr Meter – Digital, measuring and displaying SMU power only and no other auxiliary TRU attachments.

The Output Voltage, Output Current and Reference Potential Meters shall be mounted in a suitable location to facilitate easy reading and measurements.

The meters shall be arranged in such a way that the Voltmeter is to the left, the Potential Display meter in the centre and the Current meter to the right of the resin board.

All digital meters must be either LCD or TFT display types and the display must be legible in direct sunlight and from distance away of from the display of 2 meters. All of the Additional Displays shall be mounted on the detachable display panel.

Captive (banana) sockets must be incorporated below the meters mentioned above and must be continuously connected to the measurement points mentioned above. The captive sockets connected to the output current measurement point must be labelled with the shunt rating i.e 50mV = (Maximum Rated current as held in the Bill of Quantities).

11.9. Alarm Indication

Mains fail indication by means of under voltage and phase failure (if applicable) relay (voltage free contact)

AC/DC fuse fail (voltage free contact)

11.10. Testing Probes

Standard insulated banana socket points at 20mm centres for external measurement / calibration.

- Pipe-to-soil potential (Cu/$CuSO_4$ reference electrode)
- Rectifier output voltage.
- Rectifier output current (from shunt – shunt rating to be indicated on label)

11.11. Protection

11.11.1. Surge Protection

Necessary surge protection must be installed to protect the rectifier and control circuits, both input and output, against power surges and lightning. This shall incorporate a “pi” filter in the negative leg of the TRU.

11.11.2. Electrical Protection

Necessary fuse and overload protection must be provided to protect the equipment. The grading must be in a way to limit unnecessary trips. Phase rotation protection must be installed.

DC Output fuses must be capable of carrying the full load current of the unit.

The input circuit breaker must be of the magnetic type to carry inrush currents after a power failure in order to prevent nuisance tripping.

All protection devices, semiconductors, power devices and wiring must be matched to prevent overheating and component failure due to overload.

All metal components shall be connected to the common earth and to the AC supply earth.

All electrical circuits shall be floating with respect to earth.

All earth connections within the enclosure must be as short as possible and rated at possible fault current.

Earth buss bar mounting studs must be adequately sized to accommodate collective fault current.

A separate earthing system will be provided for the TRU consisting of suitable earth rods and bare earthing cable which will have a resistance below 10 Ω in compliance with SANS 10142. See typical drawing showing grounding / earthing layout for TRU, which is applicable to FDU and SMU applications.

The Contractor shall provide detailed drawings at the time of tender showing the earthing arrangement for the unit, the layout, location and means of connection to earth from the various components to demonstrate the principle of building the unit with the shortest distance to earth, thereby minimizing resistance.

11.11.3. Radio Frequency Protection

The rectifier must be radio frequency protected.

11.12. Smoothing

Necessary smoothing of the output must be provided to prevent interference with telephone, radio and other services.

Smoothing shall be such that the peak – trough amplitude of the output waveform shall be less than 10% of the mean DC output voltage across the entire range of the rectifier unit. The output ripple shall be measured using an oscilloscope with the rectifier connected to a pure resistive load.

11.13. Cabinets

The rectifier and control must be mounted on a stainless steel skeleton frame suitable for installation in a concrete enclosure where a cabinet is not specified. When a cabinet is specified The Contractor shall provide detailed construction drawings showing the proposed layout of all components.

11.13.1. Powder Coating for Chassis Plates

Coating shall comply with Type 5 of SANS 1274:2013 including the use of a wet primer.

Degrease, pickle and phosphate in accordance with powder manufacturer's requirements.

Apply powder by means of electrostatic spray to ensure a final DFT of 120 micron.

Finish colour: white

11.13.2. Electronic PCB

All electronic printed circuit boards shall be coated with a proprietary military specification conformal coating designed to prevent corrosion to the exposed component leads. All PCB's shall have a primary solder mask and legend.

11.14. Wiring

All current carrying conductors shall be insulated to withstand a minimum voltage of 1000V. All wiring shall comply with the provisions of the Wiring Code of Practice; SANS 10142 (latest edition).

All current-carrying conductors shall be multi-stranded, flexible and sized to adequately carry the design current without a rise in temperature.

Thyristor gate leads (if fitted) shall be screened or twisted pair.

All conductors shall be terminated at each end with suitably-sized, pre-insulated lugs or pre-insulated ferrules. No trimming of conductor strands will be permitted. All ferrules and lugs shall be crimped with appropriately sized crimping equipment.

All primary and secondary power cables and control wiring must be marked to ease installation and maintenance of rectifiers. Both ends of each cable shall be uniquely numbered in accordance with the wiring diagram.

Cable markers must be colour coded as well as have their number embossed indelibly on the marker. i.e.

0- Black
1- Brown
2- Red
3- Orange
4- Yellow
5- Green
6- Blue
7- Violet
8- Grey
9- White

Cable markers must be appropriately sized to suit the insulation size of the cable.

Cable markers shall read from cable to lug on all conductors.

All AC supply conductors shall be colour coded according to the incoming phase and retain the colour nominated throughout the cabinet.

Positive and negative power cables shall have colour coded shrouds/shrink sleeve over the lugs.

All conductors excluding busbars shall be routed in trunking or harnessed using polyethylene spiral wrapping.

AC carrying conductors must be routed separately from DC carrying conductors.

Grounding cables connected to surge diversion devices must be kept as short as possible and may not be routed with either AC or DC carrying conductors.

No more than two cables may be terminated at any one point.

All bolt on terminals shall be independently mounted with locknuts such that cables may be removed without having to hold the terminal.

The positive and negative output terminals must be marked Pipe, Anode, Reference etc. to prevent incorrect connections.

All terminals shall be completely accessible after completion of wiring.

All terminations made to buss bars shall be provided with spring washers.

All supply power terminations shall be enclosed and be highlighted with a warning label.

Transformer and inductor or smoothing capacitor terminations shall be covered with a transparent cover prohibiting accidental contact.

Output terminals shall be fully insulated from any metal of the housing or chassis.

All terminals shall be clearly marked and sized according to the current the terminal will carry.

11.15. Power Point

A 230V AC power point with separate earth leakage must be provided for use of small electrical hand tools and instruments inside the rectifier panel.

11.16. Drawings

Relevant drawings and manuals must be supplied with the rectifier.
A laminated schematic drawing of the rectifier must be installed in the rectifier.

11.17. Spares

A recommended spares list must be supplied.
Necessary breakdown spares must be installed in each rectifier comprising:

- 3 sets of fuses
- 1 set of semiconductors
- 1 set indicator lamps (if used)
- 1 set transient protection devices (other than chokes and capacitors)

11.18. Labelling

Terminals within a TRU/FDU/NDU shall be labelled as follows:

+ GROUNDBED or RAIL (depending on application)
- PIPE
PIPE MON
REF CELL
COUPON
EARTH

TELEMETRY

AC 400V or 240V (whichever is applicable)

SHUNT ??mV:??A (rating to be inserted for each unit type)

Labels shall be fixed by means stainless steel pop rivets such that they shall not become dislodged during the life of the unit. Component and other labelling/marking shall be engraved or fixed on fixed chassis and not on loose chassis or trunkings.

Labels shall be engraved trafolyte or other hard stamped equivalent. Labels shall be fixed to the panels with screws. Adhesive labels are not permitted.

11.19. Inspection

All rectifiers will be inspected and tests witnessed by The Client's representative prior to despatch. All material, test and compliance certificates must be incorporated into the O and M Manual.

The following tests must be carried out at the manufacturer's works, after successful completion of the tests a certificate will be issued by the manufacturer and signed by the Engineer or his nominated representative. All testing and damaged components resulting from the testing will be at the manufacturer's expense and carried out at the manufacturers premises. Adequate adjustable load resistances, adjustable power supplies and testing equipment will be made available to the engineer by the manufacturer to verify specified operational characteristics of the TRU under test.

11.19.1. Pre Power-up Testing

The various earth points, cabinet body, chassis plates and all exposed metal surfaces shall be measured for continuity to the main earth terminal.

The cabinet and AC inputs, the DC outputs shall withstand a 1 kV insulation test. The insulation testing shall be conducted with all circuit breaker and fuses in their normal operating position without power or load connected.

11.19.2. Power On Testing

The TRU shall operate for a period of 6 hours continuously at maximum current and at full rated voltage with all doors closed or until the temperature of the Rectifier heat sink is stable for a period of one hour. Where the temperature continues to rise after a period of 7 hours the equipment will be rejected. The ambient, cabinet compartment internal temperature, heat sink temperature and transformer winding temperatures must be recorded during the heat run and plotted upon conclusion of the heat run. K type thermocouples shall be used for the continuous recording of the all the various temperatures.

Immediately after the heat run, the aforementioned insulation check will be carried out without the power or load applied. A maximum heat sink temperature of 80 ℃ is permissible at the highest vertical point of the heat sink.

Control mode testing shall be carried out after the conclusion of the heat run.

11.19.3. Constant Current Tests

The manufacturer will demonstrate the TRU’s ability to control the output current to within 5 % of the pre-determined set point. The load resistance is to be manually adjusted to ensure that the output current remains constant irrespective of the load resistance. Four specific current set points are to be set 25%, 50% 75% and 100% of maximum rated output current. Voltage at the given pre-determined set points will be recorded and noted in the O and M Manual.

11.19.4. Constant Voltage Tests

The manufacturer will demonstrate the TRU’s ability to control the output voltage within 5% of the pre-determined set point. The load resistance is to be adjusted to ensure that the output voltage remains constant irrespective of the Load resistance. Four specific voltage set points are to be set 25%, 50% 75% and 100% of maximum rated output voltage. Current at the given pre-determined set points will be recorded and noted in the O and M Manual.

11.19.5. Constant Potential Tests

The manufacturer will demonstrate the TRU’s ability to control the electrolyte to structure potential within 50 mV of the pre-determined set point. Current limit and voltage limit features are to be tested and verified whilst carrying out potential mode testing. Dynamic feedback is required to demonstrate the control mode. That is, a simulated Cathodic Protection system must be used to demonstrate the control mode. In the potential mode verification a variable power supply may not be used to simulate the Reference Electrode.

11.20. Telemetry and Remote Monitoring

The rectifier shall be provided with outputs suitable for connection to a SCADA or remote monitoring system. The outputs shall be potential free contacts for alarm and status signals, and 4 – 20mA, 0 – 5V, or actual value for analogue signals. A comprehensive Ethernet Modbus signal may be provided as an alternative.

Power consumption and quality monitoring:

- Mains failure
- Fuse failure
- Output current
- Output voltage
- Pipe/soil potential

Detailed requirements for telemetry or remote monitoring will be determined by the project requirements.

12. NATURAL DRAINAGE UNITS (NDUs)

12.1. General

Typically an NDU is a device connected between a pipeline and the return rail of a DC traction system. The NDU allows current to pass through in a unidirectional manner i.e. when the Pipeline becomes more positive than the rail, then current will pass through the NDU from the pipe to the rail. When the rail is positive with respect to the pipeline no current will flow through the NDU.

It is critical that the diode within the NDU be adequately sized and protected by a series fuse which is selected to meet both the forward current and I^2t rating of the Diode as well as the cables. All field cable terminations will be made directly to sections of copper buss bar designed for cable termination.

All current carrying conductors shall be suitably rated buss bars fabricated from copper. The buss bars shall be capable of carrying a continuous current of 600 A. The temperature of the buss bar shall not increase by more than 6℃ above ambient at 600 A.

Joints and connections in the buss bars must be kept to a minimum. Suitably sized brass bolts, flat washers and spring washers shall be used to secure the joint. The brass securing bolt or bolts must have the same cross sectional area as the buss bar. The jointing faces must be liberally coated prior to jointing to ensure oxygen exclusion at the joint face with a suitable proprietary compound. Excess compound shall be cleaned from the joint after the joint has been finally tightened at correct torque setting.

Copper buss bars must be tinned or white zinc plated irrespective of whether the buss bar is sleeved with a heat shrink or plastic sleeve.

Diodes shall be of the silicon type. The Diode shall be a suitably rated hockey puck type and shall be mounted between two aluminium heat sinks and clamped to manufacturers torque settings. No parallel diodes will be permitted. Care must be taken when mounting the diodes between the heat sinks to ensure that the faces to which the diode contact are absolutely parallel.

The diode selected is to be rated at a minimum of 4 000 V peak inverse voltage and be capable of a peak forward current of 2800 A. Stud mount diodes will not be permitted.

The resistor and capacitor used in the snubber network must be suitably rated to cope with transients from both pipe and rail caused by lightning or switching surges.

The snubber devices are to be mounted separately, be easily accessible and must be as close as possible to the diode, without being mounted to the heat sink. Connections to the snubber devices must be kept completely separate from any other wiring in the NDU.

A 50mV shunt must be installed in series with the cathode leg of the diode immediately after the diode. The sensing terminals of the shunt must be brought out to captive insulated test stations (Banana Sockets) to accommodate banana plugs. A 72 x 72mm panel mount moving coil milli-volt meter must be installed. Full Scale Deflection of the meter must be 600 A and graduated in minor divisions of 20 A with major graduations of 100 A. The banana sockets must be mounted below the moving coil meter. The accuracy of the panel meter must be better than 1.5%.

A substitute shunt rated at 60A with the same physical stud spacing as the 600A shunt must be provided with the unit.

Fuses shall be of the DIN 3 indicating fuse type. Fuse holders shall be knife action type with adequate spring tension. A fuse puller must be left attached to the fuse within the NDU. A DIN 3 fuse base must be installed into the cathode leg as well as the anode leg of the NDU as close to the cable connections as possible. Only one fuse will be fitted into the cathode leg and the fuse base mounted in the Anode leg of the NDU must be fitted with a suitably rated removable link equipped with similar removal fixtures as the fuse. Fuses shall be rated to protect both the current and I^2t rating of the diode.

A 100A fuse of the same dimensions as the 600A fuse must be provided with the unit.

The Bill of Quantities may set out different specifications and will be used at the basis for pricing, manufacture and supply when read in conjunction with the technical specification. Should there be a significant conflict between the Bill of Quantities, Technical Specification or drawings the matter shall be referred to the Engineer for a final determination.

12.2. Surge Protection

Surge protection shall be incorporated so as to protect the NDU from surges from both the pipe (lightning) and the rail (switching). Note that the rail being a live load places severe demands on the quenching capabilities of any spark gaps used in the NDU. The surge diversion devices are to be connected to the field side of the fuse holders. The surge protection shall be in the form of “pi” filters in both positive and negative legs with air-cored inductors.

The brass terminating studs utilized for rail connections must differ in diameter to those utilized for terminating the pipe connections. The rail termination studs must be M16 and the pipe termination studs M10. Only one termination is permissible per stud. Termination lugs used for field cable termination must be of the distribution lug type, adequately rated and hexagonally crimped. Dimple crimping of the cable lug to cable core is not permissible. Colour coded heat shrink or plastic sleeves must be installed to identify the rail and pipe conductors. Rail conductor is to be marked with a red sleeve 40mm in length and the pipe conductor with a black sleeve 40mm in length as close to the lug body as possible. The sleeves must be tight fitting and not able to slide easily along the length of the conductor after fitment.

12.3. Housing

The NDU's are to be installed in reinforced concrete, coated steel, reinforced brick structures or other structure types as specified. A suitable frame may be specified as a replacement for a cabinet, in which case the NDU shall be mounted onto a chassis plate that shall be attached to the frame. All components must be treated so as to provide satisfactory service under the corrosive conditions of the proposed installation sites.

12.4. Powder Coating for Chassis Plates

Coating shall comply with Type 5 of SANS 1274:2013 including the use of a wet primer.
Degrease, pickle and phosphate in accordance with powder manufacturer's requirements.
Apply powder by means of electrostatic spray to ensure a final DFT of 120 micron.
Finish colour: white.

13. FORCED DRAINAGE UNITS (FDUs)

The FDU comprises a TRU/SMU and NDU mounted on a common chassis.

The FDU will typically operate in constant pipeline potential mode, unless otherwise specified by The Engineer.

Provision must be made to decouple the TRU / SMU from the NDU with a series resistor in the event that it is necessary to limit the output of the unit under natural drainage conditions. **Note:** The Engineer shall specify the resistor requirements should the need arise for this.

The FDU shall be designed and constructed in accordance with the specifications for TRU/SMU and NDU.

The rating of the TRU/SMU component of the FDU will typically be 100V 100A DC, unless otherwise specified in the Bill of Quantities or by The Engineer.

The unit shall be so designed that the transition from forced to natural drainage and vice versa will be seamless. Under natural drainage conditions, no current should flow through the TRU/SMU power circuit.

The Client may call for the upgrade of existing FDU installations to TRU/SMU and NDU installations which has the following implications:

- The NDU portion of the DC electrical circuit is routed to have the pipe common with the TRU negative output circuit and the DC traction railway line is a separate circuit from the TRU positive output circuit.
- The TRU portion of the DC electrical circuit comprises a common pipe connection shared with the NDU, but the positive output of the TRU is connected to an anode groundbed.
- The new circuit arrangement allows stray current emanating from the DC Railway Traction system to return to its source via the NDU circuit, while allowing impressed current to flow via the anode groundbed to the pipe in the TRU circuit.
- Typical installations shall include a chassis mounted TRU in the front with an NDU mounted on the back.
- See typical drawing showing grounding / earthing layout for TRU, which is applicable to FDU and SMU applications.

14. POWER FACTOR SWITCH MODE UNITS (SMUs)

14.1. Scope

This specification is for the supply and delivery of Power Factor Switch Mode AC to DC Conversion Units. SMU's will be powered by single phase AC to an upper limit of 240 volts AC power or three phase 380 – 400 Volts plus neutral AC power.

The SMUs may be connected to a variety of anode groundbed installations and metallic structures as specified by the Design Engineer. The anode groundbed resistance and the total circuit resistance will determine the voltage and current output requirements of the SMU and will be specified as such.

The supplier data sheet will specify the typical input voltage range that the device can handle.

14.2. Compliance

The tenderer shall indicate, paragraph by paragraph, either that this tender complies in every respect with this specification, or if not, precisely how it differs from the specification. A broad statement that the equipment is in accordance with the specification is not acceptable. Failure to comply with this clause may preclude a tender from consideration.

14.3. Information to be Submitted by Tenderers

A comprehensive technical description of the equipment offered shall be submitted in duplicate. The tenderer shall submit, with his tender, electrical schematic diagrams and drawings, which show constructional details of the equipment offered.

Red-lined equipment datasheet.

Tenderers shall detail the numbers and dates of the relevant standards specifications to which the equipment conforms.

The following information (datasheet to be completed) must be provided by the tenderer, prior to the start of manufacture of the Power Factor Switch Mode AC to DC Conversion Units (SMU):

- Type and Make of Unit.
- AC Input Rating.
- DC Output Rating.

- Voltage Control Range.
- Current Control Range.
- Voltage Output Limit.
- Current Output Limit.
- Ripple Magnitude and frequency.
- Surge Protection Layout including the use of Chokes.
- Identify the need for additional ripple smoothing on the DC Output by means of capacitor.

14.4. Operating and Maintenance Manuals

The successful tenderer shall be required to submit four complete sets of operating and maintenance manuals, the cost of which should be included in the prices quoted.

14.5. General Specification for SMU Enclosure Construction

The SMU may be mounted on a chassis plate for installation in a concrete bunker type installation or on stainless steel skeleton frame suitable for installation in a larger concrete enclosure. The Engineer shall specify the enclosure requirements and the Contractor shall submit details at the time of tender of the proposed layout for construction.

14.6. General Specification for Coating Systems

14.6.1. Enclosure Coating System

- Surface Preparation

Ensure surface of the area to be coated is free from dust, moisture and oil. Coat with a proprietary bonding liquid as per coverage specified by supplier.

- Coating System

After surface preparation is completely dry coat with a proprietary exterior grade PVA compatible with the surface preparation and preferable from the same manufacturer as the surface preparation. Concrete enclosures internal as well as external surfaces shall be coated as follows:

Exterior colours	:	to be specified by the Design Engineer
Interior colours	:	White, unless otherwise specified by the Design Engineer

14.6.2. Chassis Plates Coating System

Coating shall comply with Type 5 of SANS 1274:2013 including the use of a wet primer.

Degrease, pickle and phosphate in accordance with powder manufacturer's requirements.

Apply powder by means of electrostatic spray to ensure a final DFT of 120 micron.

Finish colour: white.

14.7. Electronic PCB

All electronic printed circuit boards shall be coated with a proprietary conformal military spec. coating designed to prevent corrosion to the exposed component leads. All Printed Circuit Boards (PCB's) shall have a primary solder mask and legend.

14.8. General Specification for Electrical Wiring

All current carrying conductors shall be insulated to withstand a minimum voltage of 1000V. All wiring shall comply with the provisions of the Wiring Code of Practice; SANS 10142 (latest edition), PL 631 and 771, SANS 10089-2.

Wherever possible flexible, multi-strand cable is to be used.

Where possible, and as much as possible, flexible conductors shall be routed in slotted trunking. Where it is not possible or practical for the conductors to be routed in slotted trunking, then the conductors shall be bundled together and strapped neatly with cable ties or correctly sized polyethylene spiral wrapping.

All current carrying conductors shall be multi stranded, flexible and sized to adequately carry the design current without rise in temperature.

All conductors shall be terminated at each end with fit for purpose, pre insulated lug or pre insulated ferrule. No trimming of conductor strands will be permitted. All ferrules and lugs shall be crimped with appropriately sized crimping equipment.

Where crimping cables of ≥ 10mm2, dimple crimping of lugs and ferrules is not permissible, only hydraulic hexagonal crimping dies may be utilized and must be adequately sized and include the cable size marking in the die. Power wiring minimum 2.5mm^2 and Control wiring 0.5mm^2.

Where elevated temperatures are expected beyond the operating range of PVC insulated conductors then the conductors in the heat affected area must be insulated with materials capable of withstanding the elevated temperature environment.

Cable markers must be colour coded as well as have their number embossed indelibly on the marker. i.e.

0- Black
1- Brown
2- Red
3- Orange
4- Yellow
5- Green
6- Blue
7- Violet
8- Grey
9- White

Cable markers must be appropriately sized to suit the insulation size of the cable.

Cable markers shall read from the right on horizontal conductors and from cable to lug on vertical conductors.

All AC supply conductors shall be colour coded according to the incoming phase and retain the colour nominated throughout the unit.

AC carrying conductors must be separated and not be routed with DC carrying conductors.

Grounding cables connected to Surge diversion devices must be kept as short as possible and may not be routed or combined in the same trunking or loom with either AC or DC carrying conductors. Ground cables should not run over conduit, devices or components to earth as the chassis plate of the cabinet shall be used as the connection to earth.

Joints or splices in any wiring will not be permitted. No more than two conductors shall be connected to any one terminal.

All conductors shall be numbered at both ends with reference to the Schematic Wiring Diagram supplied with the unit.

Buss bar conductors must be used on the output side of the Power factor type switch mode unit where the rating of the unit exceeds 100Ampere.

Buss bars shall be Aluminium and rated and sized according to the current that it will carry. Minimum size of buss bar will be no less than 25 x 3mm.

Buss bar joints shall be bolted or welded.

When a buss bar is bolted, the mating surfaces must be coated with conductive water repellent paste prior to assembly.

Spring washers and nuts shall be used when bolting Buss bar joints.

14.9. Terminals

In accordance with SANS 1433.

All terminals shall be completely accessible after completion of wiring.

All terminations made to buss bars shall be provided with spring washers.

All supply power terminations shall be enclosed and be highlighted with a warning label.

The SMU, inductors and capacitor (when specified) terminations shall be covered with a transparent cover prohibiting accidental contact.

Output terminals shall be fully insulated from any metal of the housing or chassis.

All terminals shall be clearly marked and sized according to the current the terminal will carry.

Entrilec terminals to be used, rail mounted and ATEX Approved.

Cable lugs to be sandwiched between flat washers and spring washers when fastened to stud type terminals, similarly where fastened to buss bars flat washers and spring washers are to be used.

14.10. Colour Coding and Labelling of Conductors, Equipment and Components

Positive electrical conductors	:	Red
Negative electrical conductors	:	Black
Earth cables	:	Green with yellow stripe

AC Supply cables

Phase 1	:	Red or Brown
Phase 2	:	Yellow or White
Phase 3	:	Blue
Neutral	:	Black
Reference Electrode cable	:	Yellow
Electrical warning signs	:	Black on yellow background
Monitor cable	:	Blue
Component Labels	:	Black on a white back ground.

All labels shall be engraved sandwich type Gravoply labels. All labels to be mounted with screws or blind rivets only. Silk screen labels or Aluminium anodized labels shall not be utilized.

14.11. Electrical Construction

14.11.1. General

The SMU is to comprise a 3 phase or single phase power factor controlled switch mode AC to DC convertor with a maximum ripple on the DC of 200mV. The maximum output voltage and output current will be reflected in the Bill of Quantities.

The output of the unit will be automatically controlled in one of three control modes unless specified otherwise by the Design Engineer:

- Constant output current.
- Constant output voltage.
- Constant Structure to Electrolyte potential.

14.11.2. Test Switch Facility

The SMU must have a facility to plug in a switch on the output circuit for over line testing on the protected pipelines. This requirement is irrespective of any built in timer which may be provided.

Manual output voltage and current adjustment facility:

Over line surveying testing requires a "manual mode" to adjust to a constant voltage range from zero to full output voltage, similarly the current depending on load resistance. This is to enable over line testing at a pre-set output current.

- Ideally the SMU can be switched with a switch through a timer socket.
- Switching of the SMU should be instantaneous without significant lag and should be such that the full set output current is achieved within 100ms of switching.

Irrespective of control mode, the SMU control equipment must be capable of output voltage, output current and potential pre-set limits. When the control equipment is changed from one control mode to another control mode, all user programmable parameters must be automatically restored to minimum values to prevent an instantaneous application of output voltage or output current to the load.

Note: Should the electronic PCB, automatic control or LCD display fail, the “manual mode” shall allow the user to switch over to this mode and manually adjust the output voltage and current to pre-set limits within the operating range of the SMU.

14.11.3. Earthing /Grounding

All metal components shall be connected to the common enclosure earth and to the AC supply earth. All electrical circuits shall be floating with respect to earth. All earth connections within the enclosure must be as short as possible and rated at possible fault current.

No earth connection cabling is permitted to run over conduit, equipment or components as the chassis plate shall be used as the return path to earth. Earth buss bar mounting studs must be adequately sized to accommodate collective fault current.

Surge protection devices attached to the earthing/grounding system and/or chassis plate shall be of modular construction and positioned in such a manner as to facilitate ease of removal and replacement, without the need to strip out the chassis plate and associated component removal.

A separate earthing system will be provided for the SMU consisting of suitable earth rods and bare earthing cable which will have a resistance below 10 Ω in compliance with SANS 10142. See typical drawing showing grounding / earthing layout for TRU, which is applicable to FDU and SMU applications.

The Contractor shall provide detailed drawings at the time of tender showing the earthing arrangement for the unit, the layout, location and means of connection to earth from the various components to demonstrate the principle of building the unit with the shortest distance to earth, thereby minimizing resistance.

14.11.4. Auxiliary Power Socket Outlet

The unit shall be provided with a surface mount industrial switched 15A power socket adequately inspected according to the Occupation health and safety act and regulations Act 85 of 1993 as amended.

The auxiliary power socket shall be fitted with a suitably rated earth leakage device and be compliant with SANS 10142.

14.11.5. Output Control

The adjustment and control of the output shall be achieved automatically in one of the above control modes through power factor switch mode AC to DC conversion. The control signal to the power factor switch mode AC to DC conversion will be 0-5VDC from an adequately rated controller capable of control in one of the aforementioned control modes. The power factor switch mode AC to DC conversion unit must have an AC input range of 90-264VAC and tolerate a frequency range of 47-63Hz.

Efficiency of the power factor switch mode AC to DC conversion unit is to be typically 90% and a typical power factor of 0.95/230VAC. The output of the power factor switch mode AC to DC conversion unit must be constant current limiting; recovering automatically after fault condition is removed. The must power factor switch mode AC to DC conversion unit must shut the output off when its main control elements reach 105 degrees Celsius and recover automatically when their temperature normalizes.

The power factor switch mode AC to DC conversion unit must further be able to be paralleled to increase the current output and enjoy current sharing technology to ensure each unit in the parallel assembly shares the current without any unit in the parallel assembly carrying more than another. No more than 4 power factor switch mode AC to DC conversion units may be stacked in parallel. When units are paralleled the wire and buss bar sizes must be adjusted to meet the current carrying capacity under the new configuration.

Each power factor switch mode AC to DC conversion unit must comply to EMC standards EN55022(CISPR22), EN55024, light industry level criteria A and have a noise immunity compliance with EN61000-4-2,3,4,5,6,8,11, EN 55024. Light industry level criteria A.

The power factor switch mode AC to DC conversion unit must be able to operate in a relative humidity level of 20-90% NON-CONDENSING and between -20 to +70 Degrees Celsius.

The entire power factor switch mode AC to DC conversion unit must be housed in its own easily removable housing with the input termination and output termination clearly marked and accessible from the front of the overall enclosure. No more than four fixing screws per power factor switch mode AC to DC conversion unit may be used and each fixing screw must be easily accessible. Lock nuts are to be used and at no point should the threaded fixing stud be able to rotate or work loose during the fastening or loosening process.

The power factor switch mode AC to DC conversion unit must have a built in external remote on / off control (POTENTIAL FREE CONTACT) as well as a remote sense function. The power factor switch mode AC to DC conversion unit must also have an output trim function capable of trimming the output of the power factor switch mode AC to DC conversion unit from 10V through to 24VDC, or a voltage range otherwise specified by the Design Engineer.

Selection of a control mode, as well as adjustment of the limits and control set points must be user programmable and the control equipment must be capable of both local as well as remote selection. Remote selection of the control mode is to be accomplished via the RS 232 port utilizing modbus protocol.

The control equipment must be capable of controlling the application of power to the load in either a pre programmable incremental percentage of maximum output stepped manner or in a linear incremental manner in addition to the aforementioned control modes the selection must be user programmable.

The input impedance of the reference electrode input to the control equipment must be no less than 500 meg ohm and must not adversely load the reference electrode thereby distorting the potential measurement.

Precise control is required and local adjustment of set points and control modes must be via sealed tactile push buttons, unless specified otherwise by the Design Engineer, and not through the use of adjustable potentiometers as these deteriorate with time especially in corrosive atmospheres.

14.11.6. Control Mode 1: Constant Output Current

Within restrictions of load circuit resistance the output current of the SMU shall be maintained constant.

14.11.7. Control Mode 2: Constant Output Voltage

Within restrictions of load circuit resistance and the current limiting settings of the controller, the output voltage of the SMU shall be maintained constant.

14.11.8. Control Mode 3: Potential Control

The output of the SMU must be automatically varied to maintain the potential between a permanently installed reference electrode and the structure, constant. This mode of control shall be subject to restrictions associated with load resistance and current limits set by the controller.

14.11.9. Meters and Monitors

a. Controller Display

The SMU will include high quality Liquid Crystal Display (LCD) back lit type or TFT tactile display elements to indicate the following;

Output Voltage
Output current
Reference Potential AC and DC
Heat sink temperature
Cabinet Ambient Temperature
Control mode selected
Level of control signal.
No DC output current- hour totalizer.

The input impedance of the reference potential digital volt meter must exceed 500 meg ohms and must not adversely load the reference electrode or the control circuitry. The accuracy of the reference potential meter must be less than + or – 20mV.

All meters must be either LCD or TFT display types and the display must be legible in direct sunlight and from distance away of from the display of 2 meters.

Captive (banana) sockets must be incorporated below the meters mentioned above and must be continuously connected to the measurement points mentioned above. The captive sockets connected to the output current measurement point must be labeled with the shunt rating i.e 50mV = (Maximum Rated current as held in the Bill of materials (BOM))

b. Additional Displays

The SMU will include high quality stand-alone analogue and digital display elements to indicate the following;

v. Output Voltage – Analog, (display min. 75mm x 75mm)
vi. Output Current – Analog, (display min. 75mm x 75mm)
vii. Reference Potential DC – Digital, (display height minimum 12mm to 15mm readable in sunlight)
viii. kWhr Meter – Digital, measuring and displaying SMU power only and no other auxiliary SMU attachments

The Design Engineer will specify whether or not a detachable display is required. In this specification provision is made for a detachable display when the SMU is installed in a concrete vandal proof enclosure. In instances where the Design Engineer specifies a metal cabinet enclosure the manufacturer shall adapt the requirements set out in this specification to suit a metallic door panel with the same layout, umbilical cable connections and meter types. Similarly, if the SMU is to be installed using a metal frame then the additional displays shall be mounted in a suitable location to facilitate easy reading and measurements.

The Output Voltage, Output Current and Reference Potential Meters shall be mounted on a detachable display panel that is positioned directly behind the door of the concrete bunker with a suitable clearance. The detachable display panel shall be fitted with an umbilical cable, or suitably rated cable loom, that feeds the meters from a central point on the main chassis plate.

The detachable display panel should be manufactured from a suitable panel resin board, or suitably powder coated metal base plate, that will retain its shape and support the meters and related components while holding it in position. The meters shall be arranged in such a way that the Voltmeter is to the left, the Potential Display meter in the centre and the Current meter to the right of the resin board.

All digital meters must be either LCD or TFT display types and the display must be legible in direct sunlight and from distance away of from the display of 2 meters. All of the Additional Displays shall be mounted on the detachable display panel.

Captive (banana) sockets must be incorporated below the meters mentioned above and must be continuously connected to the measurement points mentioned above. The captive sockets connected to the output current measurement point must be labelled with the shunt rating i.e 50mV = (Maximum Rated current as held in the Bill of Quantities).

14.11.10. Surge Protection

Surge protection devices attached to the earthing/grounding system and/or chassis plate shall be of modular construction and positioned in such a manner as to facilitate ease of removal and replacement, without the need to strip out the chassis plate and associated component removal.

The input circuitry of the unit will be protected via a C curve 10 kA circuit breaker adequately rated so as to avoid nuisance tripping. The circuit breaker must dis-engage all phases and neutral of SMU when tripping and must be capable of isolating the supply (live and neutral) from the unit.

The SMU is to be protected with thermal fuses incorporated into the positive and negative legs. The fuses are to be adequately rated to allow for maximum rated current to be maintained for one hour without rupturing. With a 20% increase in output current one of the DC fuses must rupture within twenty minutes.

All thermal fuses are to be of the mechanical indicating type whereby an irreparable form of mechanical indication occurs when a fuse is ruptured.

Each unit shall be supplied with a fuse puller, per fuse size, that is suitably affixed to the device plate using an insulated, strong yet flexible lead to prevent removal.

a. Mains Surge Protection

Surge protection devices must be installed in the incoming mains circuit immediately electrically downstream of the isolating mains circuit breaker. The Surge protection devices must be rated at a discharge current of 50kA and the maximum permitted operating voltage to be 25% above the RMS value of the applied voltage. The response time of the over voltage device is to be less than 25ns.

Where Single phase units are implemented the surge protection devices must be connected between live and earth and neutral and earth.

b. Output Circuit Surge Protection

Output Voltage ≤ 50V DC or as otherwise specified by the Design Engineer.

Surge protection devices must be installed after the DC fuses situated in the positive and negative legs of the SMU. Each unit shall be supplied with a fuse puller, per fuse size, that is suitably affixed to the inside of the device using an insulated, strong yet flexible lead.

The Surge protection devices must be rated at a discharge current of 40kA and the maximum permitted operating voltage to be 25% above the RMS value of the maximum output voltage. The response time of the over voltage device is to be less than 25ns.

The equipment must have coarse and fine surge protection and the coarse protection must be a minimum of 100kA and consist of both Metal Oxide Varistor (MOV) and Gas discharge devices and must not follow on at the rated output voltage. Gas discharge devices must be hermetically sealed.

14.11.11. Radio Frequency Protection

The SMU must be radio frequency protected.

14.11.12. Component Layout and List

Where capacitors and inductances are used in the construction of an SMU these are to be mounted in such a way that they are easily accessible for testing and removal. Trunking and any other heat sensitive devices must be kept well away from the heat bearing heatsinks.

The manufacturer shall supply a proposed construction layout diagram showing front view, side view and top view of the respective components installed inside the specified enclosure.

The manufacturer shall supply a complete component list for the SMU, with detailed specifications for each component to facilitate repair or exchange should the need arise.

14.12. Inspection and Testing

The complete Inspection and Test Plan (ITP) pack shall be presented to the client before undertaking the Factory Acceptance Test (FAT). The Engineering Package would typically include, but not be limited to the following:

- all OEM data sheets
- material, test and compliance certificates for all original components
- test and compliance certificates for assembled equipment
- the O and M Manual
- full list of components and recommended spares.

The following tests must be carried out at the manufacturer's works, after successful completion of the tests a certificate will be issued by the manufacturer and signed by the Engineer or his nominated representative. All testing and damaged components resulting from the testing will be at the manufacturer's expense and carried out at the manufacturers premises. Adequate adjustable load resistances, adjustable power supplies and testing equipment will be made available to the engineer by the manufacturer to verify specified operational characteristics of the SMU under test.

14.12.1. Pre Power-up Testing

The various earth points, cabinet body, chassis plates and all exposed metal surfaces shall be measured for continuity to the main earth terminal.

The cabinet and AC inputs, the DC outputs shall withstand a 1 kV insulation test. The insulation testing shall be conducted with all circuit breaker and fuses in their normal operating position without power or load connected.

14.12.2. Power On Testing

The SMU shall operate for a period of 6 hours continuously at maximum current and at full rated voltage in a suitable enclosure (agreed beforehand with the Design Engineer) or until the temperature of the SMU heat sink is stable for a period of one hour. Where the temperature continues to rise after a period of 7 hours the equipment will be rejected. The ambient, cabinet compartment internal temperature and heat sink temperature must be recorded during the heat run and plotted upon conclusion of the heat run. K type thermocouples shall be used for the continuous recording of the all the various temperatures.

Immediately after the heat run, the aforementioned insulation check will be carried out without the power or load applied. A maximum heat sink temperature of 80 ℃ is permissible at the highest vertical point of the heat sink.

Control mode testing shall be carried out after the conclusion of the heat run.

14.12.3. Constant Current Tests

The manufacturer will demonstrate the SMUs ability to control the output current to within 5 % of the pre-determined set point. The load resistance is to be manually adjusted to ensure that the output current remains constant irrespective of the load resistance. Four specific current set points are to be set 25%, 50% 75% and 100% of maximum rated output current. Voltage at the given pre-determined set points will be recorded and noted in the O and M Manual.

14.12.4. Constant Voltage Tests

The manufacturer will demonstrate the SMUs ability to control the output voltage within 5% of the pre-determined set point. The load resistance is to be adjusted to ensure that the output voltage remains constant irrespective of the Load resistance. Four specific voltage set points are to be set 25%, 50% 75% and 100% of maximum rated output voltage. Current at the given pre-determined set points will be recorded and noted in the O and M Manual.

14.12.5. Constant Potential Tests

The manufacturer will demonstrate the SMUs ability to control the electrolyte to structure potential within 50 mV of the pre-determined set point. Current limit and voltage limit features are to be tested and verified whilst carrying out potential mode testing. Dynamic feedback is required to demonstrate the control mode. That is, a simulated Cathodic Protection system must be used to demonstrate the control mode. In the potential mode verification a variable power supply may not be used to simulate the Reference Electrode.

14.13. Telemetry and Remote Monitoring Systems

The SMU shall be provided with outputs suitable for connection to a SCADA or remote monitoring system. The outputs shall be potential free contacts for alarm and status signals, and 4 – 20mA, 0 – 5V, or actual value for analogue signals. A comprehensive Ethernet Modbus signal may be provided as an alternative.
Power consumption and quality monitoring:

- Mains failure
- Fuse failure
- Output current
- Output voltage

- Pipe/soil potential

Detailed requirements for telemetry or remote monitoring will be determined by the project requirements.

14.14. Documentation

The SMU shall be supplied with the following documentation:

- Databook as per datasheet.
- A removable clear laminated schematic diagram and the laminated schematic diagram shall be located inside the SMU enclosure.
- SMU operation and maintenance manual (O and M) complete with schematic, parts list, fault finding flow chart, operating instructions, original certificates and recommended spare.
- Three copies of the O and M shall be supplied to the Engineer prior to commencement of the manufacturing of the equipment.
- The complete Inspection and Test Plan (ITP) Pack.

14.15. Generic SMU Data Sheet and Electrical Circuit Diagram

Note: At the time of tender generic data sheets and electrical circuit diagrams are provided. The tenderer shall provide project and application specific SMU data sheets and electrical circuit diagrams and these shall form an addendum to the specification of the accepted Tender. All the relevant information shall form part of the engineering data pack that will be present at the time of FAT at the manufacturer.

15. STEEL CABINET

15.1. General Cabinet Construction

The electrical equipment is to be housed in a weather-proof steel cabinet which is to be constructed in accordance with the tender specific drawings.

Cabinets shall be of sufficient size to allow for easy access for servicing and maintenance. The cabinet must be so designed that there are no inherent moisture traps.

Cabinets to be manufactured from 3Cr12 with No.1 Mill finish. Two coating systems are described in this technical specification.

Cabinets shall be manufactured from minimum 2,5mm thick steel and all individual panels are to be visibly hard stamped with “3Cr12" prior to the application of paint.

All external welds should be continuous seam welds. Tack welding is not permitted. Stitch welding is only permitted on the inside of the cabinet.

Cabinet doors shall be provided with suitable robust door stays to hold the door open during servicing and maintenance.

The cabinet doors must be provided with 304L stainless steel lockable handles designed to accept padlocks.

The cabinet shall be provided with a bottom plate which shall incorporate a removable gland plate. The gland plate shall be manufactured from 304L stainless steel. All holes punched into the gland plate shall be true round and suitably sized for steel gland use.
Cabinets shall be provided with channel section bases and lifting lugs suitably designed to prevent distortion during transport, handling and installation. The cabinet lifting lugs shall be of the same material as the cabinet or be hot dipped galvanised.

<u>Note:</u> Each cabinet should be provided with stainless steel bolts and washers to replace the lifting lugs once the cabinet has been installed on site. These bolts should be secured in the transformer compartment of the cabinet and marked LIFTING LUG REPLACEMENT BOLTS.

The cabinet channel base shall be 3Cr12 steel. All cabinet channel base material must be a minimum of 3mm in thickness.

All the channel bases must be pre-drilled with M16 holes to facilitate mounting on concrete plinths. It is important to adhere to the dimensions provided in the drawings as to ensure proper and correct mounting on plinths and pallets.

The housing shall be suitably designed to prevent ingress of dust and rain.

The housing shall allow for adequate ventilation of the heatsinks and power elements.

Note: No heatsink or power element shall be installed within 75mm of any cabinet wall.
It shall also have a cooling duct around the two (Instrument and Control) top compartments. Refer to drawings. Alternatives will be considered provided extra volume is then designed into each cabinet with adequate venting to suit.

Note: A set of louvres shall be pressed into the bottom of the Instrument and Control compartment floors and another set on the vertical, inner back panel of the same compartments, in order to permit convection cooling. The louvres shall be pressed into the cooling duct.

Stainless steel filter elements to provide insect proofing and dust prevention shall be bolted to the inside of the cabinet to cover the louvres.

Cabinet doors shall be sealed by means of Closed Cell Expanded Rubber such as NEO25 or approved equivalent material.

All laps, crevices and internal non-continuous welds after coating must be caulked using oleo-resinous mastic applied by gun. A rubber strip of closed cell expanded rubber such as NE24 or approved equivalent must be installed between the roof and cabinet body and channel basis. Alternative materials must be specified by the supplier with their tender submission.

An enclosure for the O&MM and facilities to attach drawings shall be located at a suitable point inside the cabinet. Rails (Z-Rails) instead of studs shall be used to fix enclosures and facilities to the doors.

All studs and wing nuts for wiring diagram holders and spare component rack to be brass. The following information is to be hard stamped or engraved onto the manufacturer's nameplate attached to the instrument panel of the cabinet:

AC rating:
DC rating:
Max. operating temperature:
Type of equipment offered: (e.g. Manual Transformer Rectifier Unit).
Serial No:
Owner:
Date of Manufacture: (Month & Year)
Contract No.:
Manufacturer:

All structural bolts, nuts and washers shall be stainless steel. Bolts with spring washers or ny-lock nuts shall be used. All studs shall be brass or stainless steel and cut to size.

15.2. Coating of Steel Cabinets

SUBSTRATE - 3Cr12 (No.1 Mill Finish)

15.2.1. Method No 1a: Wet Spray Coating

SURFACE PREPARATION

Degrease, rinse, acid pickle, phosphate and passivate, all after welding. Pickling and passivating in accordance with steel manufacturer's specifications.

COATING SYSTEM

Primer Coat	:	Plascon Epilyte 325/661 or equivalent. 1 Coat D.F.T. 30 Microns
Final Coat	:	Plascon recoatable PU Code CPC Enamel or equivalent. One Coat. D.F.T. 30 Microns

Total D.F.T. : 60 Microns.

Colour : Orange.

Preferred application by means of electrostatic spray. Equivalent Coating Material may only be used with the approval of the Engineer. Coating system to be from one supplier only.

15.2.2. Method No 1b: Powder Coating

SURFACE PREPARATION

Degrease, rinse, acid pickle, phosphate and passivate, all after welding. Pickling and passivating in accordance with steel manufacturer's specifications.

COATING SYSTEM

Apply two coats of Chemstop Polyurethane Enamel or equivalent with light sanding between coats.

D.F.T. : 35 Microns per coat
(2 x coats)

Total D.F.T. : 70 Microns.

Colour : Orange.

Application by means of electrostatic spray. Equivalent Coating Materials may only be used with the approval of the Engineer. Coating system to be from one supplier only.

15.2.3. Method No.1c: Alternative Coating

Alternatively, Tenderers may submit their own specification for surface preparation and painting. This must be accompanied with full details, records of past performance and a two year guarantee. The successful Tenderer may only use his system with the approval of the Engineer.

16. CONSTRUCTION OF TEST POSTS, CONCRETE BUNKERS AND CONCRETE ENCLOSURES

16.1. Galvanized Steel Test Posts (TP)

TP are to be constructed of galvanized steel as per standard drawing.

The TP dimensions shall be as per standard drawings. The base shall be cast in a concrete in the ground.

The door shall be lockable as per the latest revision of the drawings.

16.2. Monitoring Test Posts

Monitoring test posts are to be constructed of reinforced concrete or as specified by The Engineer. The reinforced concrete type test posts are to be monolithic construction, containing no part that operate or close, nor any that have a cover with lock. The test post should be nominally 1.4m in length with approximately the bottom 0.5m concreted into the ground. The cross section should be minimum 130mmx130mm square. The test post will be constructed with a mild steel flat bar 6mm thick by 30mm wide and 40mm long protruding from it halfway down. The flat bar is to have a 15mm diameter hole to which a recording instrument may be chained.

Where The Engineer specifies that concrete enclosures or test stations are to be painted, the following shall apply:

- The concrete stations and/or points will be sealed and painted with an undercoat. Test stations, bonding test stations and/or bunker test stations will then be painted with PVA paint. With exception of the test stations which will be painted white, all concrete structures will be painted as per Client requirements according to SABS 1091 H40.
- A 50mmm diameter orange circle will be painted around the potential test station banana jack test point.

16.3. Large/ Mushroom Head Concrete Test Post

The large / mushroom head concrete test post will contain a cavity with minimum dimensions 450x390x200mm. Must be cast with a minimum of four (4) off cable conduits and each with a draw wire. A paper base phenolic board, (Tufnol) 3mm thick will be fitted to the inside the recess. The board will contain either:

- Four (4) off link busbars. A horizontal busbar will in turn connect the top of each link busbar and extend to include a terminal for external monitoring point. The eight terminals/bolts are to be M6 brass and supplied with relevant washers and nuts.
- DIN Rail mounted terminal blocks as specified elsewhere. The number of terminal blocks and their cross connection will be set out in the Bill of Quantities.

The large / mushroom head concrete test post cavity shall be fitted with a suitable vandal-proof 5mm thick galvanised steel door, complete with a robust locking mechanism. Dimensions may vary based on the application and the Contractor / Manufacturer shall provide construction details of the proposed concrete bunker at the time of tender as part of the compulsory quality documentation to be returned.

16.4. Bonding Test Posts (BTP)

Bonding Test Posts (BTP) is to be constructed of galvanized steel or reinforced concrete depending on the project specification.

The BTP will contain cavity with minimum dimensions 245x250x135mm with a recess. The recess will be nominally 200x110x30mm. The standard EWS drawings shall apply or be modified to suit each project specification.

The door shall be lockable as per the latest revision of the drawings. The overall dimensions of the BTP shall be specified for each project.

16.5. Concrete Bunkers

A concrete bunker shall comprise of 25MPa concrete in a ratio of 1:4:4 (Portland cement: 13mm stone: river sand) placed on at least a 350mm thick complete steel reinforced 25MPa 1250mm x 1250mm x 75mm thick surround. Dimensions may vary based on the application and the Contractor / Manufacturer shall provide construction details of the proposed concrete bunker at the time of tender as part of the compulsory quality documentation to be returned. The concrete shall be agitated while wet and cured for 48 hours prior to moving. All surfaces are to be smooth and free of spalling, cracking and honeycombing. The minimum concrete wall thickness shall be 150mm. All reinforcing steel (mesh and rods) shall be 10mm in diameter and shall be hot dip galvanised to SANS 121/ISO 1461.

The door shall be manufactured from 5mm thick hot dip galvanised steel plate. The door locking mechanism shall be deadbolt locks (keyed alike to The Client's requirements) and the door shall be hung on internal concealed hinges.

400 Grade Stainless Steel 40mm rod, with an M12 internal threaded hole shall be installed at least 100mm into the concrete. The stainless steel rod shall welded onto a stainless steel base plate (50mm x 50mm x 3mm) in order to ensure that the bunker may be suitably moved on site.

Each bunker shall have a portable reference electrode drop tube which shall comprise of 110mm PVC drain pipe and shall extend from 150mm above the pipe into the bunker. At the time of tender The Contractor shall ascertain from The Client what the separation distance shall be between the pipe and test station as the drop tube shall be installed vertically

The overall dimensions shall be no less than 1050mm high, 950mm wide and 770mm deep.

The structure is to contain a recess of no less than 470mm deep and 400mm wide. The minimum distance from any outer sidewall shall be 150mm. The recess to be painted with a white PVA based paint, a suitable primer shall be used prior to application of paint.

A 5mm galvanised (SABS ISO 1461) vandal proof door shall be mounted in a recessed sill, min 75mm deep, and shall contain a vandal proof locking mechanism. The door shall also be fitted with a dummy mechanism to distract potential vandals.

The structure to contain two lifting lugs mounted on the top. 16mm eyebolt threads cast into the concrete is preferred so that the lugs can be removed after lifting.

The structure shall contain a cable duct of sufficient size (300mm x 150mm min.).

A 3CR12 backplane is to be fitted inside the recess for component mounting purposes.

A typical Bunker drawing is included in this technical specification.

16.6. Identification

The galvanised steel test posts shall not be marked unless specified as such in the project specification.

The concrete will be sealed and painted with an undercoat. The Test post will then be painted with PVA paint, colour to be specified by The Client.

Labelling characters are to be 20mm high with black paint (unless otherwise specified).

If the labelling procedure is not specified in the Bill of Quantities the Contractor shall ascertain project specific requirements from The Client at the time of tender.

16.7. Concrete Enclosure

This specification is for the construction of a precast reinforced concrete structure with a secure safe door. The structure is intended for the housing of electronic equipment at sites where theft and/or vandalism is prevalent. This specification is to be read in conjunction with the relevant standard drawing.

a. Concrete thickness to the walls /roof shall be a minimum of 90mm and the floor a minimum of 100mm.
b. Minimum concrete strength shall be 35 MPa at 7days.
c. Walls/roof/floor shall be double reinforced with the inner reinforcing comprising of 6.3mm bars at a maximum spacing of 75mm centres and the outer reinforcing comprising of 8mm bars at a maximum spacing of 75mm centres.
d. Internal dimensions shall be a minimum of 1850mm x 1850mm x 2050mm in height.
e. Two number 50mm diameter ventilation holes (approximately 1000mm c/c) shall be provided on each of the two walls adjacent to the door and be set approximately 200mm below the soffit and shall be approximately centred on each of the walls.
f. Internal corners shall be chamfered.
g. Two 300mm square “box out’s” (for cables) shall be provided through the floor slab:
    - one in the centre, and
    - one at the back left hand corner.
h. Access shall be provided centrally into the front face of the structure.

i. A secure steel door (type Mutual Zinga or similar approved) shall be fixed at multiple points to the precast concrete structure in a manner approved / recommended by the supplier of the door.

17. TESTING AND MONITORING

17.1. Pipe-to-Soil Potential Logging

Pipe-to-soil potential measurements will be complimented by measuring the stray current fluctuations over periods of twenty four hours, using data loggers.

17.2. Testing of Isolating Devices

The status of isolation devices such as isolating flanges and monolithic joints will be tested using a radio frequency tester, such as the Tinker and Rasor™ RF IT Tester (or equivalent approved) and not by measuring the potential difference on either side of the joint with a conventional digital voltmeter.

17.3. Digital Volt Meters and CP Analyser

All digital voltmeters used for potential measurements and logging will need to be calibrated.

The use of cathodic protection analysers, based on waveform analysis is encouraged.

17.4. Coating Performance Testing

The pipeline itself must be electrically continuous and all other civil structures and extraneous earths shall be electrically isolated from the pipeline at pump stations, off-takes, chambers, scour valves, air valves, non-return valves, etc. by means of isolating flange kits, etc. The pipeline shall not be bonded to Foreign Service pipelines unless designed accordingly and subsequent to interference testing.

Current draining testing shall be conducted in accordance with NACE TM0102. Not more than 5,000 m of pipeline may be tested at any given time during construction.

The Contractor shall submit a written Method Statement regarding the current draining testing for approval, prior to commencing with the Works.

The Electrical Coating Conductance shall be normalised to the 10 Ω.m soil.

The Electrical Coating Conductance shall be $<100\ \mu S/m^2$ for the pipeline.

All coating defects shall then be located using the Direct Current Voltage Gradient (DCVG) technique, as approved by the Engineer. The Contractor shall then carry out excavations and coating defect repairs, until the coating complies with the $<100\ \mu S/m^2$ criteria.

18. TEMPORARY CP

Temporary cathodic protection during construction of the pipeline is a vitally important activity. Significant external corrosion can occur on pipelines during construction if this is not done correctly.

Temporary cathodic protection under stray current conditions is time consuming as the stray current patterns change on a daily basis, as the pipeline segments increase in length. The temporary protection is provided by a number of different systems, both sacrificial and impressed current and these also change depending on the level of stray current activity on the pipeline. In addition, there are many temporary bonds, using copper cable to tie-in segments of pipeline in order to make them electrically continuous. These need to be checked and monitored on a daily basis.

It is therefore necessary to take frequent potential measurements on the pipeline segments during construction and make daily adjustments to the temporary CP systems. The procedures and methodologies for doing this are described in this section.

18.1. Temporary CP Criteria

The criteria for temporary protection during monitoring of temporary CP shall be in accordance with SANS 15589 as follows:

During temporary protection where temporary ICCP is in use, a minimum ON potential of -2500mV (excluding spiking) vs. $Cu/CuSO_4$ reference electrode shall be utilised.

The percentage time within the specified protection criteria shall be determined and ensure that a minimum of 95% of the potential recording is within the specified protection criteria.

Where temporary SACP is in use, and there is no stray current activity, a minimum ON potential of –1000mV vs. $Cu/CuSO_4$ reference electrode shall be utilised.

18.2. Installation of Temporary Cathodic Protection

18.2.1. Installation of Hi-Potential Magnesium Anodes for Temporary CP

For temporary protection using bagged Hi Potential Magnesium Anodes the following procedure will apply:

The anodes shall be installed vertically such that the top of the anode is 1.5m below the natural ground level.

The anodes shall be installed where required in conjunction with the available Type A, B, C, E or F test stations.

The distance between the anode/s and the pipe to be protected shall be 3-5m depending on available space and shall be installed on the spoil side of the pipe.

The anode tail of each anode shall be terminated on the pipeline by means of a thermit weld or stud weld onto:

- The access tee flange*, or
- Onto the barrel of the pipeline*.
- The Engineer shall specify which method is to be used at the time of tender.

The anode excavations shall be backfilled with native soils.

The GPS co-ordinates of the exact location of the Hi-potential Magnesium anode/s shall be recorded for entry into the The Client's GIS, and the test post through which they are connected to the pipe, to ensure that the magnesium anode/s is disconnected once the permanent CP system is installed and energized.

18.3. Installation of temporary ICCP systems

Under stray current conditions experienced during the construction phase, it may be necessary to implement temporary ICCP system. The following procedure is recommended for the implementation of temporary ICCP systems in order to provide protection.

The temporary ICCP systems shall comprise constant current portable TRU's when DC railway lines are being used as temporary groundbeds, or potential-controlled battery systems with temporary anodes.

The location of the ICCP stations shall depend on the following:

- Construction progress.
- Stray current levels measured on the pipeline.
- Progress in the installation of the permanent ICCP Stations.

Appropriate soil resistivity in the area where temporary protection is required.

The extent and frequency of ICCP systems shall be at the discretion of the cathodic protection site engineer and as a rule shall be applied to provide protection wherever the integrity of the pipeline may be compromised by stray current activity.

18.4. Temporary Cathodic Protection Monitoring Procedure

The temporary protection monitoring procedure shall be classified for SACP and ICCP segments as follows:

SACP segments:

- Spot ON potentials shall be taken once per week for 15 minute intervals during which the minimum, maximum and mean potentials shall be determined.
- The ON potential measurements shall be carried out at the following locations:
- Start of segment
- One third of length of segment
- Two thirds of length of segment
- End of segment
- Each segment shall not exceed 5km in length. Once a section exceeds 5km then the ON potential measurements shall be carried out at every 1 to 1.5km along the pipeline section.
- The mean potential value shall comply with the minimum ON potential of -1000mV vs. Cu/CuSO4 reference electrode.
- Where spot potentials do not comply at any location, the situation shall be rectified by the installation of additional discreet bagged magnesium anodes. The exact location of these anodes shall be the subject of interpretation by the cathodic protection engineer. The location and GPS coordinates shall be recorded for future reference.
- Results of monitoring and non-compliance interventions shall be reported on a monthly basis.
- Should the difference between minimum and maximum potential recorded exceed 800mV the relevant pipeline section shall be classified as a stray current affected pipeline section (ICCP segment).

ICCP segments:

- 24 hour stray current ON potential recordings shall be carried out once per week on all pipeline segments classified as stray current affected pipeline sections.
- The recordings shall be carried out at the following locations:
- Start of segment

- One third of length of segment
- Two thirds of length of segment
- End of segment
- Each segment shall not exceed 5km in length. Once a section exceeds 5km then the 24 hour stray current ON potential recordings shall be carried out at every 1 to 1.5km along the pipeline section.
- The ON potential recordings shall be graphically presented and the maximum, minimum and mean values determined.
- The minimum potential shall comply with the specified temporary protection criteria, i.e. a minimum ON potential of –2500mV (excluding spiking) vs. Cu/CuSO4 reference electrode.
- The percentage time within the specified protection criteria shall be determined and ensure that a minimum of 95% of the potential recording is within the specified protection criteria.
- Where stray current ON potential recordings do not comply due to stray current activity the situation shall be addressed by the installation of temporary portable transformer rectifier units and groundbeds (SiFe or MMO). The exact location of these units shall be the subject of interpretation by the cathodic protection engineer.
- Results of monitoring and non-compliance interventions shall be reported on a monthly basis.
- Only once a particular pipeline segment has an energized permanent ICCP system at either end shall monitoring be reduced to 24hr ON potential recordings fortnightly, until the commissioning of that particular pipeline segment is completed. Subsequent to this and upon approval from the owner, the 24hr ON potential recordings may be reduced to once every 2-3 months.

19. OPERATION AND MAINTENANCE MANUALS AND INSTALLATION DATA PACKS

The contractor will refer to The Client's specification regarding number of copies, format, binding etc. of submitted documents.

The CP System Operation and Maintenance Manual (OMM) will provide the owner and technical staff with knowledge on the operation of the CP system and the subsequent maintenance thereof.

19.1. OMM Requirements

In general an OMM shall include the following:

- Manual Update / Revision Register: Page where any alterations, after the final manual distributed, can be noted.
- General Description: This is aimed at Artisans and Operating personnel and should be presented in simple terms with little technical detail.
- Operating Instruction: These should be clear, concise, easy to follow and must include all necessary checks.
- Routine Maintenance: This shall include charts covering the complete installation, i.e. if a manufacturer's manual is included to cover a "brought-in" item, then the relevant maintenance instructions must be extracted and included on a master chart so that the Operator has only one check-list of periodic servicing to cover the whole installation.
- Fault Diagnosis (Flow chart could also be used) and Repair Procedures: Shall include details of all servicing replacement and repairs which Artisans or Operating personnel would be expected to carry out on site. In this section the reader may be referred to supplier's brochures elsewhere in the manual for specific detail.
- Full details of calibration and adjustment for the meters, monitors and electronic circuitry including all control and power supply cards shall be provided.
- Components
    - Component Names.
    - Component Values and/or Rating.
    - Spares Lists: where possible, drawings shall be positioned opposite to the appropriate text.
    - Component values, description and Supplier's name and contact details shall be included in the Maintenance Manual.
- Certificates: The following certificates must be included:

  - Competence test certificate.
  - Heat run test certificate (Generation Graph).
  - Handover certificate.
  - Delivery checklist complete Guarantee.
  - Coating certificate.
  - Output load test certificate – Maximum Output.
  - Overload test certificate
  - Insulation Test Certificate (1kV)
- Electrical schematic, component layout drawings and cabinet construction and layout drawing must be included with the maintenance manual.
- Telemetry: Details of Remote Monitoring operation, service, testing and repairs. Specification: Brief summary of the equipment specifications must be given
- Special and Safety instructions: Any special instructions regarding the equipment which is important to know.
- Subcontractors / Supplier's brochures and instructional literature.

19.2. Installation Data Packs

All drawings are to be to scale and presented in suitable AutoCAD format as agreed to with The Client. Prior to finalising drawings it shall be submitted to The Client for his/her perusal and approval.

Records of the installation, problems, and site meetings shall be kept and handed to The Client upon handover.

Minutes shall be kept at every meeting held with The Client or third parties affected by the contract. Copies of these minutes approved / accepted by all parties concerned shall be distributed and kept on record as the project proceeds.

Approved minutes of meetings will be used as the basis of assessing additional work, claims and extensions of time. Should The Contractor fail to keep such minutes The Client reserves the right to assess claims, additional work and extensions of time based on fair assessment of the site conditions and requirements to complete the project successfully.

The Contractor shall keep thorough records for the duration of the contract with a duplicate file for presentation to The Client on successful completion of the project. Documentation should typically include, but not be limited to:

- Quality Control Plans.
- Hazard Identification and Risk Assessment Plans.
- Test certificates.
- Certificate of Compliance for electrical works.
- Site inspection certificates.
- Minutes.
- Variation orders.
- Correspondence with The Client.
- Correspondence with third parties.
- Rainfall on site.
- Site notes reflecting working conditions, difficulties and progress on a daily basis.

20. AC MITIGATION

The use of Solid State DC Decoupling (SS-DCD) devices is the most superior form of ensuring electrical isolation. This equipment must not only ensure that it meets the safety standards enforced relating to effective earthing / grounding of a structure, but it must also ensure adequate electrical isolation for the Cathodic Protection (CP) system. The SS-DCD shall protect personnel and equipment during all types of electrical disturbances by providing an effective grounding / earthing path which will instantaneously conduct:

- AC fault currents
- Lightning
- Induced AC
- Power switching surge currents

Applications include but are not limited to:

- AC fault current protection across IFs and other devices
- Mitigation of induced AC on pipelines and other structures.
- Lightning protection for equipment including Transformer Rectifier Units (TRU), pipelines, cathodically protected tanks and other structures.
- Decoupling between primary structures and general earthing systems.

A CP engineer will conduct AC interference investigations and there-after compile a report containing findings and mitigation recommendations to be discussed with The Client's Engineer. Investigations and reports shall be conducted as per NACE SP0177 and ESKOM guidelines. Mitigation measures will be designed to maintain the following conditions on the pipelines and appurtenances.

- Steady state touch potentials at above-ground appurtenances will be below 15 VAC.
- Maximum steady state touch potentials at buried and normally inaccessible portions of the pipelines will be AC voltages specified by The Engineer.
- Maximum coating stress voltages will be below 5 000 V for more modern coatings ie. 3LPE and as low as 1200V for older bitumen type coatings.
- Short term transients will be in accordance with IEC voltage/time constraints.

Where mitigation is required to maintain the above criteria, gradient control wires, zinc grounding electrodes and gradient control mats will be designed.

20.1. Gradient Control Wires

Zinc ribbon shall be installed (where necessary, depending on the detailed AC mitigation design) within the pipeline trench at strategic locations as gradient control wires to ground any steady state AC and reduce the potential difference between the pipelines and local earth during AC power system fault conditions.

The composition of the zinc will be as per ASTM B418, and suitable independent compositional testing will be carried as directed by The Client, in addition to the quality control information presented by the supplier of the zinc ribbon.

The zinc ribbon geometry will be of the "standard" dimensions as follows:

Cross section (D1 x D2)	12.7 mm x 14.3 mm
Radii (R1 x R2)	2 mm x 5 mm
Zinc weight	0.89 kg/m
Steel core diameter	3.3 mm
Potential	-1.1 V vs CSE
Capacity	780 Amp hrs/kg

Ribbon is to be installed at pipe invert depth in the pipe trench during construction or for retrofit installations the depth shall be specified by The Engineer and where necessary, spaced at equidistant apart either side of the pipe centre-line as specified by The Engineer.

Gradient control wires will not be connected directly to the pipelines, but through low voltage solid-state decoupling devices (SS-DCD), see below. These wires should not be installed in length in excess of 400m for the given rating of the SS-DCD, unless otherwise specified by The Engineer.

The length of zinc ribbon required at each location has been detailed in the BoQ or as directed by the Engineer on site.

20.2. Valve Chamber Earth Mats

Gradient control mats (equipotential mats) and/or isolating surface layers shall be installed at valve chambers and bunkers for step and touch protection. The mats will comprise 200 x 200 x 8mm galvanised weldmesh encased in a minimum of 250mm thick 20MPa concrete. A connection point must be provided for attachment of the 25 mm^2 insulated copper cables. An alternative to the galvanised weldmesh is the used of zinc ribbon anode in a spiral formation buried at 600mm, covered with 200mm of compacted soil, then having a 200mm thick concrete slab cast and the top 200mm layer filled with compacted soil.

External mats shall be buried at a depth specified by The Engineer (this will be determined by the valve design and location) and extend 1.2m beyond the valve chamber in all directions.

Alternatively, an external “skirt” or surround of asphalt 150mm thick with an underlying impermeable 1mm thick polymeric membrane shall be placed around the chamber extending 1,2m in all directions.

Internal mats shall be placed below the stone layer of the floor of the valve chamber, or cast into a conductive screed in place of the normal cement screed as appropriate.

Continuity bonding of chamber reinforcing may be utilised subject to the approval of the Engineer in place of the gradient control mats provided the reinforcing is welded to create a continuous cage.

The internal grid (rebar or weldmesh) must be connected via two separate insulated copper tails.

The groundmats (internal and external) must be separately connected to the pipeline through suitably rated SS-DCD’s unless otherwise specified.

20.3. Cable connections

All cable connections from either zinc ribbons, gradient control mats or valve chamber reinforcing shall be 25mm^2 stranded copper with green/yellow insulation.

2 cables are required for ground mat and rebar connections. Copper to steel connections shall be crimped and encapsulated to prevent water ingress.

20.4. Solid State Decoupling Device (SS - DCD)

The SS-DCD shall be non-electrolytic, fail safe and maintenance free.

Fail safe shall imply that the failure of any SS-DCD component, shall result in an open circuit system and not a short circuit system. That is, the pipeline or structure shall never be directly connected to the earthing or grounded system.

SS DCD will be installed inside an enclosure at locations along the AC-affected portions of the pipelines, through which the gradient control wires will be connected to the pipelines.

Two types of decoupling devices are used. The first type will be used to decouple the zinc ribbon from the pipeline and the second to decouple the gradient control mats from the test station connection.

Details are as follows:

20.4.1. Performance Specification for AC Mitigation Decoupling Device

Steady state AC current:	45A
AC fault current rating:	3.7kA for 500ms
50Hz AC impedance:	0.04Ω
Lightning current rating (10/350μs))	100kA
DC blocking voltage:	-12/+1V
Diode PIV	1500V
Diode forward surge current	1200A
DC steady state current (15 min):	60A
DC sparkover voltage:	1.0kV
Lightning impulse voltage:	2.2kV

The decoupling device shall comprise a suitably rate diode stack capable of blocking direct current in both directions at the specified voltages.

Once the blocking voltage is exceeded, the diode stack shall be capable of conducting the steady state DC up to 60A (15 minute rating) without overheating.

The device shall exhibit a progressive, smooth transition from blocking to conduction and vice versa without commutating.

A bypass capacitor (network) shall be connected in parallel with the diode stack to conduct 50Hz AC up to the blocking voltage of the diode stack.

The capacitor and diode network shall be protected by a suitably rated spark gap for high voltage and lightning induced transients. This will include the appropriate inductance required to decouple the spark gap from the diode stack in terms of lightning protection zone standard practice.

Note: If DC blocking voltage higher than 12V is required, a thyristor based SS-DCD may be utilised. Details of the design and performance characteristics shall be submitted to the Engineer for approval.

The decoupling device shall preferably be of open frame construction to permit maintenance / replacement of component parts. The frame shall be sized to fit on a standard 800 X 600mm chassis plate. The unit will be mounted inside an IP65 rated enclosure.

Component parts shall be of reputable manufacture with proven performance record and certificated test data.

The decoupling device shall be provided with two M10 terminals at each pole for the connection of 25mm² single core cables.

20.4.2. Performance Specification for Transient Voltage Protection Device

AC fault current rating:	50kA
DC blocking voltage:	100V
Lightning current rating 8/20:	40kA
Lightning impulse clamping voltage:	<500V
Response time:	25ns

The test station ground mats are provided for personnel safety during short term (transient) voltage spikes which may occur due to powerline faults or lightning. They are not required for steady state AC mitigation.

20.4.3. Enclosure Construction

The SS-DCD device shall be enclosed in a suitably rated enclosure as required by SABS 0108, SABS 089 and SABS 086. The enclosure shall also be rated according to the environmental conditions prevailing. This includes but is not limited to vandal resistant concrete reinforced structures where required on transmission and distribution pipelines. Solid State DC Decoupling Devices (SS-DCD)

20.4.4. Inspection and Testing

The testing of the SS-DCD shall be carried out at the Supply Contractor's works or at the third party inspector's laboratory/works. A sample of the SS-DCD to be supplied shall be selected in accordance with BS 6001: Part 1 for testing purposes. All of the SS-DCD device components shall pass the tests and the testing shall be carried out in the presence of The

Client. The Supply Contractor will issue a Test Certificate upon completion of the tests and it shall be signed by The Client. All of the testing shall be carried out at the Supply Contractor's expense.

The SS-DCD shall be supplied with the following items :-

- A removable clear-polyester laminated circuit diagram, which shall be located inside the enclosure.
- Operation and Maintenance Manual (OMM).
- Recognised third party testing certificate that sets out the test conditions and test results confirming compliance with the performance specification of the SSDCD.

The equipment shall carry an unconditional two year guarantee. The only exceptions shall be for damages arising from vandalism, mechanical damage, external fire and flooding.

20.5. Cathodic Protection Monitoring Points

All cathodic protection monitoring points along the section of the pipeline subject to AC interference are to be of dead front construction unless the appropriate gradient control mats have been installed.

A dead front test point shall be constructed in such a way as to ensure that no metallic parts are exposed to a person on the operating side of the equipment. Contact should only be possible with insulated measuring probes. Appropriate operating instructions and a warning of the hazard shall be printed adjacent to the measurement points. Access to the live side should only be available to trained personnel. The test station is to be installed inside a galvanised steel or reinforced concrete bunker enclosure.

20.6. Safe Working Procedures In Power Line Servitudes

20.6.1. Appointment of Electrical Safety Officer (ESO)

Prior to any work commencing an Electrical Safety Officer (ESO) shall be appointed by the Contractor or the Contractor's agent. This person shall:

a) be the designated safety officer for the project,
b) have completed a recognised and accredited responsible person training course,

c) be authorised by a authorised person (GMR2.1) to work without constant supervision in a power line servitude
d) have completed the SAECC Electrical Safety Officer training course,
e) have experience in the supervision and management of temporary mitigation measures during pipeline construction, and
f) be furnished with the authority and equipment required to implement and maintain safe working conditions, keep a record of any non-compliance and advise the construction manager and the project safety officer.

20.6.2. General Safe Working Procedures

a) No person, equipment or machinery shall enter the HV/EHV servitude without the approval of the ESO. All affected areas shall be suitably demarcated and access restricted to those personnel who have been advised of the hazards and requirements when working underneath or adjacent to HV/EHV power lines.
b) All personnel shall be made aware of and be able to recognize the potential shock hazards and be trained in the approved safety procedures.
c) Pipeline construction personnel shall avoid contact with HV/EHV structures and supports. No mechanical equipment shall come closer than 5 m from any power line tower.
d) Direct connections to the power line tower structures or buried counterpoise earthing system are not permitted under any circumstances. The earthing systems of the power line and the pipeline must be kept separate.
e) Temporary construction sheds, trailers, living quarters, pipe sections, storage areas or vehicle fuelling facilities are not permitted in the HV/EHV servitude.
f) No mechanical equipment, including mechanical excavators or high lifting machinery, shall be used in the vicinity of eThekwini Electricity's apparatus and/or services, without prior written permission having been granted by eThekwini Electricity. If such permission is granted the applicant must give at least seven working days prior notice of the commencement of work. This allows time for arrangements to be made for supervision and/or precautionary instructions to be issued. The internal assessor must provide the applicant with the details of an eThekwini Electricity person to be contacted in this regard.
g) All rubber tyre construction vehicles used in the HV/EHV servitude shall be equipped with a steel chain secured to the chassis at one end and freely dragging on the earth at the other, to discharge any electrostatic build-up.
h) The minimum vertical clearance between construction equipment and overhead conductors shall be in accordance with Table 1. The actual height of the conductors at

their lowest point shall be measured by means of optical measuring equipment to ensure that this minimum clearance is achieved.

Table 1: Minimum vertical clearance underneath power line conductors

Nominal r.m.s. voltage (kV)	66	88	132	220	275	400	533 d.c.	765
Minimum vertical clearance (m)	3.2	3.4	3.8	4.5	4.9	5.6	6.1	8.5

(from Regulation 15 of the Electrical Machinery Regulations of the OHS Act (Act 85 of 1993))

i) Vehicles such as mobile cranes with extendable members that can potentially exceed this minimum vertical clearance height shall be identified and the operators issued with specific instructions with regard to the maximum permissible extension, prior to doing any work in the HV/EHV servitude.

j) If for any unforeseen reason, the life-threatening situation occurs where a construction vehicle comes into contact with a live HV/EHV conductor or a flash-over occurs, the operator(s) shall remain inside the vehicle and attempt to get it out of the contact situation using ONLY the vehicle's own power. On NO account shall the operator(s) leave the vehicle and on NO account shall any person approach the vehicle, until the contact situation has been reversed, or until the ESO has received confirmation from the electricity utility that the power line has been de-energized. Arcing may temporarily stop due to the action of the protection, however this in itself shall NOT be taken as an indication that the line is safe, since the line may automatically attempt to re-energize. Effective assistance in this situation entails ensuring that all persons present maintain a safe distance from the vehicle (>10 m) and alarming the electricity utility's operational centre.

k) Any foreign metal structures exposed during trenching inside or alongside HV/EHV servitudes shall be treated as a live electrical conductor, until measurement proves otherwise. The pipeline shall not be bonded any foreign structures without an assessment by a qualified engineer and written permission from the owner.

l) The use, storage, disposal, treatment or generation of any hazardous substances shall not be permitted in the power line servitude.

20.6.3. Daily Measurements

a) Qualified personnel shall measure and record the pipeline voltage to earth to verify that conditions are safe to work (a.c. < 15V r.m.s.), on all sections and on each day prior to the commencement of any construction or other activity involving contact with the pipeline.

b) For pipeline voltage measurements, a voltmeter of suitable range and impedance shall be used. Low resistance earth connections shall be used to avoid induction or capacitive pickup on test leads and related items that could result in erroneous readings on a high impedance instrument. A suitable reference is a metal rod driven into the earth.

c) Test leads shall be attached to the instrument first and then to the pipeline. After measurement, the leads shall be removed from the pipeline first and from the instrument last.

d) Each time a voltage measurement is made, the following data shall be recorded:

    i. location,
    ii. time,
    iii. date, and
    iv. pipe-to-earth voltage.

20.6.4. Temporary Earthing

a) Pipelines exhibiting voltages greater than 15 V r.m.s. shall be earthed with temporary driven earth rods. Pipelines parallel to a.c. power systems shall be earthed opposite the midpoint of each span, maximising the distance to the nearest HV/EHV structure.

b) The temporary connections to the pipeline shall be made with earthing clamps that apply firm pressure at the contact point with a mechanically sound connection, and with the coating at the contact point removed down to the bare metal. The connection between the earthing clamp and the earth rod shall be made with 25 mm² stranded copper cable, green PVC insulated.

c) To prevent the risk of personal injury or arc burns, the connection and disconnection of temporary earths shall be carried out in the following order:

- connection:
    i. the earthing clamp is connected to the pipeline,
    ii. the earthing cable is connected to the earth rod,
    iii. the earthing cable is connected to the earthing clamp.
- disconnection:
    i. the earthing cable is disconnected from the earthing clamp,
    ii. the earthing cable is disconnected from the earth rod,

iii. the earthing clamp is removed from the pipeline.

d) Temporary earths shall be left in place until immediately prior to backfilling. Sufficient temporary earths shall be maintained on each section until adequate permanent grounding connections have been made.

e) When the pipeline voltage remains above 15 V r.m.s. in spite of the temporary earth rods, temporary earth mats that extend a minimum of 1 m outside the work area shall be used. The connection between the pipeline earthing clamp and the temporary earth mat shall be made with 16 mm^2 or larger stranded copper cable. There shall be no contact between persons over the earth mat and those not over the mat, including the handing over of tools or materials.

20.6.5. Bonding Of Isolating Flanges, Joints And Couplings

a) Work on isolating flanges, joints, or couplings shall only proceed after the AC status has been verified. A temporary bond across the flange or the use of a properly sized temporary earth mat shall be used to protect personnel while they work on the pipe.

b) When cutting a pipeline, adequate bonding across the point to be cut shall be used, irrespective of the AC voltage measured between the pipeline and earth. When this voltage exceeds 15 V r.m.s, additional earthing shall be installed BEFORE cutting commences.

20.6.6. Precautions During Coating And Lowering-In Operations

a) Where coating is to be applied at field joints, precautions shall be taken to ensure that equipment contacting the bare pipe is adequately bonded and earthed. For the lowering-in operation, the coated pipeline shall be handled with nonconductive slings.

b) Because the coated pipeline may not be effectively earthed during part of this operation, contact with the bare portion of the pipeline shall be avoided when the support slings are removed from the end of the pipeline.

20.6.7. Work Stoppage

a) The ESO shall have liaison with the electrical utility to determine planned switching, outages, and load changes that may affect pipeline voltage. Work involving contact with the pipeline shall be stopped during scheduled switching of the electric power system.

b) **WORK SHALL BE STOPPED WHEN ANY LIGHTNING ACTIVITY IS PRESENT**.

20.6.8. Inspection And Testing And Of Pipeline A.C. Mitigation Components Prior To Commissioning

a) When the A.C. mitigation measures agreed upon by the eThekwini Electricity and the Pipeline Operator have been installed, an eThekwini Electricity representative shall be permitted to inspect all the components of this installation and to perform necessary measurements to prove the effectiveness of the A.C. mitigation system.
b) Final approval of the A.C. mitigation installation is subject to the outcome of this inspection.

20.6.9. Long Term Maintenance Requirements Of Pipeline And Power Line A.C. Mitigation Components

a) The A.C. mitigation measures shall be maintained by regular inspection and measurement of the effectiveness of the measures. The interval between inspections shall not exceed 6 months.
b) Maintenance personnel shall be provided with special training to acquaint them with the A.C. mitigation components, measurements and safety requirements.
c) Clear and detailed maintenance records shall be kept available for inspection by an eThekwini Electricity representative for the full operational lifetime of the pipeline.

21. CATHODIC PROTECTION REMOTE MONITORING UNIT (CPRMU)

21.1. CPRMU Packaging

Each CPRMU should include the following basic components, but not limited to:

- Instruction manual for CPRMU.
- Basic CPRMU unit.
- CPRMU mounting bracket for installation inside units to be monitored.
- Backup battery and charging circuit.
- Data management and storage capabilities.
- Installation software (CD ROM), 1 original and 1 copy required.
- Base station security access codes for historic data accessibility.

21.2. CPRMU General Specification

The CPRMU must be a self-contained unit, housed in a suitably rated enclosure that collects and stores the information from field variables in a suitable digital format. Two types of CPRMU are to be developed / supplied, namely:

21.2.1. CPRMU Type 1

This Type of CPRMU is to be used where external power supply is available typically at Transformer Rectifier (TRU's) and Forced Drainage Units (FDU's).

Variables to be measured as minimum requirement:

- Rectifier Condition. (On or Off).
- Pipe -to-Soil Potential, complete with input capacity range of ±50 Volts auto ranging.
- Coupon Potential, complete with input capacity range of ±2.4 Volts.
- Rectifier Output Current. (0mVdc to + 100mVdc) converted to Amps at base station or as determined by the unit shunt rating.
- Drain / diode Current (FDU, NDU, Cross bonds). (0mVdc to ±100mVdc) converted to Amps at base station or as determined by the unit shunt rating. Note: Drain current at cross bonds requires positive and negative range as current direction changes in the field.
- Rectifier Output Voltage, complete with input capacity range of ±100 Volts auto ranging.
- AC Ripple, complete with input capacity range of 20Vac RMS.

- Intruder Alarm.
- CPRMU actual unit backup power supply capacity.
- AC Mains Power Failure Alarm.

The CPRMU Type 1 internal building blocks consist of:

Applicable Microprocessor unit – with data processing and data logging capabilities.
Communicator – GSM or GPRS or direct RS232.
Power Supply Unit to work off 220V mains with AC ±10%.

Data capture modes to be adjustable between the following selections:

- Logging at set intervals starting from 1 reading per second to one reading every 30 seconds, similarly once per minute up to once per 30 minutes, similarly once per hour every day.
- Logging only if exception conditions are met i.e. Upper and / or Lower boundaries are breached.
- Mode adjustment to be available via remote signal or RS232 connection.
- Storage capacity to be minimum of 1 000 000 readings per channel.

21.2.2. CPRMU Type 2

This Type of CPRMU is to be used where no external power supply is available, typically at Natural Drainage Units (NDU's), Cross Bonds and Cathodic Protection Test Points.

Variables to be measured as minimum requirement:

- Pipe -to-Soil Potential, complete with input capacity range of ±50 Volts auto ranging.
- Coupon Potential, complete with input capacity range of ±2.4 Volts.
- Cross Bond (across shunt) or Drain Current (0mVdc to ± 100mVdc) converted to Amps at base station. Note: Drain current at cross bonds requires positive and negative range as current direction changes in the field
- AC Ripple, complete with input capacity range of 20Vac RMS.
- Intruder Alarm.
- CPRMU actual unit backup power supply capacity.

The CPRMU Type 2 internal building blocks consist of:

Applicable Microprocessor unit – with data processing and data logging capabilities.
Communicator – GSM or GPRS or direct RS232.

Optional:

RF Communicator – GSM. The unit may be used strictly as a data logger with RS 232 download capabilities, alternatively, the CPRMU Type 2 should allow for GSM Module to be integrated that will enable GSM transmission form the unit to a predefined base station. This option has been defined as GSM module and suppliers are encouraged to make this a separate module to the logger component so as to reduce the cost of the logger component as much as possible.

Note:

Power Supply Unit to work off replaceable and rechargeable battery backup. Data capture modes to be adjustable between the following selections:

- Logging only if exception conditions are met i.e. Upper and / or Lower boundaries are breached.
- Data transmission to be adjustable in daily increments to once per month, if the GSM module is in use.
- CPRMU Type 2 to power down unless programmed to transmit data regularly. Applicable only if the GSM module is in use.
- Storage capacity to be for 1000000 readings per channel.
- Mode adjustment to be available via remote signal, if the GSM module is in use, or RS232 connection.

21.2.3. Data Processor

All data processing factors shall adhere to the following minimum technical guidelines:

- Fixed Time Logging suppliers to provide the ranges and conditions of data capture.
- Logging by Exception to be based on the activation of the logging sequence only if the calculated average of an input valve changes by a pre-set percentage value. This pre-

set percentage value (∆ Value) must be user adjustable to activate logging for ∆ Value in a minimum range between 5% and 30% of a set point.

- Data Transmission to be via GSM Network using scheduled communication from a central base station or from the field unit back to base station when predefined exception or security conditions are met. For the CPRMU Type 1 and 2 data transmission must be enabled via RS 232 protocol or other suitable data transmission method such as Bluetooth.

21.2.4. Display Unit

The CPRMU must have an LCD (Liquid Crystal Display) screen.

This display has a dual function, firstly to monitor set-up values during CPRMU Type 1 and Type 2 configuration and secondly to monitor the measured variables during normal operation for comparison with external meter measurements.

The LCD must be able to display various selectable configuration menus as values using an external programming unit, during configuration of the CPRMU where applicable.

During normal operation the LCD must display input values by scrolling at suitable intervals.

21.2.5. Communicator

The GSM Communicator must comply with the requirements and specifications of Vodacom, MTN and Cell C. The Communicator must be capable of transmitting all data collected by the logger unit via the GSM network. For the CPRMU Type 1 and 2 the transmission of data must be permitted using a standard RS232 connection or other suitable data transmission method such as Bluetooth.

21.2.6. Power Supply

The Power supply module mounted in the CPRMU Type 1 should be capable of accepting both AC and DC supply voltages such as: 110-240VAC and 12 Vdc respectively. Typically the 12 Vdc supply will be supplied by an external battery.

CPRMU Type 1 and Type 2 shall have battery supply only. Assurance is required that during all operating modes the battery life will not be less than 5 years, with a minimum of 5 continuous logging sessions per year comprising duration of 5 days each. The balance of the period will be for periods of 1 reading every hour and one transmission per week.

The supplier shall specify how this will be achieved for CPRMU Type 2 at the same time of submitting the tender. Alternatives and different combinations will be considered on an individual basis and the merit of each offering.

21.2.7. Lightning Protection

The CPRMU will be equipped with suitable lightning protection lending itself to easy replacement and capable of offering protection to each of the input channels.

21.2.8. Documentation to Be Provided With the Tender

a. CPRMU front end capability to display historic field data from 1 to 120 days for multiple units.
b. Typical report (in graphical representation) of the CPRMU type 1 and type 2 layout– Data Logger type showing multiple data series.
c. Internal battery backup should have a 5 year maintenance free capacity for both CPRMU type 1 and type 2. The supplier is to state the maximum backup duration and expected battery life with the tender submission.
d. Software calibration details of the CPRMU and turnaround calibration time.
e. Details of technical backup that will be provided by the supplier.
f. CPRMU units used elsewhere and details of the clients that can be contacted for reference.
g. Operations Maintenance Manual (OMM) of the CPRMU.
h. Installation team experience details.

21.2.9. Site Regulations

The contractor shall comply with the site regulations of the relevant eThekwini Municipal Authorities and is required to complete the necessary indemnity forms for work conducted on the site. The responsible authorities shall be kept informed of all works conducted on their sites.

21.2.10. Installation

The installation specifications on which this contract is based are the South African Bureau of Standards Standardized Specifications for SANS 10142-1_2009 Edition 1.7 the Wiring of Premises - LV Installations.

Although not bound in, nor issued with this document, all the relevant sections of the Standardised Specifications of SANS 10142-1_2009 Edition (Latest Revision) shall form part of this Contract.

The Contractor should note that the following minimum requirements should be noted and implemented on site when installing CPRMU, aerials, surge/lightning protection, power supplies and other project related works:

1. Suitably sized and rated cable glands shall be used where cable pass through, into or out of an enclosure.
2. All cabling shall be numbered using appropriate sized labels that are legible.
3. Trunking or conduit shall be used to neatly route cables inside TRU, FDU and other permanent installations.
4. A legible circuit diagram shall be provided for each permanent CPRMU installation showing the correct cable numbering and routing to the terminals being monitored. The circuit diagram shall be provided in hard copy and on a CD in PDF format, with each PDF file named in accordance with the equipment number or name it is installed in.
5. Good workmanship is expected.
6. No loose cables will be accepted.
7. Each CPRMU installed in a permanent location must be mounted using a suitable bracket or enclosure that is fixed either on the inside of the equipment being monitored or the structure housing the equipment being monitored.
8. Aerials must be vandal proof and installed in the most inconspicuous manner possible.
9. The Contractor must make provision for tracing and locating the appropriate terminals to monitor. Should any uncertainty arise in this regard the matter must be raised with the Engineer, but it does not absolve the Contractor from completing the works.
10. The intruder alarm on powered, fixed installations shall have a minimum allowance of 1 contact switch for a ROCLA, or Brick Kiosk Door and a maximum of 6 contact switches, wired in series, for TRU/FDU equipment with multiple doors. The Contractor’s price in the Bill of Quantities is deemed to include these minimum requirements.

21.3. Typical CPRMU Variables

Typical input variables, operating environment and dimensions of the CPRMU are given below as guideline only. Each supplier shall provide detailed information of the proposed solution with their tender documents; failure to do so may prejudice the evaluation of the tender and lead to its rejection.

Logger interval	:	user adjustable range. (Sec, min, hr).
Logger Averaging	:	User adjustable range. (Sec, min, hr).
Power Supply	:	12V DC/110-2040VAC, OR (Type 2) Battery only.
Supply Load	:	20mA at 12V and 1% transmit duty Cycle. (Depending on the communication media).
Operating Temperature Range	:	- 20℃ to + 70℃.
Humidity Limit	:	95% at 40℃ (May Condense).
Maximum Dimensions	:	370mmmx140mmx80mm for CPRMU Type 1. 100mmx240mmx100mm for CPRMU Type 2.
Approximate Weight	:	Supplier to provide information.
Download	:	GSM Network or RS 232 (Bluetooth protocol Optional) .Contractor / Supplier to provide with submission of Tender document.

Dimensions of the unit should be such that it will fit into the existing cathodic protection units or into select test posts. The Contractor / Supplier shall provide the dimensions of the proposed CPRMU with the tender submission and if there are any deviations from the maximum dimensions listed above these shall be recorded as a deviation from the tender requirements.

21.4. Data Inputs

i. Output Voltage (0Vdc to + 100Vdc into 20M-ohm).
ii. Output Current (0mVdc to + 100mVdc into 33k-ohm).
iii. Drain / Diode Current (0mVdc to ±100mVdc into 33k-omh).
iv. Reference Cell, Voltage (± 50Vdc into 20M-ohm)
v. Digital alarm input (from galvanic isolated contact).
vi. Power failure. (Contractor / Supplier to specify).
vii. AC Ripple, complete with input capacity range of 20Vac RMS.

Input selection to be predefined for the CPRMU Type 2 most likely to be same as for item ii and iv above. Items iii and iv require positive AND negative range.

Note: Drain current at cross bonds requires positive and negative range as current direction changes in the field

21.5. Suggested Transducers

Each contractor to provide details of transducers that will be used to convert signals from direct measurements to acceptable inputs to the CPRMU. Information pertaining to the transducers to be submitted with the tender document detailing source of supply, technical support and offices capable of carrying out repair.

21.6. Communication Options

Due to the rather varied and remote nature of present and future sites that require monitoring THE CLIENT requires that the CPRMU have the capacity to transit all field data, with SMS capability for exceptions, intruder alarms and specific fault conditions programmed into the field CPRMU.

21.7. Channels

21.7.1. CPRMU Type 1

Channels are to be configured as follows, as minimum guidelines:

1=Output Current (in millivolts across the shunt). Software to display Ampere (A).
2=Diode Current (in millivolts across shunt). Software to display Ampere (A).
3=Mains Voltage Monitor. Software to display Voltage (V).
4=Pipe-to-soil Potential. Software to display Voltage (V).
5=Coupon Potential. Software to display Voltage (V).
6=AC Ripple.
7=Intruder Alarm.

Note 1: The use of galvanic isolation and a dedicated input lightning protection device are a prerequisite for each CPRMU. Supplier to provide full details of the input isolation technique that will be applied to the proposed CPRMU solution at the time of tender.

21.7.2. CPRMU Type 2

Only channels 1 or 2, 3, 4 and 6 of the CPRMU Type 1 unit will be applicable:

1 or 2= Drain Current (in millivolts across the shunt). Software to display Ampere (A).
4=Pipe-to-soil Potential. Software to display Voltage (V).
5=Coupon Potential. Software to display Voltage (V).
6=AC Ripple.
7=Intruder Alarm.

Note 1: Drain current at cross bonds requires positive and negative range as current direction changes in the field.

Note 2: The use of galvanic isolation and a dedicated input lightning protection device are a prerequisite for each CPRMU. Supplier to provide full details of the input isolation technique that will be applied to the proposed CPRMU solution at the time of tender.

21.8. Data Transfer, Storage and Management

Each Contractor/Supplier must provide the following with their tender submission:

a. A flow diagram setting out the data transfer path from the CPRMU Type 1 and 2 to end users. A full description of the data transfer process to be set out in writing.
b. A flow diagram indicating how the data from the CPRMU Type 1 and 2 can be integrated with a dedicated base station. A full description to be provided of the software, hardware and development requirements to be set out in the tender document cover letter.
c. Demonstration software to be stipulated in the tender submission. Examples of output graphs for the respective variables to be provided in A4 format with the tender document.
d. Computer hardware and software requirements to be stated clearly with the tender submission setting out what the minimum system requirements will be to run proprietary software.
e. Contractors to provide details of configurations available for data transfer on the proposed CPRMU Type 1 and 2 and the requirements for reconfiguration on site. Data destinations transmission durations and ability to back up data in the event of a failed transmission.

i. Contractors to provide the costs associated with the data transfer on a monthly basis for typical GSM options.
ii. Contractors to provide costs associated with data transfer once a day, once a week and the amount of data transferred per session.

f. For purposes of The Client's CPRMU application the following basic data transfer, storage and management option or combinations thereof are a prerequisite:

i. CPRMU Type 1 and 2 direct to several cell numbers, Data to include most recent input channel values and alarm status. Daily logged readings not required.
ii. CPRMU Type 1 and 2 direct to several email addresses. Data to include most recent input channel values and alarm status. Daily logged readings not required.
iii. CPRMU Type1 and 2 direct to a Base Station. Data to include daily logged channel values and alarm status as per the configuration of the CPRMU. The Base Station should keep full records of the respective CPRMU variables, with suitable identifiers for each CPRMU. Base station features to include data backup every month to CD Rom with a library facility. The Base station should essentially provide one site (at end user), secure and stable back up of CPRMU data. This is the chosen delivery configuration option for this tender document.

21.9. Maintenance, Servicing and Call Outs

The following section of the technical specification sets out the basic requirements in the event of maintenance, servicing or call-outs being initiated by the end user. Contractors are to provide detailed flow diagrams and written submission, with their tender, on how they intend to provide the services as and when they may be required in future.

21.9.1. Maintenance and Servicing

Each Contractor must submit with their tender a plan for dealing with maintenance and servicing related requirements that may arise over time with the installed CPRMU. The plan must include contact names, procedures to follow and how repair requirements will be reported to the end user before work is carried out.

THE CLIENT will not authorize work, maintenance and servicing of any CPRMU without proper procedures that identify the cause and nature of damage that may occur to CPRMU field installation.

21.9.2. Call Outs

Call out rates to be provided in the cover letter to this submission. The following basic criteria would constitute a call out:

- End user is unable to retrieve data from the CPRMU via the specified medium. Contractor to visit the end user / site within the eThekwini Municipal area.
- Calls out costs are to be calculated on the basis that the supplier is locally based.
- End user identifies a physical fault on the CPRMU on site and notifies the contractor accordingly. Contractor to visit the end user / site within the eThekwini Municipal area.
- End user identifies calibration errors that occur after successful commissioning of the respective CPRMU. Contractor to visit the end user / site within the eThekwini Municipal area.
- A call out will compromise the time and transport of a suitable skilled technician. The transport costs per call out are any site within the eThekwini Municipal area, with the restriction of one call out per site. Time to from and on site to be three (3) hours per hours per call out. Contractors to provide information on the structuring of costs and the personnel that will carry out the proposed visits. Should the call out period be exceeded the client will have to be informed of standard hourly rates that will apply.

21.10. CPRMU Guarantee and Defects Warranty

A guarantee of one (1) year is required on each CPRMU supplied and installed. In addition to the general guarantee a 24 months defects warranty is required. The guarantee and warranty must commence from the date that the CPRMU is installed and handed over to the end user. Contractors to provide detailed guarantee and warranty information setting out the following:

- Guarantee / Defects Warranty period.
- Components covered by the Guarantee / Defects warranty.
- Exclusions.
- Guarantee / Defects Warranty claim procedure.
- Contact details for responsible person who will deal with guarantee and defect warranty claims.

Failure to provide the above information in writing with the tender document may prejudice the tender and it may be rejected as a result.

21.11. Vandalism

Each contractor must provide details of vandal proofing that will be implemented to secure the GSM aerials required for communication purposes. Each contractor should note that the final installation sites may not all be within secure environments necessitating the need for secure aerial enclosure.

21.12. Airtime Agreement

For purpose of this tender contractors are to provide the following airtime options at the time of tender submission.

Note: The Contractor must provide pricing for ALL options clauses listed under this part of the specifications as failure to do so will invalidate the offer and the Client reserves the right not to reject the pricing and associated offer.

21.12.1. Direct with Cellular Service Provider

- Contractors should provide requirements for an airtime agreement to be signed directly with the cellular service provider (MTN, VODACOM, or Cell C). THE CLIENT requires sufficient information to support this option with respect to the following. Assurance of continuity of data.
- Contingency in the event of the supplier ceasing to exist ie. Data routing, use of CPRMU.
- Access to configuration software to make adjustments to the CPRMU.

21.12.2. Direct with Supplier / Distributor / Agent of CPRMU

Contractors to provide requirements for an airtime agreement to be signed directly with the supplier of the CPRMU. THE CLIENT requires sufficient information to support this option with respect to the following:

- Assurance of continuity of data
- Contingency in the event of the supplier ceasing to exist ie. Data routing, use of CPRMU.
- Access to configuration software to make adjustments to the CPRMU.

21.12.3. Prepaid Data Card Option

Contractor to provide existing options and recommendations based on different data transmission rates.

22. NAMING CONVENTION FOR EQUIPMENT AND MATERIALS

The labelling technique for each item will be specified by The Client. If a technique is not specified the labelling shall comprise the use of stencils with a compatible paint system approved by The Client before application.

The naming convention for all equipment shall following the following convention:

22.1. TRUs, SMUs, NDUs and FDUs

TRU, SMU, NDU and FDU shall have engraved name plates labelled with the following:

- Location name
- Reference number comprising: Client abbreviation, Unit Type first letter, supplier abbreviation, supply date month and year ie. XYZ/T/CPSA/0105
- Supplier serial number
- Date of Supply
- Client Name
- Font size to be no less than 6mm high

The Client shall specify external and internal labelling requirements for TRU, SMU, FDU and NDU for ease of identification. Typically these units will have the following external labels:

- Unit name
- Location
- Contact number
- Font size to be no less than 30mm high or as specified
- Black lettering on white background

22.2. Test Stations, Monitoring Points, Bunkers and Other Monitoring Facilities

Test stations, monitoring points, bunker type stations and other monitoring facilities shall have a sequential number system relative to the pipeline or pipe network. The monitoring facilities system shall be labelled as follows and/or in accordance with The Client's specifications:

- Monitoring test station :Type A
- IR free test station :Type B
- Recording stations :Type C
- Bunker stations :Type D

- Cross Bond stations :Type E
- Test station where ACM is installed :Type F*

  * = any letter from A-E depending on the type of installation within the ACM test station.
- Unique number supplied by The Client to follow above abbreviation.
- Client abbreviation will prefix the stations label. Example: XYZ/TP10013.
- Font size to be no less than 20mm high.
- Monitoring stations that have lockable doors / facilities shall include internal labelling comprising:
  - Date of manufacture.
  - Station number.
  - Pipeline route.
  - Label and print size will be determined by the space available in the enclosure.
  - Labelling to be on a white Trafolyte board with black lettering.

23. CONTRACTOR REQUIREMENTS

23.1. Construction, Testing and Inspection

The Contractor shall not commit any act of trespass or commit any nuisance and must confine all installation personnel to the servitude widths, access roads, etc., as approved by The Client so as to avoid any damage to adjacent crops, structures, fences, livestock, etc.

The Contractor shall provide and maintain at all stages of the work adequate drainage pipes at all contour drainage channels, existing furrows, subsoil drains, subsoil irrigation pipes, etc., which are cut by the works and the cost of this work shall be to The Contractors account.

The Contractor shall not permit any operation which may constitute a fire hazard.

The Contractor shall bear the cost of damage caused by fire started during the Contract or maintenance periods due to any negligence on the part of The Contractor or his workmen.

23.1.1. TRUs , SMUs, FDUs and NDUs

The Client or his representative shall at all times have the right to inspect and test all equipment, materials and workmanship as work progresses and to reject material and/or workmanship which is defective, does not comply with best Engineering practice or otherwise not in accordance with the Contract.

The Contractor shall manufacture one of each type of equipment for inspection and notify The Client of its completion.

Any rejected work or material shall be satisfactorily corrected and/or replaced, the cost to be borne by The Contractor.

On written instructions of The Client, The Contractor may be called upon to leave the pipeline exposed for inspection for any particular part of the works that they consider necessary. Such written notice can be given at any time during the installation of the works.

On completion of all works and prior to the commissioning, The Contractor shall avail himself for a final site inspection. This shall comprise of a thorough inspection of all works carried out and a punch / snag list shall be issued for any remedial works.

23.2. Work to be Supervised by a Qualified Representative

The carrying out of all works included in the contract shall be supervised throughout the duration of the Contract by an approved representative of The Contractor.

23.3. Supplier to Submit Full Details

The Contractor shall submit full data and particulars to enable a decision on the conformity of the equipment, etc., offered to the Specification and to enable a comparison with the other quotations / proposals received.
The data and particulars required which shall be submitted in duplicate, shall include full technical, descriptive and dimensional particulars and drawings of:-

- Transformer Rectifier Units,
- Switch Mode Units,
- Natural Drainage Units,
- Resistive Bonding Units,
- Mixed Metal Oxide Anodes and
- Any other equipment as specified in the Bill of Quantities.

No proposal / quotation will be considered which is not accompanied by sufficient data and particulars as described above. Unless specifically stated, it will be assumed that all equipment complies in full with the Specification.

23.4. Commissioning, As-Built Drawings and Records

23.4.1. Commissioning

The CP System will be commissioned by the appointed Specialist Consultant to ensure that the installation was performed to standard and that all respective equipment operates satisfactorily.

23.4.2. Drawings

All drawings are to be to scale and presented in AutoCAD 2000 format. Prior to finalising drawings it shall be submitted to The Client for their perusal and approval.

23.4.3. Records

Records of the installation, problems and site meetings shall be kept and handed to The Client upon handover.

23.4.4. Spare Parts

Spares (2 off) shall be supplied as specified and either attached to a panel affixed inside the equipment cabinet or separately in a spares box. Listing of all spares detailing their specifications, locations and sizes shall be attached to the equipment.
The component manufacturer (supplier) list and contact details shall be provided with all spares complete with current price list – fuses, MOVs, diodes, Thyristors, spark gaps and control cards.

23.5. Installation

23.5.1. Supply / Installation Obligations

The Contractor shall warrant and guarantee that the materials and workmanship provided shall be in accordance with the Contract Specification and documentation.

The Contractor shall furnish to The Client, on completion of all works and before Contractor's handover, As-Built Drawings of:

- Equipment.
- Cable routes to pipe.
- Cable routes to anodes.
- Power supply cables.
- Cabinets.
- Enclosures.
- Test posts
- All significant installations included in the Bill of Quantities or Technical Specification.

The purpose of the As-Built Drawings is to provide The Client with a correct record of all works carried out. The Contractor shall confirm at the time of tender:

- GPS sub-centimetre accuracy.
- Format for presenting captured data.
- Detailed sketches required to explain the captured data.

- The Client's contact person/s to verify As-Built Data with.

It shall be the responsibility of The Contractor to ensure that all items are available for inspection prior to delivery.

All materials, plant and equipment shall be the best of their respective kinds and spare parts, replacements and servicing facilities shall be readily available from local sources.

All work shall be carried out by qualified personnel and shall be correctly supervised.

23.5.2. Guarantee of Equipment

The Contractor is required to supply a written guarantee on the items supplied by him for a period of 2 years (this is in addition to the standard defects liability period of 1 year) from date of commissioning under continuous working conditions. In the event that the CP and AC Mitigation Contractor is appointed as a sub-contractor to the main construction contractor the guarantee terms shall, as a minimum, be the same as those of the main contractor.

Any faults as may be certified by The Client due to poor materials, workmanship or The Contractor's design (where applicable), shall be remedied and faulty goods replaced entirely at The Contractor's cost.

The Contractor is responsible for the guarantee of all items under the terms of this tender and for the safe delivery and installation of the equipment and materials, as called for in the Bill of Quantities, unless otherwise instructed in writing by The Client

23.6. Operation and Maintenance of the CP System

The CP System Operation and Maintenance Manual (OMM) will provide the owner and technical staff with knowledge on the operation of the CP system and the subsequent maintenance thereof.

23.7. CP System Acceptance Criteria

23.7.1. Operational Acceptance Period

When all tests have been successfully completed to the satisfaction of The Client, an operational acceptance period shall start and shall consist of a continuous period of operation of two weeks free from trouble. During the operational acceptance period The Contractor shall carry out all necessary servicing and any adjustments required.

23.7.2. Certificate of Completion

A certificate of completion will be issued in line with the conditions of contract applicable to the specific project in question.

24. CONSULTING AND ENGINEERING SERVICES

24.1. Method Statements and Performance Criteria Statement

Before any consulting or engineering task is undertaken the onus rests on the organisation tasked with the work to provide a detailed method statement that will include as a minimum:

- The relevant, recognised standard that will be used a baseline for reference or evaluation purposes.
- The specific method statement for the work at hand that sets out the expected challenges, proposed solutions, actual evaluation and assessment of results.
- Quality Control and Assurance Plan complete with suitable methods for application in the field and during the reporting phase to ensure a high level of repeatability and traceability.
- Hold Points for Client or authorised representative validation and sign off.
- Reporting format and level of raw data to be provided.
- Failure to provide the minimum information set out above may result in The Client exercising the right to issue a re-work instruction for the specified tasks to be repeated at no cost to The Client.

Performance Criteria Statement shall be established before field work and investigations are undertaken and will typically require the following as a minimum:

- Project Schedule with a minimum of Level 3 planning visible for main tasks.
- Milestone dates for the delivery / completion of each task.
- Anticipated delays: rain, access, interference from 3rd parties, equipment failure, permits, health, safety and environmental requirements. The Project Schedule should make adequate provision for anticipated delays that can be validated by The Client in the event of a cost implication.
- Performance Measurement and Payment shall be linked to the Project Schedule, agreed milestones and specific Quality Control and Assurance criteria that can be measured.

- The organisation undertaking the surveys, investigations, designs, QA/QC and field supervision shall submit a Performance Criteria Statement to The Client for review, acceptance and sign off before work commences on site.

Failure to provide the minimum information set out above may result in The Client exercising the right to issue a re-work instruction for the specified tasks to be repeated at no cost to The Client.

24.2. SURVEYS AND INVESTIGATIONS

24.2.1. Soil Resistivity

- Measurement at 100m intervals and 50m if less than 50 Ω.m.
- All measurements to comply with ASTM G57 (Wenner Four Pin Method)
- All measurements to be supplied with GPS co-ordinates (minimum 5m accuracy) WGS 84 Datum.
- Two readings per location by the Wenner 4 pin method with a spacing of 1m and at the average pipe invert depth. Layer resistivity to be calculated for the two layers.
- Results to be tabulated and presented as resistance and calculated layer resistivity values.
- Results to be plotted on a map using GIS software, colour coded according to parameter values.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.
- Instruments: Calibrated Null balance Soil resisitivity meter.
- Applicable wire harness.
- Steel Copper plated / Galvanised electrodes ASTM G57.

24.2.2. Spot Pipe-To-Soil Potentials

- Test post number to be provided for each recording or sub-metre accurate GPS co-ordinates.
- Measure potentials with respect to a saturated $Cu/CuSO_4$ reference electrode (unless otherwise specified) at all available monitoring facilities, valve chambers and above ground pipe segments.
- Results to be tabulated.
- Results to be plotted on a map using GIS software, colour coded according to parameter values.

- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.
- Instruments: Digital Voltmeter – 10MΩ Minimum Input Impedance.
- Reference Electrode Saturated Cu/$CuSO_4$ reference electrode (unless otherwise specified).
- Relevant SANS and NACE standards shall be weighed up against site conditions, stray current conditions, foreign structures / pipelines and the congestion of the pipeline route to select the most suitable measurement / assessment technique.

24.2.3. Stray Current

- The presence of stray currents and the magnitude shall be assessed prior to the installation of the pipeline and after the installation. Acceptable input impedance data loggers shall be used with the sampling rate of at least one value in every 5 seconds for a minimum duration of 24hrs.
- Relevant SANS and NACE standards shall be weighed up against site conditions, stray current conditions, foreign structures / pipelines and the congestion of the pipeline route to select the most suitable measurement / assessment technique.
- Recordings to be carried out at 1km intervals along the pipeline route on existing pipelines. Where a route is being assessed prior to pipe installation, an assessment is to be made by recording the potentials of existing adjacent metallic infrastructure such as existing pipelines, powerlines etc. Where the pipeline crosses a railway line, the potential of the rail is to be recorded at the crossing point. Where the pipeline route runs parallel to a railway line, the rail potential shall be recorded at the point of approach and departure of the parallelism as well as at 1km intervals in between.
- Provide Raw data files plus graphs.
- Results to be plotted on a map using GIS software, colour coded according to average, maximum and minimum parameter values. Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form. The Consultant must determine if the raw information may be provided to The Client for overlay onto their existing GIS system or if a shape file is required.
- Scale to be clearly indicated (Volt Scale to be used) and standardised for each recording.
- Instruments: Digital Recording Data Loggers.
  - Input impedance must be greater than 10MΩ.
  - Must be synchronisable – date and time stamped. If not possible a concession from The Client is required.

- Voltage ranges +20Vdc to -20Vdc and +100mV to -100mV.

24.2.4. Electrical Continuity, Isolation and Coating System

- Electrical continuity of pipelines shall be assessed under current drainage conditions.
- A DC current is to be applied to the pipeline by means of a suitable portable transformer rectifier unit and temporary groundbed and shift in pipe potential is to be determined at all available monitoring points, valve chambers and above ground pipe segments. Where an electrical discontinuity is suspected, a test is to be set up at a point beyond the suspected break and the discontinuity verified. In some cases it may be possible to install a temporary continuity bond as a means of verifying the break and extending the range of the test. Testing should cover the entire pipeline length.
- All locations requiring continuity bonding shall be identified such from the testing as well as from visual inspections of features such as in-line valves, etc.
- All pipeline electrical isolation requirements shall be determined and identified during the survey. This shall be determined from the current drain test results as well as from visual inspections.
- Results to be plotted on a map using GIS software, colour coded according to average, maximum and minimum parameter values.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.
- Equipment and Instruments:
  - Suitably rated portable transformer Rectifier unit
  - Portable generator
  - Cabling and earthing equipment
  - A suitably rated solid state DC interrupter
  - Digital Voltmeter – 10MΩ Minimum Input Impedance. Reference
  - Saturated $Cu/CuSO_4$ reference electrode (unless otherwise specified)

24.2.5. Current Requirement

- Pipeline current requirement is to be determined under current drainage conditions.

- A DC current is to be applied to the pipeline by means of a suitable portable transformer rectifier unit and temporary groundbed and shift in pipe potential is to be determined at all available monitoring points, valve chambers and above ground pipe segments.

- Spot pipe-to-soil potentials at each installed monitoring facility or selected locations prior to and during survey
- Temporary continuity bonding (Minimum 16mm² PVC cable – thermit welded / stud welded) may be installed if required. No clamped connections.
- Greater than 12 hour data recordings at selected locations
- Results to include calculated current density. Current density calculations are to take into account the attenuation profile of the test.
- Instruments:
  - Suitably rated portable transformer Rectifier unit
  - Portable generator
  - Cabling and earthing equipment
  - A suitably rated solid state DC interrupter
  - Digital Voltmeter – 10MΩ Minimum Input Impedance
  - Reference Electrode Saturated Cu/$CuSO_4$ reference electrode (unless otherwise specified)
  - Digital Data Loggers

24.2.6. Sulphate Reducing Bacteria (SRB)

- Soil samples to be collected and tested for the presence of SRB at pipeline depth.
- The laboratory facility, test kit or proposed method of assessment must be detailed and presented to The Client for acceptance and sign off before the tests are conducted. Failure to do so may result in a re-work instruction at no cost to The Client.
- Results to be plotted on a map using GIS software, colour coded according to parameter values.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.

24.2.7. Chemical Substance Analysis

Soil samples are to be analysed at 5km intervals (or as stipulated by the client) for the following:

- pH
- Calcium hardness (as CaCO3) (mg/ℓ) - Phenolphthalein
- Magnesium ion (as Mg) (mg/ℓ)
- Total sulphate ion (as SO4) (mg/ℓ)
- Chloride ion content (as Cl) (mg/ℓ)

- Total dissolved solids (mg/ℓ)
- Conductivity (mS/m)
- Redox Potential (V)

24.2.8. Holiday Detection

- Calibrated High Voltage Spark Tested as per SABS 1178 Section 7.2.2.
- Calibrated Wet Sponge Tester shall be used for internal linings.

24.2.9. Internal Inspection

- Physical inspection - access to be gained via access hole / valves.
- Digital colour photographs to be taken.
- Slime and/or any bacterial activity to be observed, collected and analysed.
- Upon The Client’s request a Close Circuit Television (CCTV) camera inspection may be conducted.

24.2.10. AC Interference

- A comprehensive AC Mitigation survey shall be carried out as per NACE SP0177, in order to evaluate corrosion and safety risk of pipeline and satisfy the requirements issued by Eskom or eThekwini Electricity Department.
- Where transmission pipelines are located in close proximity of high voltage power lines, where resistive and/or capacitive and/or inductive coupling may occur, computer modelling of the system shall be performed in order to determine the extent of the interference under steady state and fault conditions.
- All of the relevant data pertaining to the supply authority shall be obtained including tower positions (coordinates), conductor details tower geometries, locations of transpositions, peak load currents and fault current information, The soil resistivity is to be measured to depths of 200m in exponential increments as follows : 0.1m, 0.2m, 0.3m, 0,5m, 0,7m, 1m, 2m, 3m, 5m, 7m, 10m, 20m, 30m, 50m, 70m, 100m, 150m, 200m. Soil resistivity measurements are to be taken at all crossings between pipelines and powerlines as well as at 1km intervals where the servitudes run parallel.
- A three dimensional model of the system is to be constructed incorporating all pipelines and powerlines known to lie within the system.
- Soil data collected is to be processed into multilayer soil models with an RMS error of less than 15%. This modelled soil data for each respective region is to be inserted into the interference model.

- The computer model is to be used to determine the extent of steady state and fault condition interference as well as to design the measures required to mitigate the interference to within acceptable ranges.
- The likelihood of AC corrosion occurring on the pipeline/s being investigated should be based on current density estimations and not purely AC voltage and soil resistivity. Various approaches of assessing the likelihood of AC corrosion are set out in the following standards / reports: NACE SP0169:2013, BS EN 15280:2013 and NACE International Publication 35110:2010 amongst others.
- The Consulting Engineer shall provide a suitable monitoring and assessment regimes for the following:
    - Pipe AC and DC potentials to soil using approved coupons or coupon stations and calibrated copper copper sulphate reference electrodes.
    - Coupon AC and DC current densities.
    - The likelihood of corrosion based on approved methodologies set out in BS EN 15280:2013.
- Guidelines for minimum data requirements are set out in Annexure C: AC Mitigation Data Requirements Guideline.
- Equipment and Software:
    - Deep Soil Resistivity Meter :

      An appropriate deep soil resistivity meter capable of at least 800W of output and with facilities to measure and report standard deviations of each reading.
    - Software :

      Software to be used is CDEGS Right of Way Pro, Elsyca or equivalent engineering methods must be demonstrated. The software shall have the following capabilities as a minimum:
        - Allow for the construction of a complete three dimensional interference model containing multiple pipelines, multiple power lines within an environment of multiple (regional) multi-layer soils.
        - The facility shall exist to individually specify for each element within the system, three dimensional geometries, coating conductance, conductor material parameters, and energizations.
        - The software shall calculate, at a user selected interval, the steady state interference effects as well as the total (Conductive, Inductive and Capacitive) interference effects under fault conditions.

24.2.11. Pipeline Current Mapping (PCM) Survey

- Current and Current Loss Measurements to be made at 50m intervals for old pipelines (>10years) and 100m interval for new pipelines (<10 years).
- Defect locations to be identified in numerical order.
- GPS sub-metre accurate coordinates and pipeline chainages to be supplied for all measurements.
- Defect sizes (dB) to be identified and correlated with excavations.
- Results to be plotted on a map using GIS software, colour coded according to parameter values.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.
- Instruments :
  - Pipeline Current Mapping (PCM) equipment shall be used.
  - "A" Frame shall be used to pin-point defects.
  - Sub metre accurate GPS equipment shall be used.
- Relevant SANS and NACE standards shall be weighed up against site conditions, stray current conditions, foreign structures / pipelines and the congestion of the pipeline route to select the most suitable measurement / assessment technique.

24.3. Anode Groundbed

- Identify all possible locations, with and without AC power availability.
- Locate closest possible AC supply points
  - Relevant reference numbers on all masts
  - GPS coordinates WGS 84 Datum
  - Land owner details
  - AC supply owner details
- Sub-metre accurate co-ordinates to be supplied with all measurements.
- Resistivity is to be measured at pin spacings as follows : 1m, 2m, 3m, 5m, 7m, 10m, 20m, 30m, 50m, 70m, 100m, 150m, 200m.
- Distance >100m from pipeline for all conventional horizontal type anode beds.
- Soil resistivity values are to be used to derive a multilayer soil model utilising computer software.
- The multilayer soil model is to be used to calculate anode groundbed resistance within a three dimensional DC computer model. The same computer model shall be used to calculate the attenuation profile along the pipeline.

- Results to be plotted on a map using GIS software, colour coded according to parameter values.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form.
- Instruments and Software:
  - Deep Soil Resistivity Meter :
    An appropriate deep soil resistivity meter capable of at least 800W of output and with facilities to measure and report standard deviations of each reading.
  - Software :
    Suitable engineering methods must be demonstrated.

24.4. Direct Current Voltage Gradient (DCVG) Survey

- Relevant SANS and NACE standards shall be weighed up against site conditions, stray current conditions, foreign structures / pipelines and the congestion of the pipeline route to select the most suitable measurement / assessment technique.
- This survey will require a full DCVG survey equipment set including temporary rectifier systems, if there is no permanent CP system.
- Current interrupters will be installed at all DC current sources on either side of the section being tested. The switching cycle will be 900ms/450ms Off/On.
- The current interrupters shall be synchronized by means of GPS.
- The location of defects shall be made while walking directly over the pipeline. Measurements of the size of the defect shall be taken at every defect using remote earth.
- Position measurement of the defect shall be by means of GPS. GPS coordinates shall be to sub-metre accuracy.
- The coating integrity survey shall be undertaken by means of DCVG survey technique in accordance with NACE TM 0109 section 6, with compensation for stray currents. (Refer to NACE SP 0207)
- Results to be plotted on a map using GIS software, colour coded according to parameter values. The Consultant shall confirm what The Client's requirements are before commencing with the works as GIS departments vary in approach and may have different requirements for presenting and assimilating the data.
- Results to be supplied as hard copy as well as in spreadsheet and shape file soft copy form. The Consultant shall confirm what The Client's requirements are before commencing with the works as GIS departments vary in approach and may have different requirements for presenting and assimilating the data.

24.5. Close Interval Potential Survey (CIPS)

Relevant SANS and NACE standards shall be weighed up against site conditions, stray current conditions, foreign structures / pipelines and the congestion of the pipeline route to select the most suitable measurement / assessment technique. This survey will require one mobile data logger and two static data loggers.

Current interrupters will be installed at all DC current sources as well as at the pipe/coupon connection of the test stations on either side of the section being tested. The switching cycle will be 800ms/200ms On/Off. The current interrupters and the data loggers shall be synchronized by means of GPS.

Static data loggers shall be installed at test stations on either side of the section to be surveyed. These tests shall capture the “on” and “off” coupon potential values for a 24 hour period each at a minimum interval of 1s.

The “on” and “off” measurements shall be made while walking directly over the pipeline. Measurements shall be taken at least every 2m with an “off” value being recorded at least every 5m. Position measurement shall be by means of a surveyor’s wheel as well as by GPS. GPS coordinates shall be recorded on the mobile data logger while surveying.

24.6. Design and Reporting

24.6.1. General Considerations

- Reference to be made to all relevant standards and specifications.
- Pipeline and landowner servitudes to be observed and adhered to.
- Design to afford protection for at least 20 years.
- The CP system to be complimentary to the protective coating system.

24.6.2. Choice of CP System

- Possible choices of CP system types to be considered during the investigation surveys. The two choices are ICCP or SACP.
- The choice to depend on practicality, cost effectiveness and other prevalent site conditions.
- Each system type to be investigated, discussed and motivated.
- Preliminary designs and budget estimates of each system type to be provided if applicable.

24.6.3. Detailed Design Calculations

- The final design document shall include all design calculations and the conclusion reached.
- The design calculations to be based on approved technical specifications and standards. All references to submitted with the design report.
- Certain components of the design shall be determined utilising modelling software. These include AC interference effects, DC interference effects, and anode groundbed designs.

24.6.4. Commissioning and Interference Surveys

Annexure D: Annexure D: Commissioning and Interference Survey Guideline sets out minimum guidelines for The Consultant to carry out these surveys and to report accordingly.

24.6.5. Compliance Certificates and Factory Acceptance Testing

The following Annexures set out the templates for both The Contractor and The Consultant to work towards when testing TRU, SMU and FDU equipment.

Annexure A: TRU/SMU/FDU/NDU Certificate of Compliance

Annexure B: TRU/SMU/FDU/NDU Factory Acceptance Testing Template

These templates are guidelines and considered the absolute minimum reporting requirement for both The Contractor and The Consultant to use when preparing hand over documentation for The Client

24.6.6. Reporting

- Three copies of each report to be provided along with a suitably marked CD containing the report in PDF format.
- Results provided in tabulated, graphical and statistic formats where applicable.
- Comments and Discussion of results.
- Graphs of data recordings (voltage scale clearly indicated).
- Recommendations.
- Estimated budget figures.
- Raw Client data (as uploaded from the data logger including any PCM survey) and the converted *.txt file format to be included on CD for each recording made.

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25. ANNEXURES

Annexure A:	TRU/SMU/FDU/NDU Certificate of Compliance
Annexure B:	TRU/SMU/FDU/NDU Factory Acceptance Testing
Annexure C:	AC Mitigation Data Requirements Guideline
Annexure D:	Commissioning and Interference Survey Guideline
Annexure E:	Isolating Flange Guidelines
Annexure F:	Local Content Requirements for Transformers
Annexure G:	Drawing Register
Annexure H:	Revision Schedule

25.1. Annexure A: TRU/SMU/FDU/NDU Compliance Test Certificate

Compliance Test Certificate

1. Visual Inspection (TRU/SMU/FDU/NDU)

Using an approved circuit diagram conduct the following inspections:

1.1. Correct Component Connections

Check through the unit and confirm that the wire connections made on the specific components are correct. **Yes/No**

Check that all the components in the unit are compliant with the original specifications and correspond with the circuit diagram. **Yes/No**

Are fuses installed in compliance with the design? **Yes/No**

2. Insulation Test (TRU/SMU/FDU/NDU)

Carry out a 1 kV insulation test as follows:

Temporarily disconnect the MOV's mounted in the primary and secondary circuits.

2.1. Transformer (TRU and FDU where an SMU is not used. Not for NDU)

AC Input to Frame…………………………………………… Meg Ohm at 1 kV

Primary Winding to Secondary Winding………………….. Meg Ohm at 1 kV

2.2. Output (All Units)

DC Positive to Frame…………………………….……….. Meg Ohm at 1 kV

DC Negative to Frame………………………………………… Meg Ohm at 1 kV

2.3. Earth (All Units)

Earth bar / stud to any non-insulated Mounting Stud ……………………...Ohm

Does the earth bar / stud meet Technical Specification / Drawing Requirements of only 2 terminations per bolt/stud?............................. **Yes/No**

Reinstate the connections to the surge devices (Not for NDU) .... **Yes/No**

3. Display / Meter Tests (TRU/SMU/FDU)

Monitor the voltage, current and reference potentials as displayed on the analogue meters and the Reference Meters LCD display. Also record direct measurement of these parameters with a handheld multi-meter.

Measurement errors must not exceed **5%** using the handheld multi-meter as the standard. List the following results as follows:

	LCD / Panel Meter Display	Digital Multi-meter (DMM)	Error (V)	Error (%)
DC Output Voltage (V)				
DC Output Current (A)				
Reference Potential (V)				
Reference Set Point (V)				

Measurement errors are calculated from comparisons between the Controller LCD/Panel meter and the DMM. **PASS / FAIL**

4. Efficiency Test (TRU/SMU/FDU)

4.1. No Load

Input Voltage……………………….. Volts. Input Current…………………Ampere.

4.2. 25% Load

Output current at 25% of maximum Ampere; Output Voltage…………...V

Input Voltage……………………….. Volts

Input Current……………….……… Ampere

4.3. 60% Load

Output current at 60% of maximum Ampere; Output Voltage……………...V

Input Voltage……………………….. Volts

Input Current………………………. Ampere

4.4. 100% Load

Output current at 100% of maximum Ampere; Output Voltage……………V

Input Voltage……………………….. Volts

Input Current…………….………. Ampere

4.5. Efficiency Calculation

Output Voltage x Output Current = Eo
Average of the three Input Voltages x Average of the three Input Currents x 1.73205 = Ep
Eo / Ep x 100 = % Efficiency.

25% Load ……………………….. % Efficiency

60% Load ……………………….. % Efficiency

100% Load ……………………….. % Efficiency

5. Output Voltage (Manual TRU/FDU)

Lowest Tap Setting…………………………………………...Volts

Highest Tap Setting…………………………………………..Volts

Step Increments of…………………………………………...Volts

6. Output Load Test Certificate (One per Unit: TRU/SMU/FDU)

6.1. Connect a load to the unit that will permit a current output of approximately 15% more than the rated unit current for a period of 10 minutes.

Output Voltage……………………………… Volts

Output Current………………………………. Ampere

DC fuses must not rupture at this load.

6.2. Connect a load to the unit that will permit a current output of approximately 20% more than the rated unit current for a period of 10 minutes.

Output Voltage……………………………… Volts

Output Current………………………………. Ampere

DC fuses must not rupture at this load.

6.3. Connect a load to the unit that will permit a current output of approximately 25% more than the rated unit current for a period of 10 minutes.

Output Voltage……………………………… Volts

Output current………………………………. Ampere

Time delay to fuse rupture………………………………………… minutes

7. AC Overload Tests (TRU/SMU/FDU)

Replace the DC fuse links with link bars. Increase the current output to 20% above the rated unit output current.

Time the duration it takes for the AC Fuse to rupture...................................... minutes

Should the AC fuses not rupture within 30 minutes the TRU fuse selection is deemed to be incorrect.

Check all wiring for signs of discolouration after completion of the test. **PASS / FAIL**

8. DC Output Overload Tests (TRU/SMU/FDU)

Replace the AC fuse links with link bars. Increase the current output to 20% above the rated unit output current.

Time the duration it takes for the DC Fuse to rupture... minutes

Should the DC fuses not rupture within 30 minutes the TRU fuse selection is deemed to be incorrect.

Check all wiring for signs of discolouration after completion of the test. **PASS / FAIL**

9. Fault Indication and Reset Testing (TRU/SMU/FDU)

Where a unit specification requires built in fault indication, with associated relay switching, this testing shall be carried out.

Operate the following fault indicators manually and observe whether or not the indication is correct on the instrument cabinet. When the fault is manually activated, the LED indication should change from Green to Red where applicable and if an intelligent control card is installed this too shall indicate the fault condition correctly.

9.1. AC Fuse Fail **PASS/FAIL**

9.2. DC Fuse Fail **PASS/FAIL**

9.3. Remove one of leads to the Thermal Switch on the heat sink and verify that the condition registers and indicates correctly. **PASS/FAIL**

9.4. With a Load connected to the TRU check that when the load is decreased to the point where the current falls below 50mA the No Current Hour meter begins to totalize up. **PASS/FAIL**

9.5. Depress the No Current Hour Meter reset push button and check that the totalized value resets to zero. **PASS/FAIL**

9.6. Swap any two mains input phases feeding the TRU and check that the Phase rotation output relay changes state and that the indication on the instrument cabinet changes from Green to Red. **PASS/FAIL**

10. Tap Settings (Manual TRU/FDU)

10.1. Change connecting links in each of the settings below and record the open circuit voltage measured at the output buss bars where the field connections will be made with no load. Adjust the table for test results to suit the number of tap settings on the specified unit.

Fine / Coarse	Fine 1	Fine 2	Fine 3	Fine 4
Coarse 1				
Course 2				
Coarse 3				
Coarse 4				

10.2. Change the connecting links in each of the settings below and record the voltage measured at the output buss bars where the field connections will be made with a load calculated to achieve 100% of the rated unit current output for each voltage setting.

Fine / Coarse	Fine 1	Fine 2	Fine 3	Fine 4
Coarse 1				
Course 2				
Coarse 3				
Coarse 4				

11. Output Wave form (TRU/SMU/FDU)

Use an oscilloscope with a built in recording function to record the output wave form with the tap settings set to maximum voltage and maximum current. Save the wave form in the relevant job file and present a hard copy with the hand over documentation.

Measure the ripple and capture the wave form in the following two modes (where a smoothing capacitor has been specified):

11.1. Capacitor installed.. Volts AC

11.2. Capacitor not installed……………………….………… Volts AC

11.3. Measure current flowing in the capacitor circuit……….. Ampere AC

(Use a clamp on ammeter to measure 11.3)

12. Heat Run (One test per Unit Type) (TRU/SMU/FDU)

12.1. Using a Temperature logger connect the TRU up to a 100% Load and run the TRU until not further Temperatures increase is noted.

12.2. Maximum Rectifier Stack temperature…………………………………… (°C)

12.3. Maximum Transformer Coil temperature (Not for SMU)..……………… (°C)

12.4. Maximum Cabinet Internal ambient bottom of cabinet………………….. (°C)

12.5. Maximum cabinet internal ambient top of cabinet…………..…………….. (°C)

12.6. External Ambient…………………………………………..…………………. (°C)

13. Control Mode Tests (Automatic Control TRU/SMU/FDU)

13.1. Constant Current

Current Set Point: ……………………………….. (Amps)

Vary the load resistance to simulate voltage changes through the full rated voltage range of the unit and observe whether or not the current set point is maintained. **PASS/FAIL**

13.2. Constant Voltage

Voltage Set Point: ……………………………….. (Volts)

Vary the load resistance to simulate current changes through the full rated current range of the unit and observe whether or not the voltage set point is maintained. **PASS/FAIL**

13.3. Constant Potential

Structure-to-Electrolyte Set Point: ……………………………….. (V_{CSE})

Vary the load resistance to simulate current /voltage changes on the unit and observe whether or not the structure-to-electrolyte set point is maintained.

PASS/FAIL

14. Diode Test (FDU/NDU)

Disconnect the diode from any parallel or connected circuits. Using a variable DC power supply apply a voltage across the diode in the forward direction until current passes and then steadily increase the current to 20% of the unit rating. Record the following:

Unit Ampere Rating ……………… (Ampere)

Unit Fuse Rating ……………………. (Ampere) Fuse Type / Make………………………….

Voltage across diode at which current first passes ……………………………… (Volts)

Current flow measured across shunt at 20% of unit rating ……….……............. (Ampere)

Current displayed on panel meter at 20% of unit rating ………………….....…… (Ampere)

Using a diode tester. Test the diode in the forward bias ……………….............. (Volts)

Using a diode tester. Test the diode in the reverse bias ………………………… (Volts)

Shunt Rating ……………………………………………………………………….. (A/mv)

Does the shunt and panel meter rating suit the unit current rating?.................. **Yes/No**

Does the unit pass or fail the requirements of the Technical Specification and Drawings?

PASS/FAIL

For The Client :

I……………………………………………………………………… hereby acknowledge that the above test results were obtained from tests carried out in full accordance with the Technical Specification. Further, I acknowledge that the guarantee period, as contained in the aforesaid contract document, commences from date given therein.

Signed this………….day of ……………………20................ at ………………………………...

Name: ………………………………………………. Signature: …………………………………..

For the Contractor/Supplier/Manufacturer:

I **……………………………………………………………………………………..** hereby acknowledge that the above test results were obtained from tests carried out in full accordance with the Technical Specification. Further, I acknowledge that the guarantee period, as contained in the aforesaid contract document, commences from date given therein.

Signed this………….day of ……………………20................ at ………………………………...

Name: ………………………………………………. Signature: …………………………………..

25.2. Annexure B: TRU/SMU/FDU/NDU Factory Acceptance Testing

FACTORY ACCEPTANCE TESTING

Date ________/________/20______ Place____________________

Present ____

Unit Information

Supply	1Ph	3Ph
Rectifier Construction	Frame	Cabinet

Rectifier Manufacturer ______________________________

Rectifier Rating / Size ______________________________

Type of DC Output Control ______________________________

Serial No. ______________________________

Tag No. ______________________________

Visual Inspection			
Cabinet / Frame			
Workmanship & Painting	YES	NO	N/A
Frame completely coated with Galvanizing	YES	NO	N/A
Cabinet Paint no missed spots No Dents / Scratches on cabinet	YES	NO	N/A
Dimensions match general arrangement.	YES	NO	N/A
Final Coat DFT			
Electrical			
Compliance to Data Sheet	YES	NO	N/A
Surge Protection installed AC - Make:______________________	YES	NO	N/A
Surge Protection installed DC - Make:______________________	YES	NO	N/A
RMU Fitted - Make:______________________	YES	NO	N/A
Covers Over AC Terminals	YES	NO	N/A
All Labels Fitted	YES	NO	N/A
Bus bar Labels Fitted	YES	NO	N/A
DC Isolator / links Fitted	YES	NO	N/A
kWhr Meter Fitted	YES	NO	N/A
Door Switch Fitted	YES	NO	N/A
Main AC Isolator	YES	NO	N/A
ELR Fitted	YES	NO	N/A
15A Socket Outlet Fitted	YES	NO	N/A
MCB For Socket Outlet	YES	NO	N/A
Type of Diode (SKR, 16mm Stud, 1600 PIV)	YES	NO	N/A
Fast Blow Fuse	YES	NO	N/A

Fuse Current Rating Bridge ____________________ Amp

Fuse Current Rating NDU ____________________ Amp

Type of Panel Meters	Digital	Analogue	N/A
Rectifier Output Voltage Meter	Yes	Yes	N/A
Rectifier Output Current Meter	Yes	Yes	N/A
Rectifier Output Bypass Current Meter	Yes	Yes	N/A
Correct Shunt Rating for Unit	Yes	Yes	N/A
Correct Bypass Shunt Rating for Unit	Yes	Yes	N/A
Wiring Sizes and Selection	Yes	Yes	N/A
Barriers and Shrouds on Power Connections	Yes	Yes	N/A
Wiring Point to Point According to Wiring Diagrams	Yes	Yes	N/A
Tagging	Yes	Yes	N/A
Labelling	Yes	Yes	N/A

Constant Current

Setting

AC Voltage ______________ Volts AC Current ______________ Ampere

DC Voltage ______________ Volts DC Current ______________ Ampere

Percentage AC Ripple: ____

Remarks: ____

____

____

Constant Voltage

Rectifier Setting ____________

AC Voltage ________ Volts AC Current ________ Amp

DC Voltage ________ Volts DC Current ________ Amp

Percentage AC Ripple ____________________

____

Remarks: ____________________

____

____

Constant Potential

Rectifier Setting ____________

AC Voltage ________ Volts AC Current ________ Amp

DC Voltage ________ Volts DC Current ________ Amp

Percentage AC Ripple ____________________

____

Remarks: ____________________

____

____

Control Manual Variable Transformer

Rectifier Setting ____________

AC Voltage ________ Volts AC Current ________ Amp

DC Voltage ________ Volts DC Current ________ Amp

Percentage AC Ripple ____________________

____

Remarks: ____________________

____

____

Auto Control

Rectifier Setting ____________________

AC Voltage ____________ Volts AC Current ____________ Amp

DC Voltage ____________ Volts DC Current ____________ Amp

Percentage AC Ripple ____

____

Remarks: ____

____

____

Acceptance of Tests

Test Results Accepted | Yes | No |

Manufacturer's Representative

Name ____________________ Date ______ / ______ /20 ______

Designation ____________________________

Signature ____________________________

The Engineer

Name ____________________ Date ______ / ______ /20 ______

Designation ______________________________

Signature ______________________________

The Client

Name ____________________ Date ______ / ______ /20 ______

Designation ______________________________

Signature ______________________________

25.3. Annexure C: AC Mitigation Data Requirements Guideline

AC MITIGATION DESIGN: PIPELINE INFORMATION REQUIRED

1. PHYSICAL DATA OF OVERALL SYSTEM

1.1. Overview of System. Provide a map on which are indicated the following:

1.1.1. The pipelines under study,
1.1.2. All parallel or roughly parallel high voltage circuits which come within 1 km of the pipelines,
1.1.3. All other pipelines feeding or being fed by the pipeline under study,
1.1.4. All exposed structures, such as valve sites, off takes and other such facilities on the pipelines listed above,
1.1.5. All insulating flanges on the pipelines listed above,
1.1.6. All anode beds on the pipelines listed above,
1.1.7. Other pipelines which are parallel to the pipelines under study for significant distances (i.e., on the order of 2 km or more), or which cross them, or which come within 10 m of them,
1.1.8. All electric substations and generating plants within 300 m of the pipelines under study or fed by the pipelines under study.
1.1.9. Electric substations of both ends of each high voltage circuit shown on the map.

Note that it is important to study the pipeline of interest as part of a system and not in isolation: AC interference does not recognize changes in pipeline ownership nor is it necessarily blocked by an insulating flange. Please include in the drawing therefore, all parts of the pipeline network which is under the influence of high voltage power line circuits and show all circuits which are in proximity with the pipeline network.

1.2. Details of System Layout. Provide plan view drawings of the system described in Item 1 above, allowing lengths and separation distances of all power lines and pipelines to be easily determined. In particular, provide, for each power line structure (i.e., tower or pole), the following:

1.2.1. Separation distance of the pipeline under study from the centre of the structure,
1.2.2. Separation distance of the pipeline under study from the edge of the structure (e.g., from the outside of the nearest tower leg). Also, for all substations within

300 m of pipeline or generating plants fed by the pipeline, indicate the location of the pipeline on a layout drawing of the entire facility.

1.2.3. Pipeline Dimensions. Please indicate the burial depth, the diameter and the wall thickness of the pipelines described in Section 1. Please also indicate the width of the bottom of the pipeline trench, for new construction.

2. SOIL RESISTIVITY DATA

Soil Resistivity Measurements: should be made using frequency-selective equipment and the Wenner method at spacings spanning the range of 0.1 to a minimum of 100 m (preferably, 200 m) at:

2.1. All exposed structures (since gradient control grids may be necessary): e.g., at all valve sites, flow meters, etc.;

2.2. Locations where one or more power lines deviate away significantly from the pipeline or vice-versa, at phase transposition locations, at power line crossings, and at intervals along the parallelism (so that the performance of mitigating wires can be assessed);

2.3. Locations where the pipeline is particularly close to power line structures or grounds, including substation and power plant locations (for conductive coupling calculations). Recommended Wenner four pin spacings in meters are: 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 7, 10, 20, 30, 50, 70, 100, 200, and so on.

3. EXPOSED STRUCTURES

Provide drawings of valve sites, off takes, flowmeters and other exposed locations located along the pipeline under study or at its extremities. These drawings should clearly indicate the fence line, the locations and dimensions of gates, the property boundaries (i.e., the maximum extent of any gradient control grid which may be required), the locations and diameters of structures protruding out of the ground.

Note that for sites requiring protection, safety considerations often require that gradient control conductors extend at least 1 m beyond the fence line: it is therefore best that the fence line be at least 1 m within the property line so that gradient control grid conductors do not encroach on adjacent property. Furthermore, a layer of crushed rock may be required to extend outside the grid.

4. ELECTRICAL DATA

4.1. Coating Resistance. Provide an estimate or a measured value for the coating resistance of the pipeline, as installed. Note that a factory value is of no value here because damage to the coating during handling and installation reduces the coating resistance by several orders of magnitude from the factory value. Typical values lie in the range of 6,000 ohm-m^2 - 140,000 ohm-m^2 or less, with the lower values being highly dependent on the local soil resistivity. Provide this data, if possible, for all other pipelines identified in Item 1.

4.2. Anode Beds. For each anode bed identified in Item 1.1, indicate its physical dimensions, configuration of anodes (diameter, length, spacing, horizontal/vertical orientation) and how the anodes are interconnected (with bare or insulated leads). If the ground resistances of the beds are known, provide them.

AC MITIGATION DESIGN: POWER LINE INFORMATION REQUIRED

1. RIGHT-OF-WAY DATA: CONDUCTOR POSITIONS AND PHASING

1.1. Maps. Provide maps indicating, throughout the common right-of-way, transmission line routing, conductor heights above ground, and structure positions, for all circuits which run parallel to the exposed line (including exposed line feeds or taps) for even a short distance. Please note that at locations where the power line and exposed line veer apart, it is important to know the relative positions of the power line and exposed line up to a point where they are about 2 km apart.

1.2. Phase Transpositions. Specify the locations of all phase transpositions as well as the configuration of all conductors whose positions change due to the transpositions: provide enough information to allow three-dimensional modelling of all conductors throughout each transposition.

1.3. Power Line Cross Sections. Provide typical cross sections of the power line right-of-way with:

1.3.1. Phases and circuits labelled;

1.3.2. Conductor spacings and heights above ground (at structure and mid span) clearly indicated. Include overhead ground wires.

1.4. Remote Substation Locations. For all circuits which are present within the common right-of-way, even for a short parallel distance, please specify the distance between the point where they leave the common right-of-way and the substation beyond the common right-of-way to which they are connected. Please also indicate how many structures are present within this distance.

1.5. Structure Grounding. For all circuits, indicate the footing type of the supporting structures: provide a detailed description which includes the dimensions of the footing and of any associated grounding conductors, including rebars in concrete foundations. Please also indicate the distance between the structure footings if more than one are associated with a given structure (e.g., for lattice towers).

1.6. Guy Wire Anchors. Please indicate at what locations there are guy wire anchors that are electrically continuous with static wires or neutral conductors: i.e., guy wires do not have insulating breakers in them and are bonded to static wires or neutral conductors at pole top.

1.7. Counterpoises. Please indicate positioning, length and conductor diameter of all existing buried counterpoises or other conductor networks which are within or close to the common right-of-way.

1.8. Nearby Substation and Power Plant Grounding Systems. Provide drawings of the grounding systems of any substations within 5 grounding system dimensions of the exposed line (i.e., for a 30 m x 25 m substation, provide a sketch if the substation is within 5 x 30 m = 150 m of the exposed line) or of power plants (including substations) which are fed by the exposed line.

1.9. Single Line Diagrams. Provide single line diagrams showing networks associated with all circuits present in the common right-of-way.

2. CONDUCTOR CHARACTERISTICS

Specify precisely the conductor type of all phase wires and static wires of all circuits in the common right-of-way. For long counterpoises, please also indicate the conductor type.

3. GROUND RESISTANCES

3.1. Structure Ground Resistances. Provide, if available, a listing of the ground resistances of all power line structures in the common right-of-way and of all structures within a distance of 2 km beyond the point where each circuit leaves the common right-of-way. If a listing of measured ground resistance values is unavailable, provide typical value(s).

3.2. Substation Ground Resistances. Provide a listing of measured ground resistance values of all substations to which the circuits existing within the common corridor are connected.

3.3. Static Wire Connections. For all circuits, indicate whether the static or neutral wires are electrically continuous with the structures which support them and with the substations at which they terminate. Provide the BIL rating for static wire insulators (if any). Indicate which structures are bonded to the static wires and the locations of static wire discontinuities.

4. FAULT CURRENT DATA

4.1. Fault Current Contributions. Provide the single-phase-to-ground fault current contributions (magnitude and angle) from both sides of the faulted circuit and in all other transmission lines or circuits in the common right-of-way, even those whose parallel exposure to the exposed line is short or is far from the fault location, and in all circuits connected to substations/plants fed by the exposed line, for the following fault locations: At roughly 10% intervals of the common right-of-way length on each of the circuits present in the common right-of-way. For circuits with only a short parallel exposure to the exposed line, a minimum of one fault is required. Please be sure to include data for a fault occurring at any substations which exist within the common right-of-way. Note that a printout from a typical short circuit computer software package would be satisfactory and very helpful if a sufficient number of nodes have been defined to include all circuits of interest for every fault location. If possible, provide currents in all phases (including non-faulted phases), in amps.

4.2. Soil Resistivity. Please indicate what soil resistivity was assumed for the computation of the line parameters used to calculate fault current values.

4.3. Future Expansion. Please indicate for what period of time the fault current values are valid and what percentage increases can be expected in the future.

4.4. Fault Duration: primary and secondary fault clearing times for all circuits for which fault current data has been provided. Please also provide details on automatic reclosure, if any.

4.5. X/R Ratio. Provide sub-transient X/R ratio for each fault.

4.6. Fault Type. Were fault current contributions determined assuming a bolted fault? If not, please explain.

5. LOAD CURRENT DATA

For all circuits within the common right-of-way, even those with only a short parallel exposure to the exposed line, please indicate the following:

5.1. Phase-to-phase energization voltage,
5.2. Magnitude and angle of present and well-defined future peak load and emergency load flow. Indicate if maximum load currents in one circuit necessarily coincide with small (or large) load currents occurring in another circuit or circuits: i.e., is there any correlation between the magnitudes and angles of the load currents in different circuits?
5.3. What percentage increase can be expected to occur in the future for the values provided in item 5.2?
5.4. Maximum load unbalance for each circuit.
5.5. Maximum load harmonic currents for each circuit, if applicable.

6. SYSTEM FREQUENCY

Please specify the operating frequency of the power system (i.e., 50 Hz or 60 Hz or other).

7. POWER PLANTS FED BY EXPOSED LINE

For each power plant fed by each exposed line under study, provide the following information, similar to that requested in the previous sections for the power lines paralleling the exposed line:

7.1. Geographical map, to scale, showing all circuits connected to plant and the substations to which they are connected at the far end.
7.2. Cross sections of all power line circuits connected to these plants/substations.
7.3. Single line diagrams for all circuits associated with the power plants/substations.
7.4. Conductor and overhead ground wire characteristics for all circuits.
7.5. Structure ground resistances and span lengths along all circuits.
7.6. Substation and plant ground impedances (at both ends of each transmission line circuit).
7.7. Grounding details of plant and substation (plan and specifications) to which the exposed line is connected.
7.8. Plan drawing of plant, showing and labelling all power line circuits entering the plant.
7.9. Current flows in all circuits connected to the plant/substation and in all circuits running parallel to the exposed line, during single-phase-to-ground faults occurring at the plant/substation and at 10% intervals along each circuit connected to the plant/substation.

25.4. Annexure D: Commissioning and Interference Survey Guideline

COMMISSIONING AND INTERFERENCE SURVEY GUIDELINE

1. Drawings and Documentation

1.1. The latest revision of the CP and AC Mitigation Technical Specification and Drawings shall be issued to all pre-commissioning and commissioning personnel of The Consultant involved on site.

1.2. Any design reviews that lead to proposed changes to drawings, specifications or acceptance criterion must be reviewed and formally accepted by The Client.

1.3. All document packs to be handed over covering QA, QC, TRU COC, NDU COC, ACM Certification (including Type Tests), OEM Certificates and Manuals.

2. Project Management

2.1. Pre-commissioning and commissioning programs to be supplied before commencement of work on site. Typically to a Level 2 or 3 project plan. The Consultant shall confirm The Client's requirements in this regard.

2.2. Pre-commissioning and commissioning organograms indicating the names and roles of competent and suitably qualified staff to be issued before commencement of work on site. The Client may call for CV's and review personnel suitability and make the final decision. The level of skill required to complete the works must be commensurate will the task at hand to ensure safe working practice and to achieve the commissioning requirements.

2.3. The Consultant to liaise with third party pipeline owners / operators / consultants / contractors to conduct interference testing, facilitate access to test posts, joint testing activities and to ensure compliance in terms of paperwork I documentation that may be required.

2.4. Any design reviews and proposed changes must be formally accepted by The Client before changes are made to technical specifications or drawings.

2.5. Standard QA / QC punching procedures will be carried out by The Client on vandalized CP equipment or new CP installations that may arise during the pre-commissioning or commissioning phase of the project. The likely arrangement would be for The Consultant to punch and facilitate final sign off.

2.6. All data loggers shall be time and date stamped and suitably calibrated instruments. The Consultant shall liaise with The Client in this regard to ensure clear understanding of the equipment to be used. Alternative methods of capturing field data must be submitted to The Client for review and approval before work commences on site.

2.7. Connection / disconnection of any cross-bonds or critical CP equipment shall be done in conjunction with authorized third party CP representatives.

2.8. The Consultant shall manage the official cross bond agreement with all third parties and the final agreement shall be approved by The Client. The consultant shall attach copies of all correspondence with third parties to the final handover pack or as and when requested by The Client.

2.9. The Client shall reserve the right to provide input at all stages of pre-commissioning and commissioning, following approved project communication channels.

2.10. The Consultant shall manage all permits to work, way leaves etc., as required to facilitate smooth planning and execution of the pre-commissioning and commissioning works, with the relevant parties.

3. Cable Load (Current) and Continuity Testing

3.1. The Consultant shall ensure that The Contractor has undertaken suitable load testing and continuity testing on all current carrying cables.

3.1.1. TRU, SMU, NDU and FDU cables to pipe / rail.

3.1.2. AC Mitigation Test post cable connections to pipe and zinc ribbon connections.

3.1.3. Cross bond cable connections to pipe and third party test posts.

3.2. In the case of zinc spirals where two cables are attached the potential difference between the two cables should be negligible to prove electrical continuity of the zinc spiral.

4. Protection Criterion

4.1. All spot potentials shall be more negative than -950 mV_{CSE} and all recordings shall have an average potential that is more negative than -950 mV_{CSE}. Short duration positive spikes are permissible, but The Consultant shall report and manage such events informing The Client's in a timely manner. The protection level of -950mV is to be achieved for 95% of the time during a 24hr potential recording. The clauses that follow shall govern acceptance of the levels of protection as the ON Potentials contain significant IR Drop that must be eliminated to enable accurate assessment of the protection levels.

4.2. Any temporary ICCP that will not form part of the permanent ICCP must be disconnected before any testing/recordings are done.

4.3. The protection criterion shall be demonstrated by suitable means of identifying, measuring and quantifying the IR drop component of any "ON" potential values recorded on site.

4.4. An additional protection criterion should be used, in conjunction with other criteria, such as adequately polarized coupon potentials (instant off potential of -950mV_{CSE} or more negative) that are substantially free from IR drop effects associated with the always "ON" railway line stray currents and CP systems.

4.5. In instances where pre-commissioning and commissioning surveys produce results that indicate positive spikes further investigation must be carried out to determine the current density and polarity across coupons in these areas. The duration and frequency of such spikes must be investigated to determine and document whether the occurrence is transient or recurring.

4.6. The Consultant shall define the approach that will be adopted during the pre-commissioning and commissioning stages of the project to determine the polarized potential at and between test posts.

4.7. The consultant must define the procedure that will be used to confirm the areas of overlap between the TRU/SMU/FDU installations and how these results will be recorded.

5. Commissioning

5.1. Pre-commissioning : General Activities

After the final punch has been completed on the pipeline and after any necessary rectifications of defects, the following pre-commissioning activities shall be carried out, prior to final commissioning:

a. Isolating Flanges will be tested using a Tinker and Rasor RF IT Tester.

b. Operating parameters of all ICCP systems shall be checked and correct operation of TRU/SMU/FDU confirmed.

c. Correct operation of the NDU shall be confirmed.

d. Correct operation of all AC mitigation systems shall be confirmed and steady state AC voltages and currents shall be measured.

e. A final set of potential readings shall be taken with the Temporary CP Systems still energized.

5.2. Pre-commissioning : Test Post Functionality and RFC Sign Off

5.2.1. Confirm functionality of all test posts as per the Technical Specification and Drawings.

5.2.2. All labelling / test post numbering to be done verified correct as per The Client's numbering system.

5.3. Pre-commissioning : TRU and Anode Groundbed Functionality and RFC Sign Off

5.3.1. The Consultant shall provide a test procedure and carry out such tests to verify functionality and responsiveness of the all the TRU/SMU/FDU automatic control systems.

5.3.2. The Consultant shall confirm compliance of the installed TRU/SMU ground bed watering points, with the original design, Technical Specification and report accordingly.

5.3.3. The Consultant shall test the influence of ground bed on the pipeline drain point potential and confirm whether or not this complies with the original design premise and report accordingly.

5.3.4. The Consultant shall provide a procedure to confirm TRU/SMU/FDU current distribution and confirm whether or not the results comply with the original design intent. The procedure shall be submitted to The Client for review and approval.

5.3.5. The Consultant shall undertake calibration of all TRU/SMU/FDU and NDU and provide a suitable procedure for future testing and validation.

5.3.6. The Consultant shall evaluate the effect of induced AC on all anode groundbeds and determine whether or not further action is required.

5.4. Pre-commissioning ACM Functionality and RFC Sign Off

5.4.1. ACM AC steady state Voltage and current density to be measured and recorded.

5.4.2. ACM DC flow test to be conducted over the connection to the zinc ribbon.

5.4.3. ACM loop impedance test between pipe and zinc.

5.4.4. The Consultant shall ensure that the OEM of the ACM equipment produces ACM compliance certificates from a recognized third party test authority proving the stated steady state and fault current capacity.

5.4.5. ACM installation site test certificate.

5.4.6. AC / DC steady state recordings at ACM are to be carried out measure voltage and current.

5.5. Responsibilities for Commissioning

5.5.1. The Consultants' Commissioning Manager shall be responsible for the following:

a. To ensure that the cathodic protection material and hardware has been installed according to the required Technical Specifications and issued-for-construction drawings.

b. Informing all parties required for inspections or tests, or the witnessing of such tests in alignment with the commissioning program.

c. The supervision of all CP related site acceptance testing (SAT) carried out in compliance with the issued for construction drawings and project ITP / QCP procedures.

d. Commissioning and reporting on the installed CP and AC mitigation systems to confirm whether full protection is being achieved. Deviations to be reported to The Client if the excursions are not corrected within 7 days of first being detected.

e. The implementation of the permanent CP (as dictated by site stray current conditions) and AC mitigation systems.

6. Final CP Commissioning Procedure

6.1. Introduction

This document describes the procedures for the final commissioning of CP and ACM Systems installed on steel pipelines.

6.2. ICCP Commissioning Procedure — Stray current Areas

The following tests shall be carried out in order to commission the Impressed Current Cathodic Protection (ICCP) system, where stray currents are present.

6.2.1. Potential and Current Measurements

a. Data from the monthly monitoring that was carried out during pipeline construction to be used as a preliminary guideline for the initial ICCP system output settings. The latest monitoring data shall be used, after the installation and energizing of all the ICCP's and the NDU on the Pipelines. Providing full protection is achieved, then the data from the section of pipeline between two operating ICCP stations shall be used. Pre-commissioning data to be checked for adequacy before commissioning.

b. Carry out 24 hour potential recordings at all test stations.

c. The output settings of the ICCP Systems may need to be adjusted after the potential recordings are reviewed. This is an iterative process until the correct potential profile is obtained along the whole pipeline length.

d. Measure current and direction of current flow at Current Span type test stations and record results.

e. Measure current density on all DC coupons and record results.

f. Once protection has been achieved along the pipeline, record the final settings of all TRU/SMU/FDU and current flowing through NDU. This will require an iterative process.

g. Check operation of Isolating Flanges using a Tinker and Rasor RF IT Tester and record results.

6.2.2. AC Mitigation Sites

The following tests shall be carried out at all AC mitigation installation sites:

a. Carry out 24 hour potential recordings at all test stations.
b. Measure the steady state flow of AC and DC at each solid state DC decoupling device using a calibrated digital voltmeter (DVM). AC and DC Voltage and Current measurements to be recorded.
c. Measure the steady state AC (to be less than 15 V, (if not, report to The Engineer who will investigate and implement remedial action), DC potential of the pipeline and DC potential of the AC earthing system.
d. Measure the spot AC and DC voltage difference between the pipeline and AC earthing system. Value shall depend on pipe potential and how much AC is discharging through the earthing. Report values to The Engineer for acceptance.
e. Measure DC pipe potential recording (24 hours) at all AC mitigation locations.
f. Measure DC blocking voltage i.e. voltage at which current begins to flow.
g. Record all data on task specific forms.

6.3. Interference Interaction Survey

6.3.1. These tests are to be carried out jointly with foreign pipeline owners. The procedure to be agreed upon with foreign pipeline owner prior to commissioning.
6.3.2. Record foreign structure details and owner contact details for reporting purposes.
6.3.3. With the bond disconnected:

a. Carry out 24hrs ON potential recordings on The Client's pipeline and Foreign Service pipeline. Recordings to be done up to 2km from the crossing (bond) on both pipelines.
b. During the 24hrs ON potential recordings.

c. Switch OFF The Client's CP systems (either side of bond) for one hour.
d. NDU's to be switched OFF for 20 minutes during The Client's CP system isolation.
e. Switch ON The Client's CP systems.
f. Switch OFF Foreign Service CP system for one hour.
g. Switch ON Foreign Service CP system.
h. Ensure that all CP systems returned to "as found" settings.
i. Measure IR Free potential on THE CLIENT'S at crossings. Using a suitable procedure such as the SANS 53509: Cathodic Protection Measurement Techniques — Table 1 Sub-clause 4.4.2.3 Intensive Measurement Technique.

6.3.4. Connect the bond at the crossing:

6.3.5. Carry out 24hrs ON potential recordings on The Client's pipeline and Foreign Service pipeline. Recordings to be done up to 2km from the crossing (bond) on both pipelines.

6.3.6. Set-up data logger at the bond to measure current and ON potential. Carry out the following:

a. Switch OFF The Client's CP systems (either side of bond) for one hour. NDU's to be switched OFF for 20 minutes during The Client's CP system isolation.
b. Switch ON The Client's CP systems.
c. Switch OFF Foreign Service CP system for one hour.
d. Switch ON Foreign Service CP system.
e. Ensure that all CP systems returned to "as found" settings.
f. Determine the magnitude and direction of current flow in the bond.
g. Measure IR Free potential on The Client's pipeline at crossing. Using a suitable procedure such as the SANS 53509: Cathodic Protection Measurement Techniques — Table 1 Sub-clause 4.4.2.3 Intensive Measurement Technique.

6.3.7. Ensure that the bond remains connected.

6.3.8. Analyze data, discuss and reach mutual agreement with Foreign Service owner regarding bonding.

6.3.9. The Consultant shall determine mitigation measures mutually with the Foreign Service owner / CP representative. The decision on whether the bond shall be connected or dis-connected after commissioning shall be made by The Engineer.

6.3.10. All measurements to be recorded on suitably designed forms for inclusion in the final commissioning report.

6.4. Final Commissioning Report

The final commissioning report for each THE CLIENT'S shall include the following:

6.4.1. All measurements required under the QCP.

6.4.2. All the original forms on which the data was captured.

6.4.3. A complete tabular presentation of potentials at all test stations (spot and 24 hour recordings).

6.4.4. A complete graphical presentation of potentials against distance along the pipeline.

6.4.5. Complete record of all interference / interaction testing and any mitigation measures implemented.

6.4.6. Any other information necessary to ensure a smooth and complete handover to the owner to facilitate operation of the CP system.

25.5. Annexure E: Isolating Flange Guidelines

Insulating Flange (IF) - ENQ. Guideline Form: **Order/ Enquiry**

		Insulating Flange information:	
Item Description - Insulating Flange (IF)	**Special Selection**	**Bolt - Dimension (ND/INCH**	**PCS.[m]/[piece (length)]**
IF - Facing			
IF - Internal diameter(ID)			
IF - Outside diameter(OD)			
IF - Thickness			
Number of Studs/Bolts			
Stud/Bolt diameter			
Stud/Bolt Hole diameter			
Stud/Bolt Circle diameter			
Internal Lining			
External Coating			
Pipeline Product carried			
Pipeline ID			
IF - Sleeve Length			
Nominal Bolt diameter			
AWWA Class & Table ref.			
IF - Specifications			
Other Information:			

Representative Signature

Date: ____

Name & Surname: ________________________________

		Without flange information	
Isolation washers	**Special Selection**	**Bolt - Dimension (ND/INCH**	**PCS.[m]/[piece (length)]**
Carbon steel			
Hardened Coating Steel			
Glass-Reinforced Epoxy			
Zinc-Plated Steel (ZPS)			
Stainless steel (SS)			

Isolating screws/ - bolts:		
Dimensions (Metric)		
Quality class		
Pcs.		
Operating temperature		

Special Electrical isolation required:

Other General Notes:

Requesting Company:
Contact:
Address:
Country:
Cell:
Tel.:
Fax:
E-mail:

Representative Signature

Date: ____

Name & Surname: _______________________________

Insulating Flange (IF) - Practical Installation Guideline	
Item	Instruction
HOW TO TIGHTEN THE INSULATING FLANGE (IF) BOLTS	
1	Clean flanges, wipe all the dirt and make check for cracks/damages.
2	Insert full faced IF gasket between actual metal flange faces.
3	Insert isolating bolt sleeves in bolt holes.
	Calculation for Isolating sleeve length: 2 x flange thickness including raised face + 1 x thickness of the flange isolation + 2 x thickness of the isolation washer.
4	(If using stud bolts run one nut on one end until end of nut is flush with stud bolt).Place one steel bolt washer and one isolating washer over bolt and insert in bolt hole .
5	Fit one isolating washer and one steel washer on protruding bolt end. Nuts must be hand tightened nuts.
6	In order to achieve an even distribution of pressure at the flange sealing ring, we recommend to tighten the bolts as required and stipulated by the IF kit supplier, until the flange faces and the sealing ring are in contact .
7	Tighten bolts alternately across the diameter of the flange.
8	Always use torque wrench to ensure even tightening and follow the tightening torque guidelines provided.
9	Do not over tighten or leakage may occur.
10	Ensure that bolts are well lubricated .No grease on sealing surfaces.

Notes:
With flanges having a different number of bolts, you should generally follow the same procedure as per above instruction table guide.

In order to achieve an even distribution of pressure at the flange sealing ring we recommend tightening the bolts as shown above until the flange faces and the sealing ring are in good contact.

Please ensure that the bolts are greased/lubricated sufficiently so as to avoid damage to the threads by friction.
In water pipelines applications, it is advisable to use a based grease/lubricate to ensure IF's durability & effectiveness.

As a guideline, the maximum tightening torque are calculated at 85 % of the apparent yield point with coefficient to friction from $\mu = 0.140$, slightly lubricated.

If relatively soft and flexible gasket are used and tightened in a cold condition, the sealing material may relax when the system is put into operation , and the bolts may turn loose .We therefore recommend retightening the bolts after the operating temperature has been reached if possible without the operating pressure and at ambient temperature.

Bolts should be checked and re-tightened, if required, after the initial operation and before bringing the system back from ambient temperature to the operating temperature.

Isolating Flange - Tightening Torque (Nm): Technical **Rev.1 (05/06/2015)**

	Tightening							
Metric Size	**5.6 Ck 35**	**8,8**	**10,9**	**12,9**	**A2 - 70**	**42 CrMo 4 A 320 L7M 40 CrMoV 47**	**INCH Size**	**Tightening torque (Nm) A193 B7**
M4	1	3	4	5	2	2		
M5	3	6	8	10	4	4		
M6	5	10	15	17	7	6		
M8	10	24	36	42	17	15		
M10	21	50	70	85	34	30		
M12	37	85	120	145	59	52	1/2 - 13 UNC	80
M16	90	210	300	350	145	128	5/8 -11 UNC	160
M20	180	410	570	690	280	264	3/4 -10 UNC	320
M22	240	550	780	940	380	360	7/8 - 9 UNC	480
M24	310	700	1000	1200	480	456	1 - 8 UNC	750
M27	450	1050	1480	1775	-	672	1 -1/8 - 7 UNC	1050
M30	610	1400	2000	2400	-	912	1 -1/4 - 7 UNC	1450
M33	830	1900	2700	3250	-	1240	1 - 3/8 - 6 UNC	1900
M36	1060	2500	3450	4200	-	1600	1 - 1/2 - 6 UNC	2500
M39	1380	3200	4500	5400	-	2080	1 - 3/4 - 8 UNC	4600
M42	1700	4000	5600	6700	-	2560	2-8 UNC	8400
M45	2120	5000	7000	8400	-	3200	2-1/4 - 8 UNC	9800
M48	2570	6000	8450	10150	-	3840		
M52	3310	7750	10800	13000	-	4960		
M56	4120	9600	13500	16200	-	6200		
M60	5130	12000	16800	20200	-	7680		

Warning!

The fastening of the bolt shall be 8.8 with the maximum tightening torque on DIN. If not adhered to, this could result in deforming the flanges face. We advise and recommend the use of 80 % of the maximum tightening torque for the bolts .

Rev.1(05/06/2015)

EXFS 100 / EXFS 100 KU (or equivalent part)

Purpose - For indirect connection / earthing of functionally isolated parts installations under lightning conditions. Use - Device for lightning equipotential bonding according to IEC 62305 in hazardous areas.

Ref. Doc. - Approval according to ATEX Directive 94/9/EC and IECEx.

Isolating spark gap for use with IF kit and in hazardous areas with plastic sheath and M10 threaded bolts.

TYPE PART NO. (or equivalent)	EXFS 100 923 100
Isolating spark gap according to EN 62561 - 3/IEC 62561-3	Yes
Lightning impulse current (10/350 Ns) (limp)	100kA
Class (lightning current carrying capability	H
Rated power - frequency withstand voltage (50 Hz)(UwaC)	250 V
Rated impulse spark over voltage (Ur imp)	1.25 Kv
Operating temperature range (Tu)	- 20°C... + 60°C
Degree of protection	IP 67
ATEX approvals	DEKRA 11ATEX0178 X
Ex marking according to EN 60079 - 0 and EN 60079 - 1:gas	II 2 G Ex d iic T6 Gb
Ex marking according to EN 60079 - 0 and EN 60079 -31 : dust	Ex tb IIIC T80 °C Db IP 66/67
Enclosure length	100 mm
Enclosure diameter	45.5 mm
Enclosure material	plastic sheath
Connection of enclosure	M10 threaded bushing , 2x M10 x 25 mm,2x spring washer
Extended technical data:	
Rated discharge current (50 Hz)(Imax)	500 A / 0.2 sec
Nominal discharge current (8/20ps) (In)	100kA
Power frequency spark over voltage (50Hz) (Uaw)	0.5 Kv

Angled Connection Brackets - IF 1 -				Flat Connection Brackets - IF 3 -			
Angled connection bracket for EXFS….,diameter corresponds to the bolt diameter of the bolted flange joint; material : St/Zn				Flat connection bracket for EXFS….,diameter corresponds to the bolt diameter of the bolted flange joint; material : St/Zn			
Type AB EXFS….	IF1 W 11	IF1 W 14	IF1 W 18	Type AB EXFS….	IF3 G 11	IF3 G 14	IF3 G 18
Part No.	923 311	923 314	923 318	Part No.	923 311	923 314	923 318
Max.borehole diameter d1	11 mm	14 mm	18 mm	Max.borehole diameter d1	11 mm	14 mm	18 mm
Type AB EXFS….	IF1 W 22	IF1 W 26	IF1 W 30	Type AB EXFS….	IF3 G 22	IF3 G 26	IF3 G 30
Part No.	923 322	923 326	923 330	Part No.	923 322	923 326	923 330
Max.borehole diameter d1	22 mm	26 mm	30 mm	Max.borehole diameter d1	22 mm	26 mm	30 mm
Type AB EXFS….	IF1 W 33	IF1 W 36	IF1 W 39	Type AB EXFS….	IF3 G 33	IF3 G 36	
Part No.	923 333	923 336	923 339	Part No.	923 333	923 336	
Max.borehole diameter d1	33 mm	36 mm	39 mm	Max.borehole diameter d1	33 mm	36 mm	
Type AB EXFS….	IF1 W 42	IF1 W 48		Type AB EXFS….	IF3 G 39	IF3 G 42	
Part No.	923 342	923 348		Part No.	923 339	923 342	
Max.borehole diameter d1	42 mm	48 mm		Max.borehole diameter d1	39 mm	42 mm	
Type AB EXFS….	IF1 W 56	IF1 W 62					
Part No.	923 356	923 362					
Max.borehole diameter d1	56 mm	62mm					

EXFS 100: Connecting Cable, Cu 25 mm²

Connecting cable for EXFS 100; two cable lugs (Ø10.5 mm) made of Cu/gal Sn,screw,nuts and spring washer .

Type AL EXFS …	L100 KS	L200 KS	L300 KS
Part No.	923 025	923 035	923 045
Cable length	100 mm	200 mm	300 mm

25.6. Annexure F: Local Content Requirements for Transformers

1. BACKGROUND

1.1. The Preferential Procurement Regulations, 2011 (the regulations) made in terms of section 5 of the Preferential Procurement Policy Framework Act, 2000 (Act No. 5 of 2000) which came into effect on 7 December 2011, make provision for Department of Trade and Industry (the dti) to designate sectors in line with national development and industrial policies for local production.

1.2. Regulation 9 (1) of the regulations prescribes that in the case of designated sectors, where in the award of bids local production and content is of critical importance, such bids must be advertised with the specific bidding condition that only locally produced goods, services or works or locally manufactured goods, with a stipulated minimum threshold for local production and content will be considered.

1.3. The dti has designated and determined the stipulated minimum threshold for transformers, shunt reactors and associated equipment for local production and content.

2. PRODUCT DESIGNATION

2.1. A transformer can be defined as a device that transforms electrical power from one circuit to another. These devices have a critical role at various phases of the electricity delivery process, as the voltage of electricity produced in power stations may not be suitable for transmission, whereas the voltage that is suitable for transmission may not be suitable for use by consumers.

2.2. Table 1 categorizes transformers in the classes.

Table 1: Classes of Transformers

Transformer Class	Power Rating, MVA (Range)	Voltage Rating, kV (Range)
Class 0	0.001 to 1	220V to 22
Class 1	1.25 to 160	11 to 132
Class 2	40 to 315	220 to 275
Class 3A	360 to 500	220 to 275
Class 3B	40 to 1000	320 to 400
Class 4	40 to 2000	>420 to 800

2.3. Table 3 provides the stipulated minimum threshold for local content and production for transformers and associated equipment categorised by classes.

To ensure that the minimum local content designated is discharged on manufacturing activities, the components and conversion activities in the manufacture of transformers, shunt reactors and associated equipment are further designated and must also be included in bid invitations.

Table 3: Local Content Designated on a Fully-Built Unit and Components and Conversion Activities against which the overall Local Content must be discharged, per Class of Transformers.

	Components and manufacturing processes against which Classes of the overall local content must be discharged Transformers Components and % local content manufacturing processes	
Class 0	Fabrication of the tank and parts (i.e. cutting, welding, sand-blasting and painting)	100%
	Manufacture (rolling, sizing, insulation) of windings and assembly	100%
	Fabrication of the core (sizing, slitting, cutting, stacking and clamping)	100%
	Manufacture of bushings	100%
	Off-circuit tap	100%
	Oil (i.e. blending, processing and handling)	100%
	Accessories Category A: Radiators Fans Kiosks Oil conservator Breather canisters	100%
	Accessories Category B: Valves Cables	70% (by the valves instruction) 90% (by the cables instruction .
	Assembly and testing of the fully-built unit	100%
	Total minimum local content (per unit)	90%

3. BID DOCUMENT

The Client shall specify the submission requirements in the main contract document to which The Contractor shall respond in full to meet the minimum local content requirements as set out in Table 3 above.

25.7. Annexure G: Drawing Register

DRAWING REGISTER

DRAWING NO	SHEET NO	REV NO	REV DATE	DRAWING TITLE
56735	001	02	JULY 16	TYPICAL INSTALLATION DETAILS POTENTIAL MONITORING TEST POST TYPE "A"
56735	002	02	JULY 16	TYPICAL INSTALLATION DETAILS POTENTIAL MONITORING TEST POST TYPE "B"
56735	003	02	JULY 16	TYPICAL INSTALLATION DETAILS POTENTIAL MONITORING TEST POST TYPE "C"
56735	004	02	JULY 16	TYPICAL INSTALLATION DETAILS POTENTIAL MONITORING TEST POST TYPE "E"
56735	005	02	JULY 16	INSTALLATION DETAILS TYPICAL CP TEST POST SHOWING SACRIFICIAL ANODE
56735	006	02	JULY 16	TYPICAL TERMINATION DETAILS TYPE "A"
56735	007	02	JULY 16	TYPICAL TERMINATION DETAILS TYPE "B"
56735	008	02	JULY 16	TYPICAL TERMINATION DETAILS TYPE "C"
56735	009	02	JULY 16	TYPICAL TERMINATION DETAILS TYPE "E"
56735	010	02	JULY 16	TYPICAL TERMINATION DETAILS ANODE JUNCTION BOX
56735	011	02	JULY 16	TYPICAL GALVANISED TEST POST EQUIPOTENTIAL MAT
56735	012	02	JULY 16	TYPICAL CONCRETE BUNKER EQUIPOTENTIAL MAT
56735	013	02	JULY 16	TYPICAL AC MITIGATION LAYOUT
56735	014	02	AUG 16	TYPICAL TERMINATION DETAILS TYPE "F-A"
56735	015	02	AUG 16	TYPICAL TERMINATION DETAILS TYPE "F-B"
56735	016	02	AUG 16	TYPICAL TERMINATION DETAILS TYPE "F-C"
56735	017	02	AUG 16	TYPICAL TERMINATION DETAILS TYPE "F-E"
56735	018	01	AUG 16	TYPICAL INSTALLATION DETAILS HORIZONTAL ANODE GROUNDBED
56735	019	01	AUG 16	TYPICAL INSTALLATION DETAILS VERTICAL ANODE GROUNDBED
56735	020	01	JULY 16	TYPICAL AC AND DC COUPON LAYOUT WITH uPVC TUBE AND CABLE DETAIL
56735	021	01	AUG 16	TYPICAL SOLID STATE DC DECOUPLER WIRING SCHEMATIC FOR AC MITIGATION
56735	022	01	AUG 16	TYPICAL INDEPENDENT DC AND AC COUPON ASSEMBLY DETAIL
56735	023	01	AUG 16	TYPICAL STEEL REINFORCED VALVE CHAMBER EQUIPOTENTIAL GRADIENT CONTROL MAT
56735	024	01	AUG 16	TYPICAL SMU SINGLE PHASE AUTO CONTROL
56735	025	02	AUG 16	TYPICAL TERMINAL BLOCK LAYOUT
56735	026	01	AUG 16	INSTALLATION DETAILS TYPICAL CABLE TRENCH
56735	027	01	AUG 16	TYPICAL REINFORCED CONCRETE HOUSING FOR CP EQUIPMENT
56735	028	01	AUG 16	TYPICAL INSTALLATION DETAILS TRU ELECTRICAL LAYOUT
56735	029	00	AUG 16	TYPICAL INSTALLATION DETAILS TRU EARTHING/ GROUNDING LAYOUT
56735	030	02	SEP 16	TYPICAL INSULATING FLANGE
56735	031	01	AUG 16	TYPICAL BIG HEADED TEST POST
56735	032	00	AUG 16	TYPICAL TRANSFORMER RECTIFIER FRAME CHASSIS
56735	033	00	AUG 16	TYPICAL REINFORCED CONCRETE BUNKER TYPE 1

DRAWING NO	SHEET NO	REV NO	REV DATE	DRAWING TITLE
56735	034	00	AUG 16	CONCRETE CABINET BASE
56735	035	00	AUG 16	TYPICAL REINFORCED CONCRETE BUNKER TYPE 2
56735	036	00	AUG 16	TYPICAL BONDING LINK PANEL
56735	037	00	AUG 16	TYPICAL CONTINUITY BONDING ACROSS FLANGE, COUPLING, SPIGOT & SOCKET JOINT
56735	038	00	AUG 16	TYPICAL PIN BRAZE / STUD WELDING DETAILS
56735	039	00	AUG 16	TYPICAL MECHANICAL LAYOUT TRU CABINET TYPE 1
56735	040	00	AUG 16	TYPICAL MECHANICAL LAYOUT TRU CABINET TYPE 3
56735	041	00	AUG 16	TYPICAL DIAGRAM FOR 3 PHASE TRU
56735	042	00	AUG 16	TYPICAL DIAGRAM FOR 3 PHASE FDU
56735	043	00	AUG 16	TYPICAL DIAGRAM FOR SINGLE PHASE AUTO CONTROLLED TRU
56735	044	00	AUG 16	TYPICAL DIAGRAM FOR SINGLE PHASE MANUAL CONTROL TRU
56735	045	00	AUG 16	TYPICAL DIAGRAM FOR NATURAL DRAINAGE UNIT ELECTRICAL WIRING
56735	046	00	AUG 16	TYPICAL DIAGRAM FOR RESISTIVE BONDING UNIT ELECTRICAL WIRING DIAGRAM
56735	047	01	AUG 16	TYPICAL MECHANICAL LAYOUT TRU CABINET TYPE 2
56735	048	00	AUG 16	TYPICAL ACM AT AIR VALVE WITHOUT OFFSET SHOWING GALVANISED WELDMESH GRADIENT MAT
56735	049	00	AUG 16	TYPICAL ACM AT AIR VALVE WITH OFFSET SHOWING GALVANISED WELDMESH GRADIENT MAT
56735	050	00	AUG 16	TYPICAL ACM AT SCOUR VALVE SHOWING GALVANISED WELDMESH GRADIENT MAT
56735	051	00	AUG 16	TYPICAL ACM SSD CONCRETE BUNKER SHOWNG TERMINATION DETAILS
56735	052	01	AUG 16	DETAILS OF 2m X 2m BRICK KIOSK WITH REINFORCED CONCRETE INFILL
56735	053	00	AUG 16	DETAILS OF 3m X 3m BRICK KIOSK WITH REINFORCED CONCRETE INFILL
56735	054	01	AUG 16	DETAILS OF 4m X 4m BRICK KIOSK WITH REINFORCED CONCRETE INFILL
56735	055	00	SEP 16	TYPICAL GALVANISED TEST POST

NOTE: The drawing register is updated regularly by The Client and will change. It is the service provider’s responsibility to ensure that they are in possession of the most recent revision of all the relevant project drawings.

25.8. Annexure H: Revision Schedule

REVISION SCHEDULE

REVISION No.	DETAILS
V5 to V6	Sect 1.8 : Qualified Staff - General amendment to clause Sect 8 : ICCP Anode Groundbed - 8.1 removed reference to splicing of anode tails Inserted reference to "Markers" Sect 8.4.1 : Removed reference to SiFe anodes
V6 to V8	Inserted Section 14 Steel Cabinet Inserted Section 15 15. CONSTRUCTION OF TEST POSTS, CONCRETE BUNKERS AND CONCRETE ENCLOSURES
V8 to V10	Added cover page Sect 1.4 Guarantee Period - Additional Note added Sect 1.5 Safety & Work Procedures - Additional risks added Sect 1.6 Handling & Storage - Additional points added Sect 6 : Terminal Blocks - Complete section added Sect 8.3 Test Station Installation Options - Clause amended Sect 8.4.4 : CP Test Stations with Temporary CP - Information added Sect 8.5 : Coupons- Information added Sect 8.6 : Stationary Reference Electrodes (SRE) - Clause amended & Note added Sect 9.2.3 : Anode Junction Box - Cable Termination method amended SECT 9.4.3 : Vertical AGB Anode Installation - Note added Sect 12.1 : NDU's - General - New paragraph added to end of clause Sect 13 : Forced Drainage Units - Upgrade to NDU and TRU/SMU added Sect 14.11.3 : Reference to typical drawings added Sect 16 : Construction of test posts, Concrete Bunkers and Concrete Enclosures - Updated Sect 18.2.1 : Installation of Hi-Potential Magnesium Anodes for Temporary CP - Test station types updated Sect 19 : Operation & Maintenance Manuals & Installation Packs : Sub headings added Sect 20 : AC Mitigation - Last paragraph deleted Sect 20.2 : Valve chamber earth mats - conc encasement and alternative spiral ribbon added, low voltage SSD's amended to "suitably rated SSD's" Sect 20.6: Safe Working procedure in Powerline Servitudes - added Sect 22.2 : Test Stations, Monitoring Points, Bunkers and Other Monitoring Facilities - reference to Type #X removed Sect 23.3: Supplier to Submit Full Details - List expanded Sect 23.5.2 : Guarantee of Equipment - sub-contractor added to 1st paragraph Sect 23 (Ver 8): Consulting & Engineering Services - Section deleted Deleted Annexures C (Ver 8) : AC Mitigation Data Requirements Guideline D (Ver 8) : Commissioning & Interference Survey Guideline E (Ver 8) : Local Content Requirements for Transformers
V10 to V11	Foreword added Sect 2.2. British Standards Institution (BS) Specifications - BS EN 15280 added Sect 2.3. Canadian Standards Association (CSA) - Section added with CAN/CSA –C22.3 No.6-M91 Sect 24 : Consulting & Engineering Services - section added Annexure C: AC Mitigation Data Requirements Guideline - Added Annexure D: Commissioning & Interference Survey Guideline - Added Annexure F: Local Content Requirements for Transformers - Added
V11 to V12	Drawing Register updated. Title page amended.
V12 to V13	Sect 7.4 Isolating washer clause amended Annexure G: Drawing Register – Sheet 30 Typical Insulating Flange – Rev updated to 2