



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS EP COR 111

External cathodic protection of onshore facilities

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1. Scope

This specification covers the rules applicable to cathodic protection projects for onshore facilities, such as pumping stations, compression stations, gas or oil treatment plants, storage tanks, etc.

This specification applies all buried piping, buried vessels, external side of tank bottoms and in general all metallic parts in contact with soil which are cathodically protected on purpose or DC consumers, such as earthing networks, concrete reinforcing steel bars, steel foundations, etc.

Cathodic protection of pipelines is not covered by this document but by **GS EP COR 110**.

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. Should some requirements of these documents differ, those from [EN 12954](#), [EN 13636](#) or [EN 14505](#) prevail. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
BS 7361 - Part 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 for pipelines
EN 13636	Cathodic protection of buried metallic tanks and related piping
EN 14505	Cathodic protection of complex structures

Professional Documents

Reference	Title
API 651	Cathodic protection of aboveground petroleum storage tanks
API 653	Tank Inspection, Repair, Alteration and Reconstruction
NACE RP0193	External cathodic protection of on-grade metallic storage tank bottoms
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



Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
ISBN 1-57590-092-0	Peabody's control of pipeline corrosion

Total General Specifications

Reference	Title
GS EP COR 101	Design of internal cathodic protection of equipment and storage tanks
GS EP COR 110	External cathodic protection of buried pipelines
GS EP COR 112	External cathodic protection of Onshore deep well casing
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 210	Monolithic insulating joints
GS EP COR 350	External protection of offshore and coastal structures and equipment by painting
GS EP ELE 031	Design of earthing and bonding systems
GS EP ELE 051	Design and installation of lightning protection
GS EP ELE 079	Electrical apparatus for potentially explosive gas atmospheres
GS EP ELE 141	Power transformers
GS EP PLR 420	Site welding of carbon steel pipelines to API 1104 and DNV-OS-F101 (sweet service)
GS EP PLR 421	Site welding of carbon steel pipelines to API 1104 and DNV-OS-F101 (mild, intermediate and severe sour service)



3. General requirements

3.1 Qualification and Certification of Cathodic Protection specialists for design, installation Supervision, commissioning and routine inspection

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

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

The verification of the formal Certification of the individuals shall be carried out as follows:

- Conventional design work, supervision of installation, pre-commissioning and routine monitoring works to 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 to 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 Competence (Land Application Sector), APCE (Land Application Sector), Institute of Corrosion, NACE International. Any other certification scheme shall be approved by Company.

Any use of non certified personnel for cathodic protection design shall be subject to approval 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's 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's specialist or its appointed representative shall have the right to attend the site/plant/factory and to review documents/reports/drawings when he considers appropriate. Approval from Company's specialist is mandatory at each phase of the project.

3.3 Sub-Contractors

When Contractor sub-contracts site surveys, studies (basic engineering and detailed engineering), works supervision, start-up and commissioning, including the preparation of the final report to a specialized Sub-Contractor, the choice of Sub-Contractor shall be submitted to Company for approval.



Notwithstanding the above provision, 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.

In the case of complex installations or for any reason calling for the simultaneous intervention of several Contractors, special dispositions in the contract shall ensure coordination and compatibility of the various cathodic protection studies, the standardization and 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.

3.4.1 Study

The study shall include a site survey covering:

- 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 concerning the design of the structure to be protected, or taken as a DC consumer, its size, and those of 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 the preparation of a detailed study report covering:

- An analysis of all information gathered and measurements taken, and an estimate of corrosion risks
- Justified design hypotheses, particularly for coatings damage and ageing
- The list, surface areas, and nature of the structures to be protected
- as the list, surface areas, and nature of DC consumers
- The technical requirements to be followed by other disciplines (civil works, piping, electricity) for electrical continuity and discontinuity of metallic structures
- 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 minimum 20 years
- 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 their relevant installation procedure
 - Wiring diagram for electrical equipment.
- Installation instructions, indicating all precautions to be taken. Particular emphasis shall be given to the construction of:
 - Ground beds
 - Connections on anode circuits
 - Insulations between protected and non protected items
 - Insulations between items protected by different systems
 - Insulations 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
 - Reference electrode installation at fixed points.
- Instructions for checks to be carried out during the works, upon completion, and at start-up.

The location of DC power equipment (rectifier, drain point, current distribution, anodes, interconnection, and insulating joint boxes) shall be outside hazardous areas to allow permanent access on duty. If this is not possible, an enclosure corresponding to safety classification of the relevant area shall be used and the equipment fitted to allow energized readings from the outside.

The study shall be submitted to Company or 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 examined.



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 questions of property which might be involved in the installation of the cathodic protection system.

Company shall likewise deal with the acquisition of land and rights of way and settle all additional costs and compensation for any loss of crops.

Contractor shall provide Company with all the 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 the local distribution network, and unless otherwise specified, 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 the equipment shall be the responsibility of Contractor.

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

Contractor shall also supply all those spare parts which will be required during start-up of the installation.

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

- Manufacturing progress
- That the equipment conforms to the specifications
- And to be present during Factory Acceptance Testing.

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

Vendor shall supply the factory test reports, the anode material chemical analysis, the 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
- An equipment list with references and Vendor's addresses
- A list of spare parts for two years operation, with complete references
- Operating procedures
- A Complete list of measurements taken before and during the startup of the system



- Reports stating the agreements made with owners of neighbouring structures (duly signed by the various parties) on the corrective actions to be taken for any interference with these structures
- The results of the enquiry and the permission of 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 requirements of [EN 12954](#) shall apply. With zinc reference electrode (see § 7.10) the criteria shall be modified accordingly.

In addition, and unless otherwise indicated in this document, all the requirements of [NACE SP0169](#) and [BS 7361 - Part 1](#) shall apply.

4.2 Minimum negative polarization

Minimum polarization of carbon steel structures as measured with respect to the saturated Cu-CuSO₄ reference electrode shall be:

- -850 mV in general cases
- -950 mV for metallic structures buried in soils where sulphate reducing bacteria are likely to develop, such as in clay.

Less stringent potentials may be accepted in very highly resistive soils, in compliance with [EN 12954](#).

Important remark: Potential values shall be measured as close as possible to “true” values, correcting the error due to the ohmic drop in the soil. Since no reliable OFF potential can be measured directly on the steel structures, representative coupons for which OFF measurement is achievable shall be used (see § 7.10.3).

Note: More specific protection criteria may be used on a case per case basis with Company approval, depending on facilities and materials characteristics, coatings, and site.

4.3 Maximum negative polarization

The negative potential shall be limited to the most stringent of the requirements below:

- -1.2 V/Cu-CuSO₄ to prevent cathodic disbonding of coatings
- -1.1 V/Cu-CuSO₄ to avoid hydrogen induced stress cracking for high strength steels (SMYS > 700 N.mm²).



5. Site studies

5.1 Site surveys

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

- Soil resistivity measurements to assess apparent corrosiveness level and for the installation of anodes,
- Measurements of structure-to-soil potentials, if applicable, on existing and neighbouring buried metallic structures (including pipelines),
- 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 on foreign buried structures in the vicinity of the facilities.

Note: In the case of existing facilities, Contractor may, conditions permitting, carry out one or more of the cathodic protection trials, so that the 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, at representative locations and at pre-selected points for location of anodes.

These points shall be located in the vicinity of an available low voltage power line, in areas of low resistivity, and outside of any hazardous areas.

These locations shall take into account the new or future structures, protected or not, to prevent over potential and DC influences.

If soil resistivity survey results are supplied to Contractor, Contractor may proceed to check them at random and at selected points.

5.3 Direct or alternating stray currents

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

6. Design and installation of a cathodic protection systems

6.1 "Local" and "global" design

"Global" design means that the anodes are located remotely. Typically, groundbeds consist in a few deep wells, typically located at 100 m from the structures. In this design interferences are significant, and a very high part of the current is consumed by grounding or earthing circuits, or other bare structures, instead of being used to protect the structures.

"Local" design means that anodes are located in close proximity to the structure to be protected and that they are distributed along its length. With this distributed system, the current is preferentially consumed by the nearest structures to be protected, without significant loss to



other buried structures. Groundbeds consist in discrete vertical anodes at surface (3 m long at 1 m depth), continuous horizontal anode strings (for congested area), or other type of shallow anodes. Typical distance between anode and piping is 2 to 5 m.

“Local” design is more likely to achieve an adequate spread of CP currents than a “global” system. Therefore, unless otherwise specified, local design shall be the solution for Onshore facilities cathodic protection system.

6.2 Cathodic protection using sacrificial anodes

This solution shall be used:

- When the total buried surface area to be protected is small
- For local protection such as for vessels in concrete pits or remote isolated piping
- Exceptionally on larger installations when a power source is unavailable.

Sacrificial anodes shall be used only if ground resistivity in the anode installation zone is less than 30 Ω .m.

6.3 Cathodic protection using impressed current

This solution shall be used when large buried surfaces are to be protected and when an electrical power source is available.

6.4 Buried structures subject to stray currents

These structures shall be protected by impressed current systems with automatic potential control. No individual installation is allowed, and if automatic potential control is required for part of the facilities then this shall apply to all buried structures of the installation.

6.5 Sizing

Cathodic protection sub-systems shall be sized such that they compensate for the ageing of the coatings during the service life of the installation. The parameters used for sizing calculations shall be clearly given in the design report.

If any extensions of the facilities are known in advance, they shall be taken into account for sizing the cathodic protection equipment.

6.6 Earthing, grounding and other current losses

Current loss on foreign structures is significant, even with a local design. The most common current drains are:

- Rebars of concrete piles, slab, sarcophagus or basin, foundations or other buried civil works, Deep copper rod or equivalent for earthing
- Grounding system (bonding), usually copper mats, to electrically interconnect all metallic structures.



As far as those current drains are concerned, the following solutions shall be used whenever possible:

- Avoid deep copper earthing if not mandatory for local regulation (to be agreed with Electrical department)
- Use galvanized steel instead of copper for grounding
- Install polarization cell or spark-gaps when such devices could significantly decrease current consumption
- Coat buried concrete structure with coal tar epoxy coating, or cover concrete surfaces with polyethylene sheet.

Note: Rebars themselves shall not be coated with epoxy as this might create galvanic coupling leading to very fast and localised corrosion, hence possible structural dramatic consequences.

6.7 Current requirement

The following design current densities shall be taken as a basis for current requirement calculations:

- Bare steel: 30 mA/m²
- Bare copper (earthing rod or cables): 80 mA/m²
- Bare galvanised steel (earthing rod or cables): 40 mA/m²
- Steel rebars embedded in concrete (consider first row of rebars only): 10 mA/m²
- Underground coated pipework: 1 mA/m² (if no other documented value)
- Coated pipeline: current density will be chosen according to **GS EP COR 110**
- Other painted structure (tank, vessels): to be determined according to paint thickness and type. Proposed current density shall be agreed by Company
- The above values shall be increased for temperatures above 25°C: 1 mA/m² per °C.

To determine the total current requirement Contractor shall calculate which surface areas of piping, tank bottoms or vessels, bare earthing systems, and rebars are to be intentionally protected or involuntary drain current, and use for each one the relevant current density.

A contingency shall be applied to take into account small additional areas.

Note: Design of cathodic protection for well casings shall be documented on a case by case basis based on **GS EP COR 112**.

6.8 Anodic system

6.8.1 Anode weight

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

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



6.9 DC current source sizing

After commissioning, each DC current source shall guarantee the upper protection limit (Ep) defined in section 4, for the relevant equipment to be protected.

Sizing shall take into account the overall resistance (R) of the resulting electric circuit, calculated as indicated in section 6.9.3.

6.9.1 Impressed current system

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

6.9.2 Sacrificial anode system

The number of sacrificial anodes (N) and their dimensions, shall be defined to provide the total current required (I) and maintain a protection level (E in mV), throughout the anticipated life time, that is equal to or more negative than the protection limit (Ep) on the protected structures. No safety factor shall be considered.

6.9.3 Calculating circuit resistance

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

$$R = R_{an} + R_{ca} + R_{lc}$$

With:

R_{an} Resistance of the anodic weight relative to the ground (Ω)

R_{ca} Resistance of the anode and cathode connecting cables (Ω)

R_{lc} Leakage resistance of the coated structure relative to remote earth (Ω)

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

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

Unless justified by specific calculation approved by Company, the leakage resistance of the coated structure relative to remote earth shall be calculated at first approach with the following formula:

$$R_{lc} = \frac{R_f}{S_b}$$

With:

R_f Faradic resistance of steel, equal to 5 ohm.m² at 10 ohm.m electrolyte resistivity (proportional for higher resistivity)

S_b Surface of bare steel

In case of significant copper grounding connected to the structure, resistance of coated structure will be considered as negligible



6.10 Insulating joints

As a general rule, the use of insulating joints shall be limited and avoided whenever possible. Insulated flanges can possibly be used to electrically separate:

- An area which is protected by impressed current from an area which is not protected
- An area protected by impressed current from an area protected by sacrificial anodes
- Pipeline sections with different metallurgies
- Pipeline sections in a critical or aggressive environment (river crossing for instance)
- Pipeline sections with different owners

or when imposed by statutory regulations.

As a general rule, Insulating joints shall be installed at the boundary limits of the facilities to be protected, especially when they provide insulation from pipelines.

Installation of insulating joints within facilities shall be avoided, except if the advantage is demonstrated and approved by Company.

In particular, when an insulating joint is installed on a pipe entering a plant, the joint shall be installed on the plant side after the ESDV valve, for safety reasons. If the valve is grounded to the site general grounding/earthing system, then an isolating device shall be installed (see § 6.6).

Insulating joints shall be installed above ground or in non-floodable pits. In some specific cases, they should be installed buried, but such installation shall be clearly requested and approved by Company.

In the case of monobloc insulating joints with a diameter greater than or equal to 50 mm, the requirements of **GS EP COR 210** shall apply. Otherwise, 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 or piping: steel grade, transported fluid, pressure, temperature, etc.

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

If the fluid transported contains an aqueous phase, the insulating joint shall be coated internally over a sufficient length, at least on the side subject to cathodic protection, to minimize the risk of corrosion resulting from internal short circuiting of the cathodic protection current. The coated length depends on the aqueous electrolyte resistivity and on the pipe diameter. The length to be internally coated shall be calculated by Contractor according to their know-how and shall be submitted to Company for approval.

6.11 Safety devices

On sites that are subject to frequent lightning effects (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 then submit the selected device (or devices) to Company for approval, in accordance with [NACE SP0177](#).

6.12 Earthing circuits

Compatibility of cathodic protection with earthing systems shall be studied and documented. Every possibility to limit current consumption by earthing systems shall be examined in accordance with [GS EP ELE 031](#), [GS EP ELE 051](#) and applicable regulations and standards.

6.13 Specific case of Aboveground Storage Tank undersides

Above ground storage tank undersides might require cathodic protection (for internal protection see [GS EP COR 101](#)). Such decision whether to protect or not tank bottom externally should be based on:

- Soil corrosiveness assessment
- Historical data on external corrosion issues in surrounding area, if any
- Local regulation
- Mandatory requirements of international standards.

In case of lack of such information, or if there is no specific reason not to protect the tank underside, cathodic protection will be implemented. General design information (criteria, current density, monitoring, commissioning, inspection and maintenance...) will be based on [NACE RP0193-2001](#), then if necessary on [API 651](#).

In addition, installation of cathodic protection shall fulfill the following specific requirements.

For new construction:

- The tank cushion shall be made of clean washed sand. The use of a sand-bituminous layer shall not be allowed.
- Bottom plates shall be coated according to [GS EP COR 350](#)
- An impervious secondary containment membrane shall be installed approximately 50 cm below the tank.
- The anodic system shall be either by ribbon grid system, or by piggy back system, or by other pre-backfilled cable-like anode loop system, installed 30 cm below the tank plates
- Distance between ribbon or cable anode shall be 1.6 m maximum.

For existing tanks, installation of dedicated cathodic protection shall fulfill the following requirements:

- The electrical isolation of the tank versus foreign structures and earthing systems shall be achieved
- Cathodic protection shall be performed by one or several deep anodes groundbeds. Design shall be based on tank surface and shall be submitted to Company for approval. Sacrificial anodes or shallow groundbeds shall not be accepted.

If those specific requirements cannot be achieved, then tank bottoms shall be included with the other structures in the overall cathodic protection system design, but it shall be clearly indicated that the efficiency of cathodic protection cannot be guaranteed for those tank. Inspection



programs shall then be implemented according to **API 653** with the hypothesis that cathodic protection is not efficient.

7. Equipment

7.1 Transformer-rectifiers for impressed current systems

Selection of materials and installation for impressed current stations shall refer to **GS EP ELE 141** and be in accordance with recognized international standards referenced in the present specification.

Transformer-rectifiers shall be supplied by recognized Supplier and design shall be submitted to Company for approval.

Transformer-rectifiers shall operate as permanent generators connected to the circuit comprising the anode ground bed and the structure to be protected, and supplying:

- A constant current
- A constant voltage.

Constant potential (control of measured potential relative to a permanent reference electrode) operating control may be accepted on a case-by-case, based on approval from Company.

Transformer-rectifier shall be of the air cooled type unless otherwise stipulated. Minimum IP rating for indoor installation with air-conditioning shall be IP31 for outer cabinet. For outdoor installation, minimum IP65 applies (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.

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

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

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

7.2 Circuit breakers for ON/OFF potential measurements

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

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

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

Alternatively, permanent synchronised current interrupter could be installed. The type of synchronisation (GPS, radio, fiber optic...) will be submitted to Company for approval.



7.3 Spare parts

The transformer rectifiers shall be supplied ready to operate and with the spare parts needed for the commissioning period.

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

7.4 Testing

Each transformer-rectifier shall be the subject to factory inspection by Company representative. An Inspection Test Plan shall be prepared ahead of inspection.

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

7.5 Impressed current anodes

7.5.1 Anode type

MMO anodes shall be supplied from approved Vendors only.

7.5.2 Backfill composition and preconditioning

7.5.2.1 Backfill

The backfill comprises 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 Ω .cm.

This type of backfill shall be used where there is no influence from water tables, because of a specific weight below 1 kg/dm³.

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 removed using 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 determination of anode lifetime.

7.5.2.2 Preconditioning

Anodes supplied preconditioned shall be either factory centered 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, within the following limits:

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

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

When a geotextile 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 near to the closing device, to avoid possible damage of anodic connection during handling.

The backfill surrounding the anode shall be petroleum coke breeze based and shall be compacted when installed.

7.5.3 Cables

Anodes shall be supplied with HMWPE or PVDF/HMWPE double insulated cable in case of chloride containing environment, with a cross-sectional area of 16 mm² minimum, 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 insulation and seal the connection and the cable at the head of the anode.

The buried cable shall be armored or inside a plastic conduit.

7.5.4 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
- Test certificate for the mechanical resistance of the connection, carried out on 5% of the anodes ordered, and for which the minimum required value is 200 kg for Fe/Si anodes, with or without chromium
- A visual and dimensional inspection certificate.

7.6 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.

The requirements for alloy composition, quality, inspection and performance are defined in **GS EP COR 201** which is applicable to any supply of sacrificial anodes.

Anodes shall preferably be installed vertically at a minimum depth of 1 meter.

The distance between anodes at the same station shall be at least 3 meters.

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



7.6.1 Backfill

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

- 75% gypsum ($\text{CaSO}_4 - 2 \text{H}_2\text{O}$)
- 20% bentonite
- 5% sodium sulphate (Na_2SO_4).

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 geotextile bag as defined in section 7.5.2.

7.6.2 Quality control

In his 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 7.7).

7.7 Cables

Cables for sacrificial anodes shall have a minimum section of 16 mm^2 and shall be insulated with XLPE/PVC (insulation voltage 600 V) and comply with regulatory requirements.

Cables shall be connected to the protected structures using doubler plates. This connection shall be protected, preferably with epoxy resin, to prevent any possibility of water ingress into the connection.

The buried cable shall be armoured or inside a plastic conduit.

7.7.1 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, on the other side, 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, on the other side, 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 or PVC/PVC).

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 mm^2 . 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.



Buried cables shall be armoured or inside a plastic conduit.

7.7.2 Anode connecting cables

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 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.

7.7.3 Earthing cables

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

7.7.4 Measurement cables

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

Buried cables shall be armoured or inside a plastic conduit.

7.8 Cable connection accessories

These accessories are for branch connecting anode cables to the positive main cable. At the point of connection, insulation of the main cable is 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 must not be cut under any circumstances.

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

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

7.9 Junction boxes

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

When adjustable resistors are installed, the enclosure shall be large and sufficiently ventilated to dissipate the produced heat. Calculation of resistor characteristics and enclosure size shall be submitted to Company for approval.

Consequently, unless justified and by approved by Company, reinforced safety boxes shall not be required. However, 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).



The type of 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.

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.

7.10 Monitoring equipment

7.10.1 Potential test points

Potential test points shall always be installed outside hazardous areas on the protected structures and are mandatory for:

- Insulating joints
- Interconnection point between structures (parallelisms and crossings)
- Crossings with an unprotected metallic structure or foreign structure
- One end of non-metallic casings at road or non-electrified railway crossings
- Current drain points
- Anodes and groundbeds.

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

In urban areas potential test points shall be located in concrete blocks (sidewalk type test point).

In hazardous areas the boxes shall meet the requirements of applicable safety standards.

In all instances box model shall be submitted to Company for approval.

When a coupon is connected to the test post, the box shall be equipped with reed switch connection to easily perform local ON/OFF measurements.

7.10.2 Permanent reference electrodes

These electrodes are used to monitor the effectiveness of the cathodic protection system, by measuring, either directly or via a remote monitoring system, the pipe-to-soil potential at a specific location. If appropriate, they can provide a durable means of controlling a regulation device (see section 7.1).

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.

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

Permanent reference electrodes shall be assumed to be stable 72 hours after total immersion.

7.10.3 Coupons

When appropriate, coupons allowing local ON/OFF measurements together with cathodic current density measurements shall be supplied and installed. This is especially required in complex areas.

Coupon shall be circular and shall be assembled at the end of a PVC tube. This tube will allow a portable reference electrode to be inserted from surface.

Contractor shall submit to Company approval detailed information on the equipment proposed and location of coupons. A typical drawing is given for information in Appendix 2.

8. Installation

8.1 Supervision during installation

Contractor supervision on site during installation shall be mandatory. When installation is sub-contracted to a specialized Contractor, such supervision may be reduced but not suppressed.

Personnel in charge of supervision shall be certified according to § 3.1.

8.2 Impressed current DC sources

Indoor wall-mounted air-cooled transformer-rectifier sets shall be installed inside a technical building or shelter, correctly ventilated, 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 related 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 within a fence, with the control and monitoring cubicles located either inside a shelter or under a canopy.



Layout shall be in accordance with local regulatory requirements for low voltage electrical installations.

8.3 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 from the concrete base via a cable tray 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.

If the junction boxes are metallic, in order to minimize any safety issue to personnel (electrical shock), it is recommended to install suitable grounding system(s) for the junction boxes. Contractor shall submit detailed drawings and installation procedures of the grounding system for Company approval.

8.4 Test points

The junction boxes, preferably mounted on pipe supports, shall be installed as defined in section 8.3. The tubular test points shall be sealed in a concrete base.

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

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.

8.5 Cables

Where possible, the DC power and test cables shall follow the main cables routes. The positive and negative circuit cables, including those of 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 conduits.

Non armored buried cables shall be installed inside plastic conduits.

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

8.6 Cable connections

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

Connection may be executed:

- By thermit welding or electrical discharge pin brazing directly on the structure or on a welded steel plate, depending on the steel characteristics



- By bolting to a welded steel 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.
- For pipelines, the choice to use or not a doubler plate, and the welding process for the connection has to be in full compliance with General Specification **GS EP PLR 420** (sweet service) and **GS EP PLR 421** (sour service).

Any buried connection shall be insulated from the surrounding electrolyte by a suitable mastic such as cold cure epoxy. Each cable shall be secured by means of plastic collars with a 0.5 m free over length, without turn around it.

8.7 Permanent reference electrodes and coupons

8.7.1 Location

The number and location of permanent reference electrodes and coupons shall be defined in the detailed study. They shall be positioned no more than 10 cm from the outer surface of the structure.

8.7.2 Installation

Reference electrodes shall be placed in stone-free natural soil, compacted to remove any voids. They shall be laid horizontally to the required depth. After being laid, the reference electrodes shall be sprinkled with 20 to 30 liters water.

Coupons shall be placed in stone-free natural soil, compacted to remove any voids. The PVC pipe on which the coupon is assembled will be terminated into a pit closed by a removable cover. The PVC pipe shall remain empty. Typical drawing is given for information in Appendix 2.

8.7.3 Checks

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

8.8 Anodes

8.8.1 Sacrificial anodes

Except for particular cases, these anodes shall be supplied preconditioned in a non-hydrated regulating compound ("backfill").

Before installation, the anodes shall be soaked for 24 hours by immersion in fresh water.

Anodes shall normally be located at a short distance from the protected structure.

Anodes shall normally be laid horizontally at the bottom of the trench or installed vertically in a drilled hole. The trench or drilling shall be perfectly backfilled after installation.

8.8.2 Impressed current anodes

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

- Soil resistivity
- Distance from the protected structure and other buried structures
- Footprint of the anodic ground bed.

However, the following criteria shall be observed:

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

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

9. Commissioning

A general procedure for commissioning shall be prepared by Contractor and approved by Company when several cathodic protection sub-systems are installed under the responsibility of several Sub-Contractors.

Commissioning of each of the cathodic protection systems shall not take place until all welding, insulation, wiring and civil engineering work has been completed on facilities to be protected.

A detailed schedule for commissioning prepared by each of the Sub-Contractors and including preliminary and final operations shall be submitted to Company for approval.

9.1 Supervision of commissioning

Supervision of commissioning on site shall be carried out by Contractor.

When commissioning is sub-contracted to specialized Sub-Contractors, such supervision may be reduced but shall never be suppressed. Personnel in charge of supervision shall be certified according to § 3.1.

Commissioning shall be attended by Company representative and Company personnel responsible for the maintenance of the system(s) in the future.

9.2 Sacrificial anodes

The commissioning procedure shall include:

- Ensuring all installations are compliant with approved drawings
- Measuring, before making any connections between cables and anodes, the free electrical status (En) 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 protected structure 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 at its maximum value
- Measuring the new free electrical state (E) relative to the soil surrounding the structure, with the resistor, if there is one, still at its maximum value.

9.3 Impressed current

The commissioning procedure shall include:

- Ensuring all installations are compliant with approved drawings
- 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 point.

9.4 Measurements after connection and adjustment

Any structure protected by 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. During this phase, the remote monitoring system, if any, shall be tested.

Readings shall be taken on the same reference point(s) / test point(s), in order to have consistent data to analyze whether the protected structure(s) has been polarized or not.

Contractor shall record all the results on data sheets, specific to the structures and the installation, in a format approved by Company.

9.4.1 Impressed current system

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

If the upper level (E_p) is not achieved, the adjacent DC sources shall be re-adjusted to obtain a potential between -950 and -1000 mV versus saturated Cu/CuSO₄ reference electrode.

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 - E_l).



9.4.2 Sacrificial anodes

Final readings shall be made by Contractor as for an impressed current system. However, if the upper 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 the locations concerned to obtain a potential of -950 mV versus saturated Cu/CuSO₄ reference electrode.

If the protection level exceeds the lower limit (E_l), resulting in overprotection of the steel (embrittlement) or to the coating or painting system (disbonding), 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.

9.4.3 Insulating joints

For pipelines carrying fluid containing high salinity water (BSW > 5%), measurement of the possible current which could cross the insulating joint shall be made using a clamp-on ammeters. The diameter of this clamp shall be adapted to the pipe diameter. In case of current circulating across the joint (through the internal fluid) remedial action to reduce such current to an acceptable level shall be submitted to Company for approval.

9.4.4 Influence measurements

Whatever the type of cathodic protection system, contradictory influence measurements with any metallic structure that is crossed or runs in parallel shall be proposed to Company after final adjustment of the systems.

For potential variations greater than 50 mV, a correction must be agreed between the parties involved.

10. 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 effectiveness of each of the cathodic protection sub-system.

The subsequent schedule of routine inspections shall be prepared by Contractor.

11. Quality assurance procedures

11.1 General

At the beginning of the design, a Quality Plan shall be prepared by Contractor, detailing all actions related to the 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.



11.2 Equipment

In the technical part, characteristics and references of materials and apparatus used for the cathodic protection systems shall be specified:

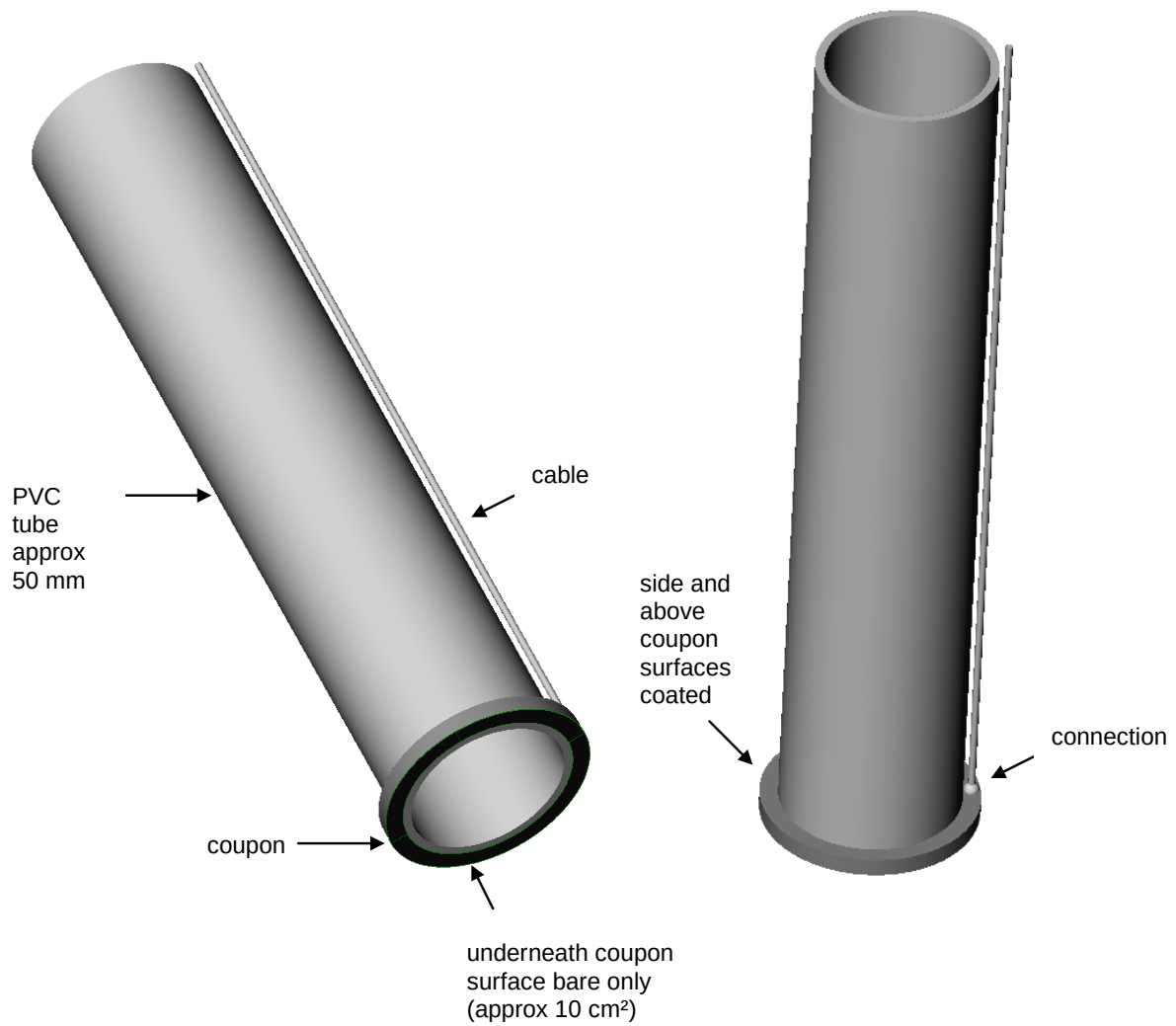
- Impressed current DC sources, impressed current and sacrificial anodes, insulating joints, safety devices, reference electrodes and other measurement devices, cables, junction boxes received on plant by Contractor
- Painting and coating
- Wiring plans.

11.3 Technical file

The technical file submitted by each of the Sub-Contractors at the end of the works shall include:

- The characteristics of the structures under cathodic protection
- The detailed calculations of the cathodic protection system
- The description of the sub-systems together with as-built location drawings, wiring diagrams and sketches
- The data sheets, test reports and certificates, notices of materials and equipment
- The results of sub-systems testing and commissioning
- The instructions for operation, checking and maintenance.

Appendix 1 Typical coupon assembling



Appendix 2 Typical coupon installation

