

GENERAL SPECIFICATION

CORROSION

GS EP COR 110

External cathodic protection of buried pipelines

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1. Scope

This document defines the minimum requirements for the design, installation and commissioning of external cathodic protection of buried pipelines used for hydrocarbons, gas or water transportation.

It applies to low carbon steel or stainless steels, coated or uncoated pipelines, including buried equipment installed along their routes such as sectioning valves, tees, anchoring flanges, etc.

It also applies to buried production flowlines between wellheads and intermediate stations and/or treatment centres.

This document does not apply to onshore facilities located in restricted areas such as wells, intermediate stations, treatment or storage centres. Cathodic protection of these facilities is specified in **GS EP COR 111**.

2. Reference documents

The reference documents listed below form an integral part of this General Specification and apply when they are not in conflict with those of the present document.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document. Should some requirements of these documents differ, those from [ISO 15589-1](#) prevail

Reference	Title
BS 7361-1	Cathodic protection - Part 1: code of Practice for land and marine applications
EN 12954	Cathodic protection of buried or immersed metallic structures - General principles
ISBN 88 7398 020 1	Cathodic Protection - Luciano Lazzari, Pietro Peddeferri - Polipress
ISBN 1-57590-092-0	Peabody's control of pipeline corrosion
ISO 15589-1	Petroleum and natural gas industries - Cathodic protection for pipeline transportation systems
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 SP0286	The electrical isolation of cathodically protected pipelines

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Reference	Title
GS EP COR 111	External cathodic protection of onshore facilities
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 210	Monolithic insulating joints
GS EP COR 220	Three layer polyethylene external coating for pipelines
GS EP COR 221	Three layer polypropylene external coating for pipelines
GS EP COR 222	Fusion Bonded Epoxy (FBE) external coating for pipelines
GS EP COR 350	External protection of offshore and coastal structures and equipment by painting
GS EP COR 420	External field joint coatings of pipelines
GS EP ELE 079	Electrical apparatus for potentially explosive gas atmospheres
GS EP ELE 141	Power transformers

3. General requirements

3.1 Qualification and Certification of Cathodic Protection specialists responsible for the design, installation supervision, commissioning and routine inspection

Design, installation supervision, commissioning, and routine inspection of cathodic protection systems of buried pipelines shall be carried out exclusively by competent and specialised personnel.

The qualification of each of the specialists shall be demonstrated to Company before commencement of the work.

Verification of the formal Certification of the individuals shall be as follows:

- Conventional design work, supervision of installation, pre-commissioning and routine monitoring works shall be carried out by certified personnel at level 2 for all certification schemes except for NACE International where it shall be level 3.
- Complex design work, verification or commissioning shall be carried out by certified personnel at level 3 for all certification schemes except for NACE International where it shall be level 4.

Accepted Certification schemes are AFAQ AFNOR Compétence (Land Application Sector), APCE (Land Application Sector), Institute of Corrosion, NACE International. Any other certification scheme shall be approved by Company.

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Any use of non certified personnel for cathodic protection design shall be subject to Company approval on a case by case basis (demonstration of competence through detailed curriculum vitae and description of experience).

3.2 Company involvement

Contractor shall involve Company specialist or its appointed representative at each phase of the project, and more particularly during:

- Study
- Design
- Equipment selection and procurement (Factory Acceptance Tests)
- Installation
- Commissioning.

Company specialist or its appointed representative shall have the right to visit the site/plant/factory and to review documents/reports/drawings when he considers appropriate. Approval by Company specialist shall be mandatory at each phase of the project.

3.3 Sub-contractors

When Contractor sub-contracts the study, works supervision, adjustments commissioning, or the preparation of the final report to a specialised Sub-contractor, the choice of Sub-Contractor shall be submitted to Company for approval.

Notwithstanding the above, Contractor remains responsible to Company for the successful completion of the cathodic protection project and in no case he may use:

- Company approval for the choice of Sub-contractor
- Company approval for the study report

to release him from his contractual liability.

If the simultaneous intervention of several Contractors is needed, special dispositions in the Contracts shall apply to ensure: coordination and compatibility of the various cathodic protection studies, standardisation for the selection of equipment, checking of technical requirements at interfaces, preparation of an overall start-up and commissioning activity, and the issue of a common final report.

3.4 Definition of tasks

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

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3.4.1 Study

The study shall include a site survey including:

- The collection of all relevant information, the data required for the estimation of corrosion risks and the evaluation of coating materials
- The collection of all documents and information on the design of the structure to be protected, its size, and its characteristics which are likely to influence the design of the cathodic protection system
- The collection of all documents and information pertaining to the environment of the work: the presence of nearby metallic structures whether cathodically protected or not, the presence of works likely to emit stray currents, the presence of high voltage cables or transmission lines, electric power stations, transformer stations, etc., which may damage cathodic protection installations, coatings, or the structures itself
- The collection of all information on availability of electrical power for the supply of cathodic protection installations.

The study shall also comprise a detailed study report including:

- An analysis of all information gathered and measurements taken, and an estimate of corrosion risks
- Justified design hypotheses, particularly for the electrical insulation values of the coatings, in new and aged conditions,
- A technico-economical discussion of the various schemes envisaged,
- Design notes justifying the sizing and layout of equipment: anodes, transformers-rectifiers, cables, etc. Unless otherwise specified, the cathodic protection system shall be designed for a service life of 20 years minimum
- A list of materials, including assembly accessories, and the corresponding technical specifications
- A list of possible Suppliers
- Schematic diagrams
- Detailed equipment diagrams
- Detailed installation drawings, indicating:
 - The location of insulating joints
 - Electrical bonding to be installed
 - Special insulations to be installed
 - The layout of different types of equipment and the relevant installation procedure
 - Wiring diagram for electrical equipment.

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- Installation instructions, indicating all precautions to be taken. Particular emphasis shall be given to the construction of:
 - Ground beds
 - Connections on anode circuits
 - Insulation between protected and non protected items
 - Insulation between items protected by different cathodic protection systems
 - Insulation between items protected by the same system, which must be separated temporarily for various operational reasons, such as routine checking of the quality of the coating, etc.
 - Influence correction with third parties or nearby installations
 - Reference electrode installation at fixed points.

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

The study shall be submitted to Company or to its representative for approval.

3.4.2 Administrative formalities

If local legislation requires that an enquiry takes place before a cathodic protection system is installed, the preparation of the legal file is the responsibility of Contractor, and the study shall not receive definitive approval until the results of the official enquiry have been obtained.

Company shall be responsible for transmitting the file to the competent administrative body. Company shall also receive the results of the enquiry.

Company shall be responsible for any question of property which may be involved in the installation of the cathodic protection system.

Contractor shall provide Company with all information and documents required to deal with these property matters, including:

- Extracts of land survey maps
- Delimitation on the land survey maps of the land to be acquired and the temporary and/or permanent rights of way to be acquired.

If the installations require a power supply from a local distribution network, and unless otherwise specified, the formalities with the local distribution company shall be carried out by Contractor. However, the network extension and connection costs shall be borne by Company.

3.4.3 Equipment supply

Unless otherwise specified, supply of all equipment shall be the responsibility of Contractor.

Contractor shall also supply spare parts recommended by Vendors for a two year operating period.

Contractor shall also supply all those spare parts which might be required during startup of the installation.

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Contractor shall make all the necessary arrangements with Vendors to allow Company access at all times to the workshops during the manufacturing period to check:

- Manufacturing progress
- Equipment conformity with specifications
- And to be present during Factory Acceptance Testing.

A provisional manufacturing schedule shall be given to Company for planning inspections.

Vendors shall supply factory test reports, anode material chemical analysis, certificates of approval for electrical equipment to be used in hazardous areas, etc., to Contractor who shall include them in the final report.

The final report shall consist of:

- A detailed description of the installation
- Vendor's drawings and operating and maintenance instructions
- As built drawings
- Equipment list with references and Vendor's addresses
- A list of spare parts for two years of operation, with complete references
- Operating procedures
- A complete list of measurements taken before and during startup of the system
- Reports stating agreements made with owners of neighbouring structures (duly signed by the various parties concerned) on the corrective actions to be taken for any interference with these structures.

The results of the enquiry and the permission of the local authorities if the installations are to be in countries where such installations are subject to special legislation.

4. Protection criteria

4.1 General

Unless otherwise indicated, all the requirements of [ISO 15589-1](#) shall apply.

In addition, and unless otherwise indicated in this document, all the requirements of [EN 12954](#), [NACE SP0169](#) and [BS 7361 - Part 1](#) shall apply. With zinc reference electrode (see § 9.7.2) the criteria will be modified accordingly.

Unless justified by particular circumstances, any buried pipeline that requires cathodic protection shall be electrically insulated from other structures to which it may be connected.

4.2 Protection potential

The pipe-to-soil potential is used as a criterion for effective cathodic protection.

This potential is measured relative to a saturated copper/copper sulphate reference electrode.

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The cathodic protection system shall permanently modify the electrochemical free potential of the entire surface of the pipeline in the negative direction, and below the following limits:

- -850 mV/Cu/CuSO₄ for steel in an aerated soil
- -950 mV/Cu/CuSO₄ for steel in a de-aerated soil with confirmation of the presence of active sulphate reducing bacteria.

To avoid detrimental effects on the applied coating (cathodic disbanding) or hydrogen induced stress cracking of the steel, the potential shall be higher than the overprotection potential. This overprotection potential may vary from -1.2 V/Cu-CuSO₄ for low carbon steel pipe to -1.0 V/Cu-CuSO₄ for a high strength steel pipe in aerated soils.

Potentials shall be measured as close as possible to "true" values, correcting the error due to ohmic drop in the soil.

More specific protection criteria may be accepted by Company on a case by case basis, according to pipeline characteristics, coating and surroundings.

5. Site studies

5.1 Site surveys

Before definition of the cathodic protection design, Contractor shall undertake a site survey including:

- Soil resistivity measurements along the pipeline route to assess apparent corrosiveness level and, at points either side of the route, for the installation of impressed current anodes
- Measurements of pipe-to-soil potentials, if applicable, on crossing and parallel buried metallic structures (pipelines, rails) or on the existing pipeline to be protected
- A list of low voltage power lines which may be used to feed an impressed current DC source, and high voltage lines, which may have a detrimental influence
- A list of existing cathodic protection equipment for crossing and parallel buried structures in the vicinity of the pipeline route.

Note: In the case of an existing pipeline, Contractor may, conditions permitting, carry out one or more cathodic protection trials, so that the apparent insulation resistance and initial current requirement can be evaluated.

5.2 Soil resistivity measurements

Soil resistivity shall be measured by the four aligned and equidistant pins method (Wenner's method), or by the Schlumberger method or by inductive electromagnetic technique, according to the following minimum requirements:

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5.2.1 Along the pipeline route

Measurements shall be carried out:

- Every 1 or 2 kilometres (according to accessibility)
- At crossings with existing pipelines, DC electrified railway, and high voltage power lines
- When there is a visible change in the nature of the soil at ground level.

5.2.2 At pre-selected locations for impressed current anode ground beds

These locations shall be in the vicinity of an available low voltage power line or in areas of low resistivity, at appropriate intervals away from the pipeline route and accessible to an excavator.

Notes:

- The location of the pre-selected locations can be either side of the pipeline route, as chosen by contractor with Company approval, but outside of any hazardous areas
- If soil resistivity survey results are supplied to Contractor, Contractor may check them at random every 3 to 5 km along the pipeline route and at selected locations for impressed current anodes.

5.2.3 Results

The results shall be set out in the form of a table, specifying the place, kilometric position, distance between points, corresponding resistivity value and any observations made at ground level.

5.3 Existing metallic structures

Unless data is supplied to Contractor by Company, existing metallic structures, buried or in contact with the soil, crossed or parallel, shall be identified and their owners contacted to obtain necessary information about their structures, to obtain authorisation to carry out potential measurements, and to assess their particular technical requirements with respect to the new cathodic protection system. Such information shall include:

- Pipeline
 - Year of construction
 - Overall diameter and steel grade
 - Coating systems (pipe and field joints)
 - Cathodic protection systems (impressed current or sacrificial anodes, test points located in the vicinity of the pipeline route, level of protection)
 - Technical requirements (common test facilities, cable connection method, specific insulation).

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- Railway
 - Electrical power supply (AC or DC)
 - Location of nearest DC substation
 - Presence of insulating joints on rails close to the pipeline route.

At each test point of an existing pipeline or rail crossing point, the potential with respect to a portable Cu-CuSO₄ reference electrode shall be measured. When the potential varies by more than 50 mV, a recording over 30 to 60 minutes shall be taken.

5.4 High voltage power lines

Unless otherwise indicated, only power lines with a voltage greater than or equal to 60 kV shall be taken into account.

These include lines that:

- Cross the pipeline route
- Remain parallel to the pipeline route, within a corridor of 500 m either side.

The survey shall include:

- The identification reference fixed to the pylons
- Nominal voltage between phases
- Pylon type and base dimensions at ground level
- Shortest distance from pylons to pipeline
- Presence of electrical interconnection between pylons (guard cable).

5.5 Direct or alternating stray currents and telluric currents

Site surveys shall verify whether the pipeline is subject to DC or AC stray currents or telluric currents. In this case, the protection system design should enable maintenance of the polarisation potential for 95% of the time and, in the case of alternating current, protecting the personnel against any electrical hazard.

6. Electrical insulation of the pipeline

The pipeline may:

- Include steel casings, intermediate stations comprising other metallic structures in contact with the ground, river crossings, arrivals (or departures) of sealines at landfalls
- Be connected to future or existing pipelines, to large metallic structures in contact with the ground such as wells, treatment, or storage centres.

The pipeline's cathodic protection system shall be segregated from other metallic structures by the provision of electrical discontinuity.

If regulation or any technical reason entails the continuity of all metallic structure, adequate solutions (polarization cell, surge arrester, isolating spark gaps or other) shall be submitted to, and approved by Company to ensure cathodic protection efficiency.

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Contractor shall indicate, in the detailed study, the means and equipment proposed to ensure such electrical isolation (insulating joints, insulating plates, centering tools, closing plates). However, these shall be designed in accordance with safety rules with respect to overvoltage protection, and satisfy the requirements below.

6.1 Insulating joints

Except if otherwise approved by Company, the pipeline ends, including also intermediate stations and branching points, shall be fitted with an insulating joint of the monolithic or flanged type depending on the fluid transported.

In the case of monolithic insulating joints with a diameter greater than or equal to 50 mm, the requirements of [GS EP COR 210](#) shall apply. In other cases, the type of insulating joint shall be submitted to Company for approval and shall satisfy the requirements of [NACE SP0286](#).

In all cases, insulating joints shall comply with the construction and operating conditions of the pipeline: steel grade, fluid transported, pressure, temperature, etc.

For the location of insulating joints, particular attention shall be paid to the avoidance of any short circuit that may be caused by supports, walkways, fittings (valve) or any other metal structure, whether temporarily or permanently installed. In addition, they shall be located above ground, on a straight section of the pipeline, and if the design permits, inclined, in order to avoid any risk of internal short circuit of insulating parts by internal deposits.

In the case of different cathodic protection systems (sacrificial anode) for sections of the pipeline, an insulating joint shall be installed at the interface, in an aerial section, or underground in a watertight and accessible cellar.

6.2 Safety devices

On sites subject to frequent lightning (keraunic number normally over 21), Contractor shall install safety devices such as surge diverters or polarization cells, which shall remain operational without requiring constant checking.

Contractor shall submit the selected device (or devices) to Company for approval, in accordance with recommendation [NACE SP0177](#).

6.3 Earthing circuits

In order to limit current losses, the pipeline cathodic protection shall be electrically insulated from earthing circuits of intermediate stations and treatment and/or storage centres.

Earthing devices may be required for security reasons. These devices shall be either equipment according section 6.2 or separated earth points, composed of zinc alloy or galvanized steel, buried in backfill and situated near high voltage power lines (section 5.4).

7. Pipeline coatings

In order to limit the number and capacity of cathodic protection systems used for external protection of buried pipelines, an external coating is used.

The coating is applied in the factory on line pipes and the field joint coating is applied on site with suitable materials compatible with the linepipes coating.

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These plant coatings are generally:

- Three layer polyethylene (as per **GS EP COR 220**) or polypropylene (as per **GS EP COR 221**) based external coatings, with or without concrete mechanical protection in the case of long river crossings
- Epoxy powder fusion bonded coatings (as per **GS EP COR 222**).

Field joint coatings shall be compliant with **GS EP COR 420**.

Buried fittings such as sectioning valves shall be coated with a thick coating according to system P08 in **GS EP COR 350**.

8. Calculation parameters and methods

The design bases specified below shall be used to ensure that a cathodic protection system will work in normal operating conditions. They may be adapted in the Project Particular Specification for specific sites or conditions, or by Contractor subject to technical justification and Company approval.

Sizing parameters shall include:

- Current densities (J_p) to be applied to bare surfaces according to the type of material to be protected (steel, copper, rebar concrete, etc.)
- Current densities (J_{pr}) to be applied to coated surfaces according to the coating system
- Surfaces to be protected (S)
- The design life.

8.1 Current densities

The different bare (damaged coating, anchoring or earthing of line) and coated surfaces shall be considered separately in current demand calculations.

Unless otherwise stipulated in the Project Particular Specification, the following current densities (J_p) for bare surfaces shall be:

- Steel in soil: 30 mA/m²
- Copper in soil: 80 mA/m²
- Steel rebars embedded in concrete (first range of rebar to consider only): 10 mA/m².

For coated steel surfaces, the values in the table below shall be used depending on the coating system and on the age of existing structures or design life of new structures.

For dry soils (resistivity above 1000 ohm.m), current density shall be half of the values given in the table below.

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Current densities (J_{pr}) for coated surface

Coating system	Current density J_{pr} (mA/m ²)			
	Initial	Final (design life)		
		10 years	20 years	30 years
Coal-tar, bitumen enamel, cold applied tape	0.2	0.4	0.6	0.8
Fusion bonded epoxy	0.05	0.2	0.5	0.7
Three-layer PE or PP	0.02	0.05	0.1	0.3

8.2 Protection current

To evaluate current demand, Contractor shall take into account all the metallic surfaces to be protected in a given pipeline section, and use the relevant current densities as defined in section 8.1 for the specified design life.

Pipeline sectioning shall be defined from pre-selected points for DC current sources and soil resistivity profiles.

For the total surface to be protected, the current demand is then equal to:

$$I = S_{pr} \cdot J_{pr} + J_p \cdot S_p$$

With:

- I Protection current for the total surface (mA) at beginning or end of life
- S_{pr} Area of coated structure to be protected (m²)
- S_p Area of bare structure (copper, rebar...) to be protected (m²)
- J_{pr} Current density values defined in section 8.1 (mA/m²) for coated surfaces at beginning or end of life
- J_p Current density values defined in section 8.1 (mA/m²) for bare surfaces

8.3 Temporary protection

Temporary protection may be required for the first year (or more) after burial of the pipe, depending on the project. In this case, design parameters given in § 8.1 and § 8.2 shall apply.

Resistivity for further anodes resistance calculations will be assumed to be maximum 30 ohm.m, even if the surrounding soil resistivity is higher.

8.4 Number of DC sources

The number of DC sources distributed along the pipeline route is directly dependent on the average apparent electrical characteristics of the pipeline at the end of the design life and the potential criteria as defined in section 4.

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As a general rule, the distance between two consecutive DC current sources shall be limited to 40 km for an impressed current system and 1 km for a sacrificial anode system using magnesium anodes. This distance may be increased depending on coating quality.

However, checks shall be carried out based on theoretical equations adapted for a pipeline of finite length, as the one recommended in chapter 4 of the book "[Cathodic Protection](#)", from [Luciano Lazzari and Pietro Pedferri](#), each section being considered as laid in a uniform electrolyte and with uniformly distributed constant characteristics.

For more complex cases, modeling of the system shall be carried out demonstrating that an adequate level of potential will be reached at each location during the whole design lifetime using software approved by Company (e.g. BEASY or equivalent).

8.5 Anodic system

The quantity of installed anodes shall fulfill the current requirement, the design life, and the design constraints.

The anodes shall be of the MMO (mixed metal oxide anodes on titanium substrate) type.

8.6 DC current source dimensioning

After commissioning, each DC current source shall guarantee the upper protection limit (E_p) defined in section 4, in the relevant pipeline sections.

Dimensioning shall depend on the overall resistance (R) of the resulting electric circuit, calculated as indicated in section 8.6.3.

8.6.1 Impressed current system

The output voltage (U in V) from the DC source (normally a transformer/rectifier) shall provide a DC current output at least equal to the minimum total value (I) with an additional 25% safety factor.

8.6.2 Sacrificial anode system

The number of sacrificial anodes (N) and their dimensions, at each current injection point, shall be defined to provide the total current required (I) and maintain a protection level (E in mV), throughout the anticipated life span, that is equal to or more negative than the protection criteria (E_p) on the relevant pipeline section. No safety factor will be considered.

8.6.3 Calculating circuit resistance

8.6.3.1 Overall system resistance

The overall resistance (R) of the system is equal to:

$$R = R_{an} + R_{ca} + R_o (\Omega)$$

With:

- R_{an} Resistance of the anode groundbed relative to the ground (Ω)
- R_{ca} Resistance of the anode and cathode connecting cables (Ω)

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R_o Apparent resistance of the pipeline section (or pipe-to-earth leakage resistance, or coating transverse resistance) from the DC current source (Ω). This value shall be assessed based on coating system and ageing. Without additional information, the following values shall be chosen:

Pipe-to-earth leakage resistance in 10 ohm.cm soil

Coating system	Practical transversal resistance of pipeline (Omhm.m ²)			
	Initial	Final (design life)		
		10 years	20 years	30 years
Coal-tar, bitumen enamel, cold applied tape	50,000	25,000	20,000	15,000
Fusion bonded epoxy	60,000	30,000	15,000	10,000
Three-layer PE or PP	500,000	200,000	100,000	30,000

Note: It will be assumed that pipe resistance increases proportionally to soil resistivity.

8.6.3.2 Anode and cable resistance

The anode groundbed resistance calculation shall use the formula described in the book "[Peabody's control of pipeline corrosion](#)" or other similar sources.

The cable resistance shall be provided by the Manufacturer's documentation.

9. Equipment

9.1 Sources for impressed current systems

When a low voltage AC power supply is available at a reasonable distance, a transformer-rectifier shall be used. This will normally be of the air cooled type unless otherwise stipulated.

If there is no low voltage AC power supply, the DC source shall be self-powered and comprise electronic regulation, associated with either a set of gas thermo-generators, particularly on pipeline carrying a gas that can be used for their feed, or a set of solar panels and batteries.

In the case of self-powered DC sources, the power drawn shall be minimal, limiting the resistance of the circuit (section 8.6.3) to 1 ohm and Contractor shall submit the chosen solution, with a technico-economic assessment, for Company approval.

9.1.1 Transformers Rectifiers

Supply and installation of transformers shall refer to **GS EP ELE 141** and be in accordance with recognised international standards listed in the present specification.

Minimum IP rating for indoor installation with air-conditioning shall be IP31 for outer cabinet, and minimum IP65 for external installation (cooling to be achieved through the walls of the cabinet)

Micro-switch rectifier technology is the preferred solution. Other technology shall be submitted to Company for approval.

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Transformer-rectifier shall be supplied by recognized Suppliers and the design shall be submitted to Company for approval.

9.1.2 Control

Output should be continuously variable from 0 to 100% of the rated output. The AC ripple voltage shall be controlled not to exceed 5% of DC output for the range 5-100% of full output rating.

The unit shall be capable of operating output control modes as follows:

- A constant current
- A constant voltage.

Whatever the type of device, the source shall be capable of supplying stable and permanent current, ranging from the initial to the final current requirements mentioned in § 8.1, whilst still being able to provide an adequate level of control. Constant potential (control of measured potential relative to an external permanent reference electrode) operating control may be accepted on a case-by-case basis and only for specific purposes, with Company approval.

9.1.3 General characteristics

The equipment shall be suited for the chosen location which shall in all cases be situated outside of any hazardous area and be accessible at all times. For outside installation, protection against the sun is required, and ambient design temperature shall be 55°C.

Control, regulation, and protection devices shall be installed inside the cabinet and accessible.

All electronic components shall be contained within a suitably rated IP enclosure to prevent dust ingress when the cabinet door is opened.

For solar powered units, the capacity of the sealed, maintenance-free batteries shall be rated for a minimum of five (5) consecutive days without sun.

For gas thermo-generators, the capacity of the gas tanks shall be calculated for a duration of five (5) consecutive days of shutdown when fed from a gas pipeline and one (1) month between two refilling when fed externally.

9.1.4 Breakers for ON/OFF potential measurements

Each of the DC current sources necessary for ensuring cathodic protection of the pipeline shall be equipped with a breaker allowing ON/OFF potential measurements.

The type and characteristics of breakers shall be adapted to the maximum nominal current output.

When more than two CP stations are necessary, breakers shall be such that separate synchronisation devices can be temporarily connected.

Alternatively, permanent synchronised current interrupter may be installed. Type of synchronisation (GPS, radio, fiber optic...) shall be submitted to Company for approval.

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9.1.5 Spare parts

Transformer rectifiers and self-powered DC sources shall be supplied ready to operate and with spare parts needed for the commissioning period.

Contractor shall submit a list of spare parts for two years operation to Company for approval.

9.1.6 Testing

Each transformer-rectifier shall be the subject of Factory Acceptance Tests which shall be defined in the Project Particular Specification.

For self-powered DC sources, Contractor shall submit a quality inspection plan to Company, accompanied by inspection and test procedures, for approval.

9.2 Impressed current anodes

MMO anodes shall be supplied from approved Vendors only.

9.2.1 Backfill composition and preconditioning

9.2.1.1 Backfill

The backfill shall comprise 99 grade petroleum coke breeze, containing at least 98% carbon, with a particle size ranging from 0.2 to 0.7 mm and a maximum resistivity of 25 $\Omega \cdot \text{cm}$.

This type of backfill shall be used where there is no water table influence, since its specific weight is less than 1 kg/dm^3 .

Where there is influence from water tables, the backfill may be:

- Installed in a geotextile packing containing coke breeze and anodes, if the water table can be temporary displaced with pumps, allowing enough time for installation.
- Otherwise composed of bentonite (25%), gypsum (70%) and sodium sulphate (5%) mixed with water to form a compact mud. In this case, the lack of beneficial effect of coke breeze on the anodic reaction shall be taken into account for the anode lifetime.

9.2.1.2 Preconditioning

Anodes preconditioning shall be either factory centred inside a closed steel cylindrical "canister" made of spiral wound galvanized sheet steel with a minimum thickness of 0.5 mm, or preferably installed in a backfill-containing geotextile bag.

The dimensions of the canister or the bag shall be adapted to the dimensions of the anode:

- External diameter at least three times that of the anode (and 12 cm minimum)
- Length at least 1.3 times that of the anode.

If a canister is used, the end of the canister with the cable entry shall be fitted with a cable gland and a lifting handle, to avoid having to handle the arrangement by the cable.

If a bag is used, the ends of the bag shall be fitted with a closing device ("plastic collars" or others). On the cable entry side, the cable will do a tight loop inside the bag, to avoid possible damage of anodic connection during handling

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9.2.2 Cables

Impressed current anode shall be supplied with PVDF/HMWPE or ETFE/HMWPE double insulated cable with a minimum cross-sectional area of 1 x 16 mm², unless otherwise stipulated in the Project Particular Specification.

The cable shall be connected to the core of the anode located at the bottom of a cavity provided for this purpose, the relevant connection being carefully sealed and insulated with a two part, chlorine-resistant epoxy compound.

A suitable sleeve or heat-shrinkable cap shall be provided to reinforce the insulation and seal tightness of the connection and the cable at the head of the anode.

9.2.3 Quality control

Contractor shall deliver the anodes together with the following documentation:

- Chemical analysis certificates of the castings
- Certificate of conformity of the cable-to-anode core connection, specifying that the connection resistance is no greater than 0.06 Ω
- A test certificate for the mechanical resistance of the connection, carried out on 5% of the anodes ordered
- A visual and dimensional inspection certificate.

9.3 Sacrificial anodes

This section mainly deals with magnesium alloy anodes.

Other types, such as zinc and indium activated aluminium, are normally not used to protect buried structures. However, zinc ribbon may be used for cathodic protection of the pipeline section inside the annular space of a steel casing and zinc anodes to provide an earthing system.

The requirements for alloy composition, quality, inspection and performance of sacrificial anodes shall be as requested in **GS EP COR 201**.

Sacrificial anodes may be used bare, where soil resistivity is below 10 Ω.m, but preferably preconditioned in a regulating compound or backfill as defined below.

9.3.1 Backfill

The backfill used with magnesium and zinc anodes shall comply with the following composition requirements:

- 75% gypsum (CaSO₄ - 2 H₂O)
- 20% bentonite
- 5% sodium sulphate (Na₂SO₄).

The weight of the backfill surrounding each anode shall be at least equal to the net weight of the anode and be contained in a cotton bag or a metal canister as defined in section 9.2.1.

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9.3.2 Quality control

In its proposal, Contractor shall specify:

- The alloy composition and net weight of the anode
- The composition and weight of backfill
- The dimensions of the anode and backfill
- The type, section, and length of the anode cable (see section 8.4).

9.4 Cables

Four types of cable shall normally be used:

- Main circuits (anodic and cathodic)
- Anode connection
- Earthing
- Measurements.

These cables shall comply with regulatory requirements.

The buried cable shall be armoured or inside plastic conduits.

9.4.1 Main circuit cables

For an impressed current system, these cables shall include:

- The links between the anode ground bed and the positive pole of the rectifier, or of an intermediate junction box
- And the link between the protected structure and the negative pole of the rectifier, if necessary through a test/junction box where several structures are involved.

For a sacrificial anode system, these cables shall include:

- The bonding links between the anode ground bed and a test/junction box
- And between the protected structure and the same box.

The cables shall be single core, flexible or semi-rigid copper cables, with double insulation (PE/PVC, XLPE/PVC or PVC/PVC). For cables connecting impressed current ground bed anodes, one shall refer to § 9.2.2.

For safety, the anodic circuit shall prevent accidental cut-out by providing a loop, or by duplicating the link to maintain the anode power feed.

The cross-sectional area of the main cables shall be defined according to the maximum current, and be at least equal to 16 mm². The cross-sectional area may be greater if the anodic mass or structures to be protected are distant from the rectifier (30 to 100 m or more) in order to minimize voltage drop in the cable.

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9.4.2 Anode connecting cables

The anodes may be connected either to the main anodic circuit or individually and directly to the positive pole of the transformer-rectifier, or to a junction box.

In the first case, the length of the anode cable shall be as short as possible, but not less than 2 m.

In the second case, the cable section shall be determined to keep the voltage drop in the cables as low as possible, and at most equal to the permitted limit.

9.4.3 Earthing cables

Unless otherwise indicated by regulations, earthing shall be provided by insulated copper cables, semi-rigid and rated according to standards for low voltage electrical installations.

9.4.4 Measurement cables

These cables are used to carry out the various cathodic protection measurements, independently of the other cables. Each measurement cable shall have a minimum cross-sectional area of 6 mm². The nominal voltage allowed for these cables is 450/750 V.

9.5 Cable connection accessories

These accessories are for branch connecting anode cables to the positive main cable. At the point of connection, the insulation of the main cable shall be removed over 4 to 5 cm to allow connection of the anode cable, itself stripped over 2 to 3 cm, by clip-screwed or crimped connector. The main cable shall not be cut, under any circumstances.

After checking mechanical strength and electrical continuity, the connection shall be insulated by cold cure epoxy resin into a mould previously placed around the joint and sealed at each end.

The connection shall not be handled until the resin is completely cured as per its product data sheet.

9.6 Junction boxes

These boxes are mainly a marshalling point for anodic or cathodic cables at DC current sources, and shall preferably be located outside of hazardous areas so that they can always be accessed when live.

Consequently, unless otherwise specified by Company, reinforced safety boxes shall not be required. However, junction boxes shall provide minimum protection against shocks and water ingress, whether made of insulating material (PVC, polycarbonate, etc.) or metal (steel, cast aluminium, stainless steel).

Junction boxes shall be:

- IP55/IK08 for outdoor locations
- IP31 for indoor locations.

Internal equipment, such as the number and sizes of copper strips, cable terminals, resistors and any other particular components, shall be defined in the detailed study.

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The junction box, internal equipment and support structure shall be selected and/or treated to withstand the specific climatic conditions.

Cables shall be easy to disconnect for measurements and their entry into the junction box shall be via cable gland of metal or insulating material, or via support pipe according to the type of box selected.

9.7 Monitoring equipment

9.7.1 Potential test points

Test points shall be provided along the pipeline route in the following cases:

- At road and rail crossings and for pipeline sections within casings
- At the point of intersection of one or more pipelines
- In sections where several pipelines run in parallel
- To measure current circulating in the pipeline
- At insulating joints
- At high voltage line crossing points with particular devices
- At all other points defined in the detailed study.

Outside urban areas, these test points shall comprise a junction box, as defined in section 9.6. or, depending on the number of cables connected and the size of internal accessories, a 3" or 4" pipe:

- Made of rugged plastic or metal, in which the cables are located
- Provided with a lockable opening in the top part
- Internally fitted with an insulating plate located in front of the opening, supporting equipment (terminals, shunt strips, resistors, diodes, surge diverters, etc.)
- With reed switch connection to easily perform local ON/OFF measurements on coupons (if any)

Test points shall be at least 1.5 m above ground and the other end shall protrude 5 cm beyond the concrete base.

Where there is a risk of vandalism, alternative design shall be submitted to Company for approval.

Note: The test points may be used as kilometric pipeline markers, but shall then be constructed as such.

In urban areas (except within the plant's fence), test points shall comprise a junction box as defined in section 9.6, placed inside a concrete pit or vault.

All materials for test points shall be designed to withstand the specified climatic conditions.

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9.7.2 Permanent reference electrodes

These electrodes are designed to monitor the cathodic protection system efficiency, by measuring, either directly or via a remote monitoring system, the pipe-to-soil potential at the point of interest. If appropriate, they can provide a durable mean of controlling a regulation device (see section 9.1).

Reference electrodes shall be made of pure electrolytic zinc in a backfill medium. The composition of the zinc shall be as follows:

- Aluminium: 0.005 max
- Cadmium: 0.003 max
- Iron: 0.0014 max
- Lead: 0.003 max
- Copper: 0.002 max
- Zinc: remainder (99.995 min).

The backfill composition shall be as follows:

- 75% of anhydrous calcium sulphate
- 18% of bentonite
- 5% of anhydrous sodium sulphate
- 2% of sodium chlorite.

The location and number of permanent reference electrodes shall be determined in the detailed study of the system by Contractor.

However, one electrode shall be provided at each:

- Impressed current source where there are stray currents
- Pipeline current test station along the route
- Test point, where the pipeline is buried more than 3 m deep
- Test point in urban areas and when the surface is asphalted or concreted
- Test point where the pipeline is weighted with concrete or protected by concrete slabs.

Before energizing, permanent zinc electrodes shall be immersed in fresh water for at least 24 hours to ensure that the bentonitic compound is completely humidified.

The permanent reference electrode shall be assumed to be stable 72 hours after its total immersion.

9.7.3 Coupons

CP coupons allowing local ON/OFF measurements together with cathodic current density measurements shall be supplied and installed regularly along the pipeline.

The design of CP coupons shall be as per Appendix 1 of [GS EP COR 111](#) in order to limit IR drop in OFF potentials measurements.

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In normal operation, CP coupons shall be permanently connected to the pipeline through a test box. A specific connection shall be implemented in the test box in order to allow plugging of a fast recording monitoring device without depolarization of the bare steel surface.

9.7.4 Remote monitoring

For long pipelines (more than 300 km), a remote monitoring system shall be installed. The system shall use technology (RTU and SCADA) compatible with the site's existing control system. The data transmission network shall be adapted to site constraint.

The remote monitoring system shall be capable of performing at least the following:

- Collecting and reporting DC voltage, current, and reference electrode potential at a programmable interval
- Switching ON and OFF and simultaneously the current interrupters (if any)
- Sending failure alarms
- Communicating return-to-normal reports
- Generating reports to a website in selectable format for importing into a database.

Contractor shall submit detailed information on the equipment proposed for Company approval.

10. Installation

10.1 Impressed current DC sources

Indoor wall-mounted air-cooled transformer-rectifier sets shall be installed inside a technical building or shelter, and in a well ventilated place that is easily and permanently accessible.

For outdoor installation, it shall be located outside hazardous areas in accordance with safety regulations. If this is not possible, all of the components for adjustment, monitoring, protection and connection, including the cubicle, shall satisfy the requirements relating to electrical apparatus located in potentially explosive areas, as described in [GS EP ELE 079](#).

Self-powered DC sources shall be located outside hazardous areas and within an enclosed area enclosed by a fence, with the control and monitoring cubicles located either inside a shelter or under a canopy.

The layout shall be in accordance with the Contractor instructions, and local regulatory requirements dealing with low voltage electrical installations.

10.2 Junction boxes

Junction boxes shall be mounted on a metallic support (steel pipe or section) anchored in a concrete base.

Where cable entry is by cable glands, cables shall be routed up from the concrete base via cable tray used for fixing and protection purposes.

Through the concrete base, if there is no pipe support, the cables shall be protected in PVC sheathing of sufficient diameter to allow the cables to pass easily and, if necessary, accept additional cables.

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10.3 Test points

Test points shall be installed within the permanent right of way of the pipeline(s), at a fixed distance from the centre line and, if possible, on the same side, except for those close to insulating joints, inside a fence, or in urban areas.

The junction boxes, preferably mounted on pipe supports, shall be installed as defined in section 10.2. The tubular test points shall be sealed in a concrete base.

In addition, the frequency of the test points shall be determined in accordance with the following requirements:

- Pipeline current measuring point:
 - Upstream and downstream of each impressed current source, except where an insulating joint electrically separates the two sections, or when there is only one section
 - Between two impressed current sources 5/6 km apart
 - At the junction between new and old or buried/underwater pipeline sections without insulating joint.
- One pipeline potential point every 1 to 2 km for a normal route and 0.5 to 1 km for urban areas.

In asphalted or concreted areas, regular access shall be provided to the natural soil to allow contact of a portable electrode near to or above the protected pipeline at the test point location.

These access points shall comprise a rigid PVC tube, 75 to 100 mm in diameter, extending to the surface and closed by a removable cap.

10.4 Cables

The positive and negative circuit cables, including those for the permanent reference electrodes, shall be buried to a depth of 0.8 m on a sand bed with a warning mesh placed 20 cm above, or laid in specially provided underground concrete or plastic ducting.

Non-armoured buried cables shall be installed inside plastic conduits.

All cables shall be suitably tagged inside the cathodic protection equipment (transformer-rectifier, junction boxes, test points) and left unconnected to avoid over-voltage during the work.

10.5 Cable connections on pipeline

The electrical resistance of the negative cable connection to the pipeline shall not cause a voltage drop detrimental to the efficiency of the cathodic protection system.

This connection, located at the 12 o'clock position of the pipeline, may be executed:

- For buried links, by thermit welding or electrical discharge pin brazing directly on the pipeline or on a doubler plate, depending on the steel characteristics
- For buried or overhead links, by bolting to a doubler plate (50 x 60 x 6 mm), with a 13 mm hole drilled in its centre. The bolts and nuts used to fix the cable lug shall be brass or cadmium plated or galvanized steel.

In any case, the connection process has to be submitted for approval to Company.

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Any buried connection shall be insulated from the surrounding electrolyte by a suitable mastic such as cold cure epoxy. The cable shall not be wound around the pipeline and shall be fixed to it at the top, by S shaped polyamide collars about 0.5 m long.

Note: For good mechanical behaviour of the steel plate during handling, a rolled plate shall be inserted between the pipeline and the steel plate.

10.6 Permanent reference electrodes

10.6.1 Location

The number and location of permanent reference electrodes shall be defined in the detailed study. They shall be positioned no more than 10 cm from the outer surface of the pipeline, either above the centre line or on the side, at mid-axis.

10.6.2 Installation

Reference electrodes shall be placed in stone-free natural soil, compacted to remove any voids.

They shall be laid vertically, to the required depth, within a PVC pipe, extending into a pit closed by a removable cover. The permanent reference electrodes shall remain accessible and removable through the PVC pipe in order to be calibrated after a few years of operation, and possibly replaced if faulty.

After installation, reference electrodes shall be sprinkled with 20 to 30 litres water.

10.6.3 Checks

After installation and final backfilling, the permanent electrode potential shall be checked relative to a calibrated portable reference electrode (Cu-CuSO₄ or calomel) positioned nearby.

10.7 CP coupons

10.7.1 Location

The number and location of CP coupons shall be defined in the detailed study. As a minimum they shall be installed every 5 to 10 kilometers along the pipeline ROW.

The bare steel part shall be positioned in the vicinity of the pipeline (10 to 50 cm) in order to be in the same environment as a coating defect on the pipeline.

10.7.2 Installation

CP coupons shall be placed in stone-free natural soil representative of the pipeline environment, compacted to remove any voids.

They shall be laid vertically at the required depth, the PVC pipe being extended (if necessary) up to the ground level to reach a pit closed by a removable cover (see appendix 2 of [GS EP COR 111](#)).

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10.7.3 Checks

Just after installation, the natural potential of the CP coupon shall be measured using a portative reference electrode (Cu-CuSO₄ or calomel) positioned inside the PVC tube. This natural potential will be kept in order to later evaluate the polarization of the coupons.

10.8 Anodes

10.8.1 Sacrificial anodes

Except for particular cases, sacrificial anodes shall be supplied preconditioned in a non-hydrated regulating compound ("backfill"). Preferably the anodes shall be soaked for 24 hours before installation, and in any case before backfilling, by immersion in fresh water.

The anodes shall normally be located at a short distance from the protected pipeline, but shall satisfy the following minimal requirements:

- 2 to 3 m distance from the pipeline, at the 9 or 3 O'clock position
- Depth of 1 m minimum or three quarters of the pipeline diameter measured from the 12 o'clock position.

The anodes shall normally be laid horizontally at the bottom of the trench for a new pipeline. However, for an existing pipeline, and to limit the civil engineering work, the anodes may be installed vertically in a drilled hole.

The trench or drilling shall be perfectly backfilled after installation.

10.8.2 Impressed current anodes

The location of impressed current anodes shall depend on the following parameters:

- Soil resistivity
- Distance from the protected pipeline and other buried structures
- Land occupation of the anodic ground bed.

This means that it cannot be standardized. However, the following criteria shall be observed:

- Anodes shall be laid in soil of the lowest possible resistivity
- The distance between the nearest anode and the nearest point of the pipeline shall be greater than 80 m
- A minimum distance of 80 m from nearby metallic structures shall be respected, unless specific measures are undertaken to limit the anodic influence on such structures.

The detailed study shall define the land occupation of the anodic ground bed, the number and spacing between anodes, and the depth and routing of the cables.

11. Commissioning

Commissioning of the cathodic protection system shall not take place until all welding, insulation, wiring and civil engineering work have been completed on the pipeline and associated surface installations.

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A detailed schedule for commissioning, prepared by Contractor and including preliminary and final operations, shall be submitted to Company for approval.

11.1 Sacrificial anodes

The commissioning procedure shall entail:

- Measuring, before making any connections between cables and anodes, the free electrical status (E_n) relative to the soil of all structures, whether protected or not, and connected inside the junction boxes and test points, including permanent reference electrodes and anodes
- Connecting the cables and anodes to the pipeline inside the junction boxes or test points, with the variable resistor, if there is one on the anodic circuit, set to zero
- Measuring anode current output (I_a), with the variable resistor, if there is one, set to zero and then to its maximum value
- Measuring the new mixed electrical state (E) relative to the soil surrounding the pipeline, with the resistor, if there is one, still at its maximum value.

11.2 Impressed current

The commissioning procedure shall entail:

- Measuring, before making any connections between cables, the free electrical status (E_n) relative to the soil of all structures, whether protected or not, and connected inside the junction boxes and test points, including permanent reference electrodes
- Connecting all the cables inside the junction boxes and to the DC sources
- Checking out operation of each DC source:
 - Checking the power supply voltage and DC output voltage (U_o) off-load (0 to 100%)
 - Powering up and measuring DC characteristics (current I , voltage U and potential E at the drain point) for 25, 50 and 100% of nominal rating of the DC source.
- Adjustment to the minimum of each source to obtain the required protection level (E_p) at the furthest points from the source.

11.3 Measurements after connection and adjustment

Any structure under cathodic protection is subject to a polarization phase before a permanent protection level can be reached. After connecting the DC sources, Contractor shall take preliminary readings (potentials and currents) to ensure that the system is fully operational and correctly adjusted (with regards to protection levels). During this phase, the remote monitoring system, if any, shall be tested.

Contractor shall record all the results on data sheets, specific to the pipeline and the installation, prepared for this purpose, for submission to Company.

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11.3.1 Impressed current system

After these measurements at minimum settings, and a period of 48 hours, Contractor shall take final readings of the operating parameters and the protection level (ON/OFF measurements) at the same points (portable reference electrode located at the same points).

If the protection level (E_p) is not achieved, the adjacent DC sources shall be re-adjusted to obtain a potential of between -950 and -1000 mV.

If the protection level at the least negative point is greater than the required limit (E_p), this may result in a lower setting on the same DC sources.

For a system controlled automatically, Contractor shall set up the regulation parameters to maintain the protection level within the specified minimum-maximum range (E_p -EI).

11.3.2 Sacrificial anodes

Final readings shall be taken by Contractor as for the impressed current system. However, if the protection limit (E_p) is not reached, either the anode output current (I_a) shall be increased, if a variable resistor is available, or additional anodes shall be installed at these locations to obtain a potential of -950 mV.

If the protection level exceeds the lower limit (EI), resulting in detrimental overprotection either to the steel (embattlement) or to the coating or painting system, the anode output current (I_a) shall be limited by the installation of a variable resistor, if there is not one already, or by increasing the resistance value, or by disconnecting some of the anodes.

11.3.3 Influence measurements

Whatever the type of cathodic protection system, contradictory influence measurements shall be proposed to Companies owning any metal structure that is crossing or that runs in parallel after final adjustment.

These potential measurements shall be used to determine whether there is any influence from the cathodic protection system:

- Of the pipeline on the existing structure
- Of the existing structure on the pipeline.

For potential variations greater than 50 mV, corrective action shall be agreed between the parties involved.

12. Routine inspections

A further series of measurements shall be performed in the first three to four months of operation after commissioning. The results shall demonstrate the efficiency of the cathodic protection system.

The subsequent schedule of routine inspections shall be prepared by Contractor at the request of Company.

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13. Quality assurance procedures

13.1 General

At the beginning of the design, a Quality Plan must be prepared by Contractor, detailing all actions related to cathodic protection calculation, the definition of the systems to install, procurement, checks and reception of equipment, and commissioning on site. These shall be described in detailed procedures.

All the calculations, systems, and materials used shall be approved by Company.

13.2 Equipment

Characteristics and references of some materials and apparatus used for the cathodic protection systems shall be documented such as:

- Impressed current DC sources, impressed current and sacrificial anodes, insulating joints, safety devices, reference electrodes and other measurement devices, cables, junction boxes as receptionned in plant by Contractor
- Painting and coating
- Wiring plans.

13.3 Technical file

The technical file submitted by Contractor at the end of the work shall include:

- The characteristics of the pipeline to protect
- The detailed cathodic protection calculations
- The systems related to the installation
- The data sheets and test certificates of the materials
- The detailed drawings of the different systems
- The measurements obtained during commissioning.