

PETRONAS TECHNICAL STANDARDS

TECHNICAL SPECIFICATION

INSTALLATION AND COMMISSIONING OF CATHODIC PROTECTION SYSTEMS

PTS 30.10.73.33

OCTOBER 2011



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PTS Title:	Installation and Commissioning of Cathodic Protection Systems

This revision of PTS **30.10.73.33 - Installation and Commissioning of Cathodic Protection Systems (October 2011, Revision 0)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The previous version of this PTS **30.10.73.33 (January 2000)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU/Divisions in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

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1 INTRODUCTION

1.1 SCOPE

This new PTS specifies requirements and gives recommendations for the installation and commissioning of onshore and offshore cathodic protection systems and gives test procedures for pre-commissioning, commissioning and monitoring of such systems.

This PTS should be read in conjunction with the relevant design documents of the cathodic protection system(s), which should include specific installation and commissioning procedures.

This PTS is a revision of the PTS of the same title and number dated April 2003. A summary of changes from the previous edition is given in (1.7).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS, and to Contractors nominated by them.

This PTS is intended to be used for new construction projects, retrofitting and the operation and maintenance of cathodic protection systems in relation to exploration and production facilities, oil refineries, chemical plants, gas plants and supply/marketing installations. When PTSs are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards to safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

For the purpose of this PTS, the following definitions shall hold:

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

cathodic protection	process of reducing or preventing corrosion of metal structures in contact with an electrolyte by the flow of direct current from the electrolyte into the structure surface
cathodic protection station	combination of equipment installed to provide cathodic protection to the structure to be protected
current density	amount of current per unit area of the steel surface, coated or uncoated, in contact with the electrolyte
drain point	point on the pipeline or structure where the connection of the negative terminal of the cathodic protection voltage source is made to conduct (drain) the returning current from the pipeline to the voltage source
electrolyte	conductive liquid or material such as soil or water in which an electric current can flow
deep groundbed	one or more anodes installed vertically at a nominal depth of 15 m (50 ft) or more below the earth's surface in a drilled hole for the purpose of supplying cathodic protection. Sometimes referred to as deep anode bed (NACE SP 0572)
foreign structures/pipelines	metal structures or pipelines other than the structure or pipeline under consideration, in contact with the same electrolyte, and which are or may fall under the influence of the cathodic protection system; they may be owned by the Principal or other companies and may or may not be equipped with cathodic protection
groundbed	system of buried or submerged electrodes, to conduct the required current into and through the electrolyte to the steel surface to be protected
isolating flange	set of two flanges assembled with an insulating gasket and insulating sleeves and washers, for the purpose of electrically isolating two metallic pipe sections
isolating joint	factory assembled pipe fitting provided with insulating gaskets and resins, to be welded into a pipeline or piping for the purpose of electrically isolating two metallic pipe sections
midpoint	point on a pipeline between two cathodic protection stations where the influence of the two cathodic protection stations is expected to be equal and the protection levels are usually lowest
natural potential	pipe-to-soil potential measured when no cathodic protection is applied and polarisation caused by cathodic protection is absent
"OFF" potential	pipe-to-soil potential measured immediately after the cathodic protection system is switched off and the applied electrical current stops flowing to the pipeline surface, but before polarisation of the pipeline has decreased
"ON" potential	pipe-to-soil potential measured while the cathodic protection system is continuously operating

pipeline	pipeline and associated equipment as defined in the scope of the cathodic protection design contract
pipe-to-soil potential	difference in electrochemical potential between a pipeline or foreign structure/pipeline and a specified reference electrode in contact with the electrolyte. Similar terms such as structure-to-soil potential, pipe-to-electrolyte potential and pipe-to-(sea)water potential are sometimes used as applicable in the particular context
polarisation	change of the pipe-to-soil potential caused by the flow of DC current between an electrolyte and a steel surface
polarisation cell (Kirkcell)	device inserted in the earth connection of a structure that isolates for DC in the cathodic protection range
reference electrode	potential is accurately reproducible and which serves as a reference for pipe-to-soil potential measurements
stray currents	electrical currents running through the electrolyte, originating from a foreign DC source and causing interaction with the corrosion and cathodic protection processes of the structure or pipeline. Stray currents may also originate from the pipeline's cathodic protection system and act upon foreign structures/pipelines
structure	structure and associated equipment as defined in the scope of the cathodic protection design contract

1.4 ABBREVIATIONS

Ag/AgCl	Silver/Silver Chloride as used for the Silver/Silver Chloride type of reference electrode
Cu/CuSO ₄	Copper/Copper Sulphate as used for the Copper/Copper Sulphate type of reference electrode
AC	Alternating Current
DC	Direct Current
PVC	Poly Vinyl Chloride
ROV	Remotely Operating Vehicle (underwater)
SBM	Single Buoy Mooring

1.5 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (6).

1.6 PROPRIETARY NAMES

The names "Wenner", "Shepard", "Kirkcell" and "Swain" are used in this PTS to indicate measuring techniques or equipment types, commonly understood by those names in cathodic protection engineering. They are not intended to indicate a requirement to apply equipment of that particular brand name.

1.7 CHANGES FROM PREVIOUS EDITION

The previous edition of this PTS was dated January 2000. Other than editorial changes, the following are the main changes since that edition:

Section	Change
1.3.2	Include definition for deep groundbed
2.2	Include reference to ISO 15589-1 and ISO 15589-2
3.1	New addition to include inspection requirement
3.3.1	Improve requirements for communication on any change of construction
3.3.3.1	Include reference to NACE Standard SP0572
3.5.2	Include recommendation for installation of "spare" test cables for buried structures
3.5.2.5	Provide guidance for placement of permanent reference electrode
3.7.2.3	More elaboration on testing through potential measurement and include isolation checker as another alternative method
4.2.1	Include reference to BS EN 50162
6	Include reference to PTS 30.48.00.31-P, NACE SP0572, BS EN 50162, ISO 15589-1 and ISO 15589-2

2 GENERAL

2.1 HOW TO USE THIS PTS

The installation of cathodic protection systems is an important step during the execution of a cathodic protection project. Most components of a cathodic protection system are buried or immersed and therefore not accessible for inspection after installation, costly to replace (if at all possible) and prone to deterioration by electrochemical effects if not installed properly.

During installation of a cathodic protection system several (pre-commissioning) checks have to be carried out to show that the design requirements are met, before the system or parts of it are backfilled.

Upon completion of the installation of the cathodic protection system, the system shall be commissioned in accordance with written commissioning procedures to give evidence that the system operates or can operate in accordance with the design and that the protection criteria can be met.

It is assumed that the design of the cathodic protection system has been made in accordance with the recommended standards (2.2). The design documents shall include the design protection criteria, a materials schedule, all relevant drawings and installation and commissioning procedures. This documentation shall be available during installation and commissioning.

This PTS has been written to provide common installation and commissioning procedures and specifies the minimum tests which should be executed during and after installation. It may assist the designer of a cathodic protection system in writing specific procedures in line with Group practice. Because of the general nature of this PTS, a mere reference to this PTS is usually insufficient and specific instructions to cover specific equipment and local conditions are usually required.

2.2 CATHODIC PROTECTION DESIGN STANDARDS

This PTS shall be used in conjunction with the following cathodic protection design standards and with the relevant design documents:

Onshore pipelines	: PTS 30.10.73.31 ISO 15589-1 ^(see note)
Offshore pipelines	: PTS 30.10.73.32 ISO 15589-2 ^(see note)
Offshore structures	: PTS 37.19.30.30
Mounded storage vessels	: PTS 34.51.11.30
Bottoms of vertical tanks	: API RP 651
Ships	: BS 7361-1

General guidelines for cathodic protection are given in PTS 30.10.73.10

Note: The design requirement specified in ISO 15589-1 and ISO 15589-2 might differ than the PTS requirements. The more stringent requirements shall be followed.

2.3 CATHODIC PROTECTION CONTRACTORS

The installation and commissioning of cathodic protection systems shall be under the supervision of qualified and experienced cathodic protection specialists, preferably the design consultant's representative. In particular the installation of groundbeds and permanent monitoring facilities shall be closely supervised.

3 INSTALLATION

3.1 INSPECTION

Careful inspection during entire installation process, both of the cathodic protection system and of the structures to be protected are vital to the successful application of cathodic protection.

Inspection should focus on ensuring that coatings are properly applied and not damaged during construction, and that proper isolation and bonding are achieved. For buried structures, these inspections must be performed before backfilling. Once the structure or other system components are buried, identification and correction of any discrepancies is difficult. If the coating on a structure is damaged (or absent) cathodic protection requirements will increase dramatically. Open bonds and shorts to other structures are common causes of inadequate protection and the resulting interference can cause accelerated corrosion damage.

Coatings inspection shall be performed following [PTS 31.40.30.31](#), [PTS 31.40.30.32](#), [PTS 31.40.30.33](#) and [PTS 31.40.30.34](#) depending on type of coating. Electric Holiday Detectors should be used for all coating inspections. If properly used they can detect flaws in the coating which may not be visible. In addition to the use of the Holiday Detector, the inspector shall also make detailed visual inspection of the coatings and occasional measurements of the bond strength. Visual inspection should also include observation of the following:

- surface preparation and coating
- handling of the pipe
- lowering of the pipe into the ditch or seabed
- backfilling operations

Packaged galvanic anodes shall be inspected and steps taken to ensure that backfill material completely surrounds the anode. The individual container for the backfill material and anode shall be intact. If individually packaged anodes are supplied in waterproof containers, the containers shall be removed before installation. Lead cable shall be securely connected to the anode and be inspected for assurance that it is not damaged.

Other galvanic anodes, such as the unpackaged "bracelet" or ribbon type, shall be inspected to ensure that dimensions conform to design specifications and that any damage during handling does not affect application. If a coating is used on bands and the inner side of bracelet anode segments, it shall be inspected and, if damaged, repaired before the anodes are installed.

The rectifier or other power source of an impressed current system shall be inspected to ensure that internal connections are mechanically secure and that the unit is free of damage. Rating of the DC power source shall comply with the construction specification.

Impressed current anodes shall be inspected for conformance to specifications concerning anode material, size, length of lead cable, anode lead connection, and integrity of seal. All cables shall be carefully inspected to detect defects in insulation. Anode backfill material shall conform to specifications.

3.2 POWER SOURCES

3.2.1 Transformer rectifier stations

Transformer rectifiers and control and monitoring equipment shall be installed at locations as directed by the design document. Prior to the installation the area classification shall be checked and the unit shall meet this PTS.

The installation checklist for transformer rectifiers stations ([Appendix 1](#)) should be used.

Floor-mounted units shall be installed on a stable base. When installed outdoors, a concrete plinth shall be constructed with separate cable ducts for AC and DC cables. The equipment shall be fastened to the plinth or the floor using suitable fastenings. Wall mounted units shall be sufficiently supported and bolted to the wall. All units shall be installed so that sufficient ventilation is provided.

Sufficient room shall be provided around the units to allow full opening of all doors and panels and to provide access for reading meters and to carry out visual inspection, adjustments and repairs.

When installed outdoors, sufficient security shall be provided by using lockable cabinets and main circuit breakers. The enclosure shall be weather proofed to a degree of protection of at least IP 54 in accordance with IEC 529. When installed off-plot, security fencing may have to be erected all around the unit. If applicable a sunshade shall be erected above the transformer rectifier.

Oil cooled units shall be filled with the supplied transformer oil to the indicated level, leaving sufficient room for expansion after energising the unit. When a unit is supplied oil-filled, the level shall be checked and adjusted when necessary. Oil temperature gauges shall be installed or checked. Silica gel breathers shall be installed. The content of the breathers shall be dry as indicated by the (blue) colour of the crystals. Pink or white crystals indicate moisture contaminated silica gel, which shall be dried or replaced.

Transformer rectifiers shall be connected to the power supply in accordance with [PTS 33.64.10.10](#).

All functional testing of the transformer/rectifier unit shall be done with the secondary (DC) cables disconnected from the structure to be protected. Dummy load resistors or circuits shall be used for such testing.

Upon completion of the installation, the unit shall be left de-energised. The main circuit breaker shall be locked open and/or the primary or secondary fuses shall be removed and stored separately from the unit until final commissioning.

3.2.2 Solar Generator Stations

The solar generator system shall be supplied complete with supporting framework.

The location of the solar generator station shall be checked for any obstructions to insolation of the solar panels such as other buildings, trees, etc.

A suitable foundation shall be constructed, able to support the solar generator, batteries and regulators according to the generator Manufacturer's written recommendations.

The foundation shall be suitable to withstand the effect of the maximum prevailing wind forces on the solar panel structure.

The structure shall be oriented so that solar panels, when installed, face the direction of maximum insolation.

Sufficient room shall be provided around the solar panels to provide access for maintenance and cleaning of the panels and control equipment.

Battery containers or supports shall be constructed so that spillage of the full content of one battery unit can be contained in an acid resistant container.

Sufficient security shall be provided by using lockable cabinets or buildings and/or by constructing a security fence around the solar generator station.

All functional testing of the solar generator unit shall be done with the secondary cables disconnected from the structure to be protected. Dummy load resistors or circuits shall be used for such testing and may be left in place until final commissioning is required.

Upon completion of the installation, the unit may be left energised to keep the batteries charged. The secondary fuses shall be removed and stored separately from the unit until final commissioning.

3.3 IMPRESSED CURRENT GROUND BEDS

3.3.1 General

The location and the soil resistivity of the groundbed site should be verified to confirm the design parameters. During construction, test results may require modifications in the design, e.g. anode depth, location etc. These activities should be carried out by or in close co-operation with the design contractor of the groundbed. Any modification should be clearly documented and communicated to the Principal.

Prior to installation, impressed current anodes shall be inspected for defects, conformance with the anode specification, and size and length of anode cable tails, and to ensure that anode caps, if used, are secure. Care must be exercised to avoid damaging anodes during handling and installation. Cable tails should be visually inspected for defects in insulation.

Care must be taken to avoid damage to the cables or cable insulation. Each anode shall be tagged with a unique number or code.

Anodes should never be handled, lifted or lowered using the anode cable, unless specifically allowed by the Manufacturer in the installation instructions (e.g. strung anodes).

Impressed current anodes are usually installed in carbonaceous backfill. If the backfill material is supplied loose, it should be installed properly, so that there are no voids around the anodes. Anodes may also be delivered pre-packaged with compacted backfill in metal canisters.

3.3.2 Surface Groundbeds

Surface anode ground beds shall be constructed as directed by the design document. The installation checklist for surface groundbeds ([Appendix 2](#)) should be used.

3.3.2.1 Vertical Groundbeds

For vertical anode installation, holes shall be excavated in appropriate diameters and depth. Power auger equipment may be used where available and where local conditions permit.

Pre-packaged anodes shall be lowered into the holes and backfilled with the original soil. The soil around the anodes shall be compacted by fluidizing the soil with water.

Non pre-packaged anodes shall be positioned in the centre of the holes on a layer of at least 10 cm of tamped backfill. The holes shall be filled with backfill, which shall be tamped in thin layers to approximately 10 cm above the top of the anode. Water may be used to fluidize the backfill. When multiple anodes are installed in one hole, the cable tails of the lower anodes shall be protected from damage during installation of the upper anode(s).

The holes shall be finished with the original soil or, if additional venting is required, with fine gravel. If required by the design, separate headworks shall be erected over each anode hole. Otherwise the original ground profile shall be restored.

Depending on the type of soil, different techniques may be used to install vertical anodes, such as by using water jets to drive the (pre-packaged) anodes into the soil. In such cases, the installation Contractor shall provide a description of the procedures to be followed.

3.3.2.2 Horizontal Groundbeds

For horizontal anode installation a trench shall be excavated to the appropriate depth and length. At the bottom of the trench a slot of about 30 cm by 30 cm shall be excavated to accommodate the anodes and backfill.

The anodes shall be laid in the trench on a layer of tamped backfill material and shall be covered with a layer of backfill material, so that the anodes are positioned in the centre of the backfill.

3.3.2.3 Anode Cable Installation

Upon installation of the anodes, the cables shall be laid in the trench, not directly above the anodes, in a layer of soft sand. For underground cable installation (see section 3.6). If a ring main feeder system is used, the anode cable tails shall be spliced into the ring cable using C-crimps or line taps without cutting the ring cable strands. The ring cable shall be connected to the feeder cable. Underground splices shall be made in accordance with (3.6.1). If a central distribution box is used, the cable tails shall be laid in the trench and shall be terminated in the distribution box.

The trench shall be finished with original soil. If needed, cable warning tape or cable protection tiles shall be used (3.6.1).

On completion of the groundbed the resistivity of the groundbed and if possible the individual anodes shall be measured to remote earth using a low resistance earth Megger.

If the groundbed resistivity is outside usable limits for operation within the design parameters, the Principal and Contractor shall investigate the cause and take remedial actions.

The location of the groundbed shall be indicated e.g. by the installation of groundbed marker posts at both extremities of the groundbed.

3.3.3 Deep Groundbeds

3.3.3.1 Groundbed Design Options

Various types of deep groundbeds are possible and any specific type is chosen to suit the local conditions and/or output requirements. Installation of deep anode systems is described in NACE Standard Practice SP0572.

Options for the bore hole include:

1. Various diameters, to facilitate the installation of large anode systems and depending on the available drilling equipment.
2. Holes cased or uncased down their entire length or part of it, depending on open hole or closed hole option and sub-soil stability. Casings, if specified, can be made of steel, (perforated) plastic or a combination of these.

Options for the anode system include:

1. Conventional anodes with individual cable tails (silicon iron, magnetite).
2. String type anodes having various active sections with one feeder cable (linear distributed anodes).

Options for the total groundbed include:

1. Open hole. Open holes can be used when anodes can be suspended in groundwater at depth.
2. Closed hole. Closed holes are required when no groundwater is present. Closed holes require low resistivity (coke) backfill and venting facilities. Coke backfill can be supplied loose or pre-packaged with the anodes in metal canisters.

The selected design options shall be detailed in the design drawings.

3.3.3.2 Construction

A deep groundbed shall be constructed in accordance with the design document and drawings.

The installation checklist for deep groundbeds (Appendix 3) should be used.

A surface casing larger than the nominal diameter of the bore hole shall be set to a depth of approximately 5 m.

A hole of the specified diameter shall be drilled to the required depth.

All cuttings, mud and other foreign matter shall be removed from the bore hole.

A record shall be kept of the drilling. The various layers, total depth and water level shall be recorded. A bore hole resistivity profile should be made during drilling to confirm the boundaries of the low resistivity layers.

The form for recording the drilling of deep ground beds ([Appendix 4](#)) should be used.

If specified, a casing shall be set in the bore hole. Normally a non conductive (plastic) casing is used for the inactive length of the groundbed.

A bore hole headwork shall be constructed in accordance with the design drawings.

Anodes shall be lowered on suspension ropes in the bore hole to the specified depth.

Anodes shall never be handled using the cable tails. Anodes shall be provided with centralisers to centre them and to prevent cable damage of lower anodes. The anode lead wires shall be permanently identified before installation.

If specified, a venting pipe perforated over the active length shall be installed along with the lower anode.

If specified, a slurry of carbonaceous backfill shall be gradually poured or pumped into the bore hole to the required depth, so that there are no voids around the anodes. This may be done using a large diameter hose which is lowered down to the bottom of the hole and is retracted as the level of coke rises. The quantity of the backfill material shall be recorded.

The top of bore hole shall be backfilled with graded soil or gravel to prevent cable isolation damage.

The anode cable tails shall be terminated in the anode connection box and the headwork cover set in place. Care shall be taken that anode cables have sufficient slack to cope with any backfill settlement.

On completion of installation, the resistance of each anode to remote earth shall be measured and recorded using a low resistance earth Megger. These anode details shall be recorded ([Appendix 5](#)). After completion of the groundbed the total groundbed resistance shall be measured and evaluated against the design. Any major deviation from the design values shall be reported to the Principal.

3.3.4 Underwater anodes

Impressed current anodes may be used for immersed structures such as jetties, sheet piles, platforms, sub-sea (loading) pipelines etc. The required anode systems may be of different designs depending on local situations. The following guidelines should be followed to prevent premature failure of the anodes. It is emphasised that the integrity of impressed current anode cables and cable connections is vital for prolonged service. Failure of cables and cable connections is the most important cause of failure of offshore anodes and anode beds.

Underwater cables shall be installed in accordance with ([3.6.2](#)).

Underwater anodes may be installed fixed to the structure, suspended from the structure deck or roof or positioned on the bottom of the sea or other water. The location of the anodes shall be such that they are immersed at all times.

Anodes that are fixed to the structure shall be designed for that method of installation. The distance between the anode and the structure shall be as large as possible. The structure surface close to the anode shall be provided with a di-electric shield or/and be coated using a heavy duty isolating paint to avoid local overprotection and excessive current loss. Anode cables shall be connected to the underwater anode and sealed using pressure glands or by permanent moulding with epoxy resin.

Suspended anodes shall be suspended from the roof/deck hangers using special insulated wires or ropes. The electrical cables shall not be used for suspension unless the system is has been designed for that purpose. The anodes shall be located so that a maximum distance from all structure members is obtained and no interference with (shipping) operations occurs.

Anodes that are to be laid on the sea bed shall be installed on a suitable support raft to avoid movements due to current and wave action. The raft shall be positioned remote from the structure and outside shipping and fishing areas. Electrical connections shall be made using waterproof cable splice kits.

3.4 SACRIFICIAL ANODES

3.4.1 Installation in Soil

Soil anodes are usually pre-packaged in backfill (gypsum/bentonite) in cotton bags. Prepackaged anodes should be kept dry during storage. If individually pre-packaged anodes are delivered in waterproof containers, these containers must be removed before installation.

Prior to the installation, sacrificial anodes shall be inspected for defects, conformance with the anode specification and size and length of anode cable tails. Care must be exercised to avoid damaging anodes during handling and installation. Cable tails should be visually inspected for defects in insulation.

The location in relation to the object to be protected and the installation depth of the anode shall be checked against the design.

Before installation, the anode with backfill shall be soaked in water for at least 4 hours. Prepackaged anodes shall be installed in augered holes, watered down and backfilled with native soil.

Where anodes and backfill are provided separately, anodes should be centred in the hole and surrounded by the special backfill. This backfill shall be fully wetted and compacted prior to backfilling with native soil.

Anode leads shall be terminated into a test station ([see 3.5.2.7](#)). The test station shall be located such that anode cables are kept as short as possible.

The checklist for recording the installation and commissioning test results ([Appendix 6](#)) should be used.

3.4.2 Marine Anodes, Above Water Installation

Anodes that are installed above water are for instance:

- platform anodes during new construction;
- ship's anodes during new construction or retrofitting during dry docking;
- internal tank anodes (storage tanks, ship's ballast tanks) during maintenance shutdown or repair;
- anodes for SBMs or mooring systems.

Location of the anodes and different anode types/sizes shall be checked against the design. For asymmetrical anodes, the design may specify which face of the anode should point towards the structure. In some cases certain anode faces need to be painted.

Anodes shall be fully welded to the steel structure unless the anodes are specifically designed to be replaced without welding during the life of the system (e.g. SBM anodes, some tank anodes). When anodes are to be bolted to supports, e.g. using U-bolts a tack weld shall be made between the anode core and the support to ensure low electrical contact resistance.

When retrofitting anodes, especially on coated surfaces, all old anode cores and supports that are not re-used should be removed where possible.

When replaceable anodes are installed, the distance between supports shall be as specified to allow the anodes to be interchanged without problems. All dimensions shall be recorded for future reference.

Installation on coated surfaces may require special precautions, such as:

- Anode cores and supports may need to be coated to the same standards as the structure coating.
- During installation of anodes on coated areas, coating damage by dragging or dropping anodes or by weld spatter, etc. shall be avoided.
- If coating operations are required after the installation of the anodes is complete, the anodes shall be protected from painting by wrapping them in paper or covering them with soft soap. The paper wrapping shall be removed after painting. Plastic wrapping is not recommended, and grease shall never be used for the protection of anodes during painting.

The checklist for recording the installation and commissioning test results ([Appendix 7](#)) should be used.

3.4.3 Marine Anodes, Under Water Installation

Anodes that are installed under water are for instance:

- Jetty anodes installed after piling;
- Jetty and platform anodes for retrofitting;
- retrofit anodes for SBMs or mooring systems;

The same procedures may be used when installing anodes above water where welding is not allowed.

Underwater installation is usually performed using divers.

Where possible, anodes should be installed using underwater welding. When welding to critical members of a structure, the welding procedures should be verified and approved.

Anodes may be installed using mechanical means such as bracelets or G-clamps to which they should be welded before installation. Bracelets should be provided with at least one contact bolt per half bracelet. In G-clamps the clamping bolts should serve as contact bolts.

Contact bolts should have a rough flat face contacting the structure, providing sufficient friction to prevent loosening of the bolt and providing sufficient contact surface. Pointed bolts should not be used. Contact bolts should be tightened with sufficient torque to cut through any scale and paint. The contact of a clamped connection should be checked where possible. Normally, the resistance of the clamped connection is not greater than 0.01Ω.

Specially designed anode-bolting attachments may be available. If mountings of this type are used, the contact faces should be clean and free of paint or scale. Serrated washers should be used to ensure a lasting electrical contact.

The checklist for recording the installation and commissioning test results ([Appendix 7](#)) should be used.

3.4.4 Subsea Pipeline anodes

Subsea pipelines are normally provided with bracelet anodes, supplied as two half bracelets. The half bracelets may be half shells of anode material or segmented anodes, consisting of slender anodes welded to a steel bracelet. Depending on the design the two halves are connected by bolting or welding. The anodes should be installed so as to prevent slippage.

It is recommended to apply a epoxy type coating on the inner surface of the bracelet anode facing the pipe, to the surfaces facing the concrete coating and to the exposed parts of the steel bracelet.

Electrical contact with the pipe may be made by installing an electrical cable between the bracelet and the pipe or by welding a steel strip between the bracelet and the pipe. When the two half bracelets are only bolted together, one cable per half bracelet is required.

Welding to the pipe shall be done using approved welding procedures. Attachment of cables to the pipe shall be done in accordance with (3.6.2).

The anodes shall be installed over the anti-corrosion coating. Any cut-outs in the coating to attach electrical connections shall be repaired to standards similar to the original coating.

When installing anodes on concrete coated pipes, the gaps between the concrete and the anode shall be filled using a suitable type of concrete or mastic. Electrical contact between the concrete reinforcement steel and the anode is not permitted.

When installing non-tapered bracelet anodes on pipes without concrete coating, additional plastic tapers may have to be installed in accordance with the design.

The checklist for recording the installation and commissioning test results ([Appendix 7](#)) should be used.

3.5 JUNCTION BOXES AND TEST FACILITIES

3.5.1 Junction Boxes, Distribution Boxes and Test Posts

Junction boxes and distribution boxes shall be installed at suitable levels so as to prevent any ingress of dirt or water.

Where necessary the supports shall be stabilised in concrete.

Cables shall run into the boxes through ducting and suitable cable glands.

When using all-concrete boxes or test posts, the cable ducts may be cast into the concrete. On no account shall cables be clipped direct to, or cast directly into the concrete.

If junction boxes are supported by pipe, this pipe may be used as cable ducting.

When test stations are to be installed below grade level (pit type), they shall be provided with a drain facility to drain any (rain) water.

Junction boxes, distribution boxes and test posts shall be provided with cable terminals, bolted to an insulated panel or insulated "Klippon" type cable terminals suitable for the number and size of cables to be installed. The box shall provide ample room to terminate the cable ends without excessive bending of cables and without the cables exerting stress on the cable terminals.

When installing current control devices such as resistors and diodes, sufficient ventilation or heat sinks shall be provided to avoid a temperature rise of more than 10 °C above ambient temperature.

All test terminals and shunts shall be accessible upon opening the door of the distribution box or test post. Test posts may be provided with contact terminals at the outside of the box for quick access. Such terminals shall be made of corrosion resistant materials (e.g. brass or stainless steel) and shall be fully isolated from the box, also when concrete boxes are used.

For cable installation, see section ([3.6](#)).

3.5.2 Test Facilities

The following test facilities shall be installed at the locations as specified in the design document.

The cables to each pipeline or structure shall be identified by colour coding or tags. Recommended colour coding is given in the diagrams in ([Appendix 8](#)).

Make sure there is sufficient slack in the cables to allow for subsidence without putting any stress on the "cable-to-structure" connection.

Attachment of "spare" test cables to buried structures is recommended as excavation to reconnect test cables could be expensive.

3.5.2.1 Potential Monitoring Station

A standard potential monitoring station shall have two separate cables attached to the pipeline and terminated in the test post ([see figure A.8-1](#)).

3.5.2.2 Drain Point Control Facilities (at CP Stations)

At the drain points, each negative connection to the pipeline shall be provided with current measuring facilities. For single pipelines the ammeter built into the current source may suffice. Where multiple negative connections are installed separate shunts and blocking diodes shall be provided, installed in a distribution box.

At the drain point a potential monitoring station shall be installed using a separate test cable connected to the pipeline for the measurement of the drain point potential ([see Figure A.8-2](#)).

3.5.2.3 Foreign Pipeline Bonding Station

At crossings with foreign pipelines, a bonding facility shall be provided, consisting of two separate cables attached to each individual pipeline, terminated in a test post with suitable facilities to install direct or resistive bonds. The cables to each pipeline shall be identified by colour coding or tags ([see Figure A.8-3](#)).

3.5.2.4 Test Facilities at Isolating Joints/Flanges

At all isolating joints/flanges, two cables shall be connected to each side of the joint or flange. All cables shall be separately terminated in one test post with suitable facilities to install direct or resistive bonds ([see Figure A.8-4](#)).

3.5.2.5 Test Facilities at Casings (Road/Railway Crossings)

Test facilities shall be installed at both ends of the casing, but on casings shorter than 10 m the test facility shall be installed at one end only.

In each test facility, two test cables shall be connected to the pipeline and, if steel casing is used, ([see Figure A.8-5](#)), two test cables shall be connected to the casing. All cables shall be terminated in one test post.

When a non-metal, or externally coated metal casing is used and a sacrificial anode is installed inside the casing, the anode cable tail shall be terminated inside the test post where the anode-to-pipeline connection can be made ([see Figure A.8-6](#)).

Ribbon anodes are best installed inside slotted PVC pipes to avoid electrical contact with the casing and to enable replacement when required.

Permanent reference electrode in accordance to ([3.5.2.8](#)) should be installed at strategic locations for buried pipeline across road/railway for future monitoring of pipe-to-soil potential. As general guideline, reference electrode should be installed at minimum of every 25m interval if the road/railway crossing is more than 50m wide.

3.5.2.6 Sacrificial Anode Connection

Where underground sacrificial anodes are installed, two cables shall be connected to the pipeline or structure and, together with the anode cable tail(s), terminated in a test post with facilities to install direct or resistive bonds (see Figure A.8-7).

3.5.2.7 Line Current Test Stations

Where required by the design, line current test stations shall be installed consisting of two sets of two cables connected to the pipeline at about 100 metres distance from each other and terminated in one test post (see Figure A.8-8). The cables connected in the remote location shall be strapped to the pipe (new pipeline construction) or buried at sufficient depth close to the pipeline.

3.5.2.8 Permanent Reference Electrodes

Permanent reference electrodes may be installed on pipelines, under vertical tanks (see Figure A.8-9) and buried or mounded vessels, on underwater on offshore pipelines and structures.

Before installation, permanent reference electrodes shall be inspected for the correct type and for any damage to the electrode or cable. Damaged cables shall not be used. Sufficient cable length shall be provided for installation without underwater or underground splices.

Before installation the electrode shall be calibrated against a standard reference electrode while immersed in water or wet soil in accordance with the Manufacturer's instructions. The location shall be checked to comply with the design. The electrode shall normally be installed close to the pipeline or structure in accordance with the Manufacturer's instructions or the design drawings. Cable tails shall be identified by tags. After installation the cables and the electrodes shall be protected from any damage due to ongoing construction work.

Where permanent reference electrodes are installed, a permanent (test) cable connection to the pipeline/structure shall be made, which shall be separated from the negative current connection (drain cable). Underground cables shall be installed in accordance with (3.6.1).

Underwater cables shall be installed similar to under water anode cables (3.6.2). The electrode cable tails and the test cable to the structure shall be terminated in a junction box.

3.5.2.9 Monitoring Facilities on Offshore Structures

On offshore structures, monitoring points shall be located so that all critical members will be monitored. The selection of locations shall be such that about 10% of the typical members, such as jetty piles, are covered.

At the elected monitoring stations, permanent connection points to the structure shall be installed. These may consist of a cable, connected to the structure and terminated in an accessible place, or a dedicated corrosion-free stud or earthing boss welded to the structure. The dimensions of the terminals shall be such that a standard size cable clip can be attached to it. The locations of the test stations shall be selected to provide safe access to the structure's edge where the reference cell is to be lowered into the water.

Where permanent reference electrodes are installed, both the reference cable(s) and the structure connection are to be terminated in one junction box.

All test stations shall be marked using a permanent identification and their location and identification code shall be recorded.

3.6 CABLE INSTALLATION

3.6.1 Underground Cables

Cathodic protection cables shall be handled and laid with extreme care as damage to the insulation and/or sheathing may result in premature cable failure. During installation the cable reel shall be supported so that cable may be pulled from the reel without causing kinking or twisting.

The cable type and size shall be checked for compliance with the design. Underground cables shall be identified by colour or tags.

Cables shall be installed at the specified depth in sand padding and cable warning tape and/or cable tiles shall be used.

Cable runs shall be of one continuous length. Joints shall not be acceptable except with the written permission of the Principal.

Cable joints shall be made using an approved splice and sealed using splice encapsulation kits.

Any damage to the cable insulation or sheathing of all cables, including anode connection cables, shall be reported.

All proposed repairs shall be implemented only after approval.

3.6.2 Underwater cables

Underwater cables for anodes, permanent reference cells or other test facilities should be double insulated and armoured and be run in one continuous length. Underwater cable splices are not allowed.

Cables running to the surface along the structure shall be supported by strapping to the structure or be run in protective conduit. In the tidal and wave zone, cables shall always be run in conduit.

On the structure's deck, from the point of suspension to the current source or junction box, anode cables shall be run in protective conduit or in cable trays.

Cables running on the sea bed shall preferably be buried. Cables running from the sea bottom onto the shore shall be protected from wave action. In the beach/shore area they shall be run inside a continuous length of protective conduit and be buried at sufficient depth to prevent being washed out. At the end of the conduit the cable shall be protected from wear caused by rubbing against the conduit.

3.6.3 Cable to Structure Connection

The method of attachment to the structure may vary according to circumstances. The various methods are described in [PTS 30.10.73.31](#).

Whichever method is selected, care should be taken to ensure that a sound electrical connection is made.

The cable to structure connection shall be checked for mechanical strength prior to final backfilling.

All below-ground electrical connections shall be fully encapsulated to comply with the original coating standards before backfilling.

3.7 ISOLATING COUPLINGS/FLANGES

3.7.1 General

Isolating couplings or flanges for pipelines need to be suitable for the operating conditions encountered on the particular installation, e.g. pressure and temperature, and the product.

3.7.2 Isolating Joints

3.7.2.1 Welding

The isolating joint shall be welded into the pipeline at the specified location so that the joint is not subject to bending moments and stress.

Welding shall be carried out so that the heat generated does not damage the insulating material. Manufacturer's instructions with respect to welding shall be strictly followed.

3.7.2.2 Testing Prior to Installation

Following delivery of the isolating joint, the Contractor shall measure the electrical resistance with a 1000 V insulation tester and the resistance shall be greater than 1 MΩ in air.

3.7.2.3 Testing After Installation

After installation and with both sides of the joint earthed, the joint shall be tested by applying a DC current in the pipeline on one side of the joint. This may be achieved by the use of a permanent cathodic protection system or by a temporary groundbed and DC supply.

A Swain meter shall be used to confirm zero current flow across the isolating joint.

As an alternative to this test a potential measurement may be performed. Upon applying the current to one side of the joint, the interrupted structure-to-electrolyte potentials on both sides shall be recorded.

Functioning isolating joint will indicate more negative "ON" potential than "OFF" potential on the protected side with the two values cycling on the same timing as the current interruption. On the opposite side of the isolating joint, the "ON" potential and "OFF" potential will be nearly the same and sometimes the "OFF" potential can be more negative than the "ON" potential due to potential gradient from the cathodic protection system.

Another alternative is through the use of isolation checker that is based on a high radio frequency. This method of testing is more reliable for in service isolating joint.

Test results shall be reported to the Principal for review and acceptance.

If more than one isolating device is installed in parallel, or when earthing or instrument cables are installed in parallel with the isolating joint, the failure may also be caused by another device and the test using the "Swain" type meter is then required to locate the fault.

3.7.2.4 Repairs

Isolating joints are factory assembled and repairs shall not be performed by the Contractor. If a unit is found to be faulty, it shall be replaced.

3.7.3 Isolating Flanges

3.7.3.1 Installation

Isolating flanges shall be welded into the pipe at the required locations specifically for the purpose of cathodic protection isolation. Isolating flanges that may have to be dismantled for the servicing of other equipment (valves, spading off) are not recommended.

For new construction, isolating flanges shall be assembled before being welded into the pipeline or piping system to ensure correct alignment and to avoid stresses during installation. Before installation, the assembled isolating flange set shall be tested in accordance with the procedure for isolating joints (3.7.2.2) and the resistance shall be at least 1 MΩ.

When insulation is installed on existing flanges, it is essential for the bolt holes and flanges to be exactly aligned to prevent damage to the insulating material. Oversized bolts or dowel pins shall be fitted at equal spacing around the flange to maintain alignment during installation.

When insulating existing flanges that are not exactly aligned, smaller diameter bolts of a higher strength shall not be used unless approved by the Principal.

Approved gaskets designed for isolating flanges shall be installed without the use of graphite filled lubricants or greases. Information concerning the use and application of gaskets can be found in [PTS 30.10.73.10](#).

The insulating sleeves shall be inserted into the bolt holes and checked for length and clearance. The bolts shall then be passed through a steel washer, an insulating washer and then the sleeve in the flange. Insulating washers shall then be fitted over the bolts next to the opposite flange, then a steel washer and the nuts shall be installed.

The bolts shall be tightened up so that an even stress is maintained on the flange faces.

Isolating flanges inside banded and other designated hazardous areas, with the exception of flanges used in H₂S service, shall be profiled with moulding putty and wrapped with selfadhesive reinforced bitumen/PVC laminate tape. The tape shall be suitable for the expected service temperature and shall be resistant to degradation by ultra violet radiation.

Isolating flanges shall be painted with non-conductive paint or shall be tape wrapped using a standard contrasting colour for easy identification.

3.7.3.2 Testing After Installation

After installation, an isolating flange shall be tested similarly to an isolating joint.

If an isolating flange is found to be defective, the bolt to flange resistance shall be measured in dry condition using a 500 V insulation tester. If the resistance between any bolt and the flange is less than 100 kΩ the bolt shall be marked and the insulation repaired.

If all bolt to flange resistances are in excess of 100 kΩ and the flange has not been accepted due to the test results, the gasket shall be replaced.

3.7.3.3 Repairs

Bolts showing low resistance to flange shall be removed and the insulation sleeves and washers replaced. Should the gasket require replacement the flange shall be dismantled and reassembled using new insulating materials.

When existing isolating flanges are repaired, bolts shall only be removed from, and replaced in, a line in service if arrangements cannot be made to shut down the line, and in addition the following conditions are met:

- the flange has eight bolts or more;
- prior approval shall be obtained from the responsible operations department using the required procedure;
- bolts shall only be removed and replaced one at a time;
- bolts shall be correctly tightened after replacement;
- the line shall not be subject to pulsating pressure;
- the line shall not be blocked off and subject to a static pressure exceeding the maximum operating pressure.

3.8 ELECTRICAL EARTHING

The object under cathodic protection should be electrically isolated from common or plant earthing systems to avoid a loss of current.

For safety reasons however it may be necessary to install a safety earthing, which should be covered by the design. The earthing system shall be compatible with the cathodic protection system by installing polarisation cells or diode circuits, suitable specified and rated for the purpose, in the earthing circuit or by the installation of separate earthing electrodes, made of zinc or galvanised steel, buried in low resistivity backfill and not in direct electrical continuity with other earthing systems.

If pipeline earthing is to be installed to mitigate the effect of AC induced voltages on the pipeline, this should be done at the locations where the anticipated or measured voltages to the ground are highest and where the pipeline is exposed and can be touched by personnel.

3.9 POLARISATION CELLS

When specified, polarisation cells shall be supplied complete with steel enclosures. The polarisation cell should be placed on a reasonably level, stable, well-vented and protected location. The polarisation cells shall be assembled in accordance with Manufacturer's written instructions. Safety and personal protection shall be applied.

The cables shall be sized and the cable connections shall be made in accordance with Manufacturer's written instructions.

3.10 TEST COUPONS

Test coupons may be installed to monitor the effectiveness of the cathodic protection. Test coupons shall be sized in accordance with the design document. Test coupons shall always be installed in combination with a potential monitoring station. Two separate cables shall be attached to the test coupon and the cables terminated in the test post.

The distance between the test coupon and the object shall conform with the design and a record of installation details shall be kept.

4 COMMISSIONING

4.1 PRE-COMMISSIONING TEST

Prior to the commissioning of the cathodic protection system, the Contractor shall complete construction and pre-commissioning checks and submit the results on check lists to the Principal for approval.

4.1.1 Transformer Rectifier Units

The pre-commissioning tests shall be done in accordance with Manufacturer's written recommendations. The tests shall include as a minimum:

- verification of AC power supply and earthing connections;
- verification of correct installation of oil, silica gel breathers, etc. (3.2.1);
- energise and test without load for one hour;
- testing at 50% capacity for two hours with dummy load connect to the DC side;
- testing at 100% capacity for two hours with dummy load connected to the DC side;
- calibration of the unit's meters;
- de-energising and connecting of DC cables to the appropriate terminals.

If an electronic component of the rectifier needs to be replaced during the precommissioning tests, e.g. due to rectifier malfunction or failure of the unit to fulfil the performance requirements, then the pre-commissioning test shall be repeated.

4.1.2 Solar Generator Stations

The pre-commissioning tests shall be done in accordance with Manufacturer's written recommendations. The tests shall include as a minimum the proper functioning of the equipment throughout the working range with a dummy load connected to the DC side.

On completion of the tests the unit shall be switched off and the DC cables connected to the appropriate terminals.

4.1.3 Groundbed Resistance

For surface groundbeds, all pre-commissioning tests are described in section (3.3.2).

For deep groundbeds, all pre-commissioning tests are described in section (3.3.3).

For sacrificial anodes, installed in soil, the open circuit potential shall be measured with respect to a Cu/CuSO₄ reference electrode. If needed or specified, the resistance to remote earth shall be measured using a low resistance earth "Megger".

4.1.4 Test Facilities

Checks shall be made to ensure that all test facilities (number and type) are installed in accordance with the design document.

All test facilities shall be listed and where applicable cable marking/identification shall be confirmed and recorded.

The results of all tests and checks carried out during pre-commissioning shall be available during commissioning.

4.2 COMMISSIONING TESTS

4.2.1 Impressed Current Systems

All temporary Cathodic Protection, bonds with foreign structures and earthing facilities shall be disconnected.

If magnesium ribbons are installed in a casing, they shall be disconnected to allow the natural potential of the carrier pipe and the open circuit potential of the magnesium ribbons to be measured.

The 'natural' structure to electrolyte potential shall be recorded at the following locations:

- i) at test facilities installed on the object to be protected;
- ii) at test facilities of any foreign structure in the vicinity of the structure and/or groundbed.

The power source shall be energised and the output adjusted from zero using manual voltage control, to obtain a structure-to-soil potential at the drain point of about -1000 mV versus a Cu/CuSO₄ reference electrode. The voltage and current output shall be recorded.

If magnesium ribbons are installed in a casing, they shall be connected and the potential of the carrier pipe and the current at the magnesium ribbons shall be measured and recorded.

The current measurement shall be done performed using a shunt.

The potential at the drain point shall be measured after initial energising and after polarisation. If the potential exceeds the overprotection limit, the current output shall be reduced.

If more than one structure is protected by the same power source, the current to each structure shall be adjusted by changing the resistor value in each drain cable.

After at least 24 hours of polarisation, the structure to soil potential at key monitoring stations such as pipeline mid points and remote locations shall be measured at regular intervals and the necessary adjustments shall be made to achieve protective potentials throughout the structure. For uncoated structures and for structures with aged coatings full polarisation may require several days, up to several months.

Individual anode outputs shall be measured and recorded. Where resistors have been provided in individual anode circuits, the outputs of the anodes shall be balanced within the design capacity.

Where earthing facilities/polarisation cells have been installed to mitigate induced AC voltages, AC potentials shall be recorded prior to and after the connection of the zinc earthing.

The insulating effectiveness of isolating joints and isolating flanges shall be checked in accordance with the procedure in (3.7).

After polarisation, structure to soil ON/OFF potentials shall be measured at all test facilities. The measurements shall be carried out by interrupting the power source. The permissible duration of the interruption depends on the rate of depolarisation, which is determined by local conditions. In extreme conditions, for instance sandy soil of high specific resistance, it must not be more than one second per minute.

Where automatic potential controlled power sources are used, ON/OFF potential measurements shall be performed with the potential control circuit switched off and the unit adjusted manually to the required potential.

If potential control has been installed, the potential setting shall be adjusted to the required drain point potential and the potential control switched on.

If voltage and/or current limiting circuits have been installed, the settings of these circuits shall be adjusted to a value approximately 10% higher than the recorded voltage and current output. Such a setting will prevent overprotection in case of failure of the potential control circuit while allowing sufficient swing in case of a change in current demand.

Interaction (interference) testing on all foreign structures/pipelines crossing or in close proximity to the object shall be carried out in accordance to BS EN 50162. Where bonding stations are provided, adjustments shall be made to the resistive bonds, so that interference to the foreign structures/pipelines remains within acceptable limits.

Potential measurements on marine facilities shall be carried out with the power source switched ON.

4.2.2 Sacrificial Anodes in Soil

Before connection of the sacrificial anodes, the natural potential of the structure and the open circuit potential of the sacrificial anode shall be measured and recorded at all test stations, including the “unprotected” side of isolating joints/flanges.

After connection of the anodes the structure potential and the current at each anode shall be measured and recorded. The current measurement shall be performed using a shunt.

The structure shall be allowed to polarise for at least 24 hours, after which the structure to soil potential shall be measured and recorded at all test stations. All potential values shall comply with the design protection criteria.

The structure to soil potential at the “unprotected” side of the isolating joints/flanges shall be measured and recorded. If a polarisation of more than 20 mV from the natural potential is measured in either polarity direction, the isolating joint/flange shall be checked.

4.2.3 Sacrificial Anodes in Water

Although welded or clamped anodes will operate automatically when immersed in water, the functioning of the system shall be checked upon completion or immersion of the system. Commissioning tests consist of the measurement of the structure to electrolyte potential at all test stations installed (3.5.2.9). All results shall be recorded for future comparison.

For subsea pipelines not longer than 2 km, the pipe-to-water potential shall be measured at each end of the pipeline. For subsea pipelines longer than 2 km the pipe-to-water potential shall be measured at each end and at intervals of 500 m or less by a suitable method (e.g. by divers or remotely operated vehicles and by means of a trailing wire or other approved technique).

5 COMMISSIONING REPORT AND AS-BUILT DRAWINGS

On completion of all construction and installation work, all construction drawings shall be updated for field modifications to the original design, to show the “as-built” system.

A report shall be made of any field repairs to the anode bed(s) and connecting cables, including repair locations and type of repair.

A detailed commissioning report shall be provided with all data obtained during the installation, pre-commissioning and commissioning. This report shall also contain all construction checklists, Manufacturer's documentation and an analysis of the final protection levels and current outputs to show compliance of the installation with the design and protection criteria.

6 REFERENCES

In this PTS, reference is made to the following publications:

NOTES: 1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

PETRONAS TECHNICAL STANDARDS

Index to PTS publications and standard specifications	PTS 00.00.05.05
Cathodic protection	PTS 30.10.73.10
Design of cathodic protection systems for onshore buried pipelines	PTS 30.10.73.31
Design of cathodic protection systems for offshore pipelines	PTS 30.10.73.32
External polyethylene & polypropylene coating for linepipe	PTS 31.40.30.31
External fusion-bonded epoxy powder coating for line pipe	PTS 31.40.30.32
Bituminous enamel coating of steel linepipe	PTS 31.40.30.33
Thermoplastic lined pipelines	PTS 31.40.30.34
Electrical engineering guidelines	PTS 33.64.10.10
Mounded horizontal cylindrical bulk storage vessels for pressurised gases at ambient temperatures	PTS 34.51.11.30
Design of cathodic protection systems for offshore structures	PTS 37.19.30.30

DATA/REQUISITION SHEETS

Data/requisition sheet for design of cathodic protection system for onshore, buried pipelines	PTS 30.10.73.93
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NOTE: The latest revisions of data/requisition sheets are contained in [PTS binder 30.10.01.10](#)

AMERICAN STANDARDS

Cathodic protection of aboveground petroleum storage tanks	API RP 651
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Issued by:
American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, Pennsylvania 19103 USA

BRITISH STANDARDS

Protection against corrosion by stray current from direct current systems

[BS EN 50162](#)

Cathodic Protection

[BS 7361-1](#)

Part 1: Code of practice for land and marine applications

Issued by:

*British Standards Institution
389 Chiswick High Road
London W4 4AL, UK*

NACE STANDARDS

Design, installation, operation, and maintenance of impressed current deep groundbeds

[SP0572](#)

Issued by:

*NACE International
1440 South Creek Drive
Houston, TX 77084-4906*

INTERNATIONAL STANDARDS

Petroleum and natural gas industries
Cathodic protection of pipeline transportation systems
Part 1: On-land pipelines

[ISO 15589-1](#)

Petroleum and natural gas industries
Cathodic protection of pipeline transportation systems
Part 2: Offshore pipelines

[ISO 15589-1](#)

Classification of degrees of protection provided by enclosures

[IEC 529](#)

Issued by:

*Central Office of the IEC
3, Rue de Varembe
CH 1211 Geneva 20, Switzerland
Copies can also be obtained from national standards organizations.*

APPENDIX 1 INSTALLATION CHECKLIST FOR TRANSFORMER RECTIFIER STATIONS

Procedure	Activity / Property	Result / Check	Unit
Check that the installation has been de-energised	AC side DC side		
Make rectifier data sheet	See Table A1-1		
Check and compare rectifier unit with	Drawings Requisitions		
Check protection type of the enclosure	IP 20, door open IP 54, door closed		
Check exterior for	Rust Painting Damage Scratches Dents Broken parts		
Check and compare against drawings	Labels Tagplates External cable connections		
Check fixing bolts for	Tightness		
Check for tightness by hand	Wire connections		
Check cable terminals	Separated from other terminals		
Check packing material	Remove packing material		
Check presence of	Terminal partition Warning plates Cover plates		
Check inside the cubicle	Permanent electrode connections		
Check rating and compare with drawings	Fuses Circuit breakers		
Check information/instruction plates against drawings			
Check the cubicle interior	Clean, dry, free from dust and loose articles		

TABLE A1-1 RECTIFIER DATA SHEET

Activity	Result	Unit	Remarks
Field project no.			
Location			
Tag no.			
Manufacturer			
Type and serial no.			
Year of manufacture			
Type of rectifier oil cooled/ air cooled/ other			
Primary voltage / phase 1 or 3 phase		V	
Primary frequency		Hz	
Rated load		kW	
Rated voltage		V	
Secondary rated voltage		V	
Secondary rated current		A	
Permanent reference cells installed yes/ no			
Factory inspection report no.			
Site inspection report no.			

**APPENDIX 2 INSTALLATION CHECKLIST FOR IMPRESSED CURRENT SURFACE
GROUNDBED**

Procedure	Activity / Property	Result / Check	Unit
Check anode materials and dimensions, check for damage.	Material: Silicon Iron / Magnetite / Graphite / MMO Dimensions: Weight: Damage:		cm x cm kg
Check anode backfill type, quality, volume and weight.	Type: Coke breeze / other fine / course / pre-packaged Backfill, volume, weight		m ³ , tons
Check anode cable dimensions and check for damage of sheathing and anode connection. Measure cable resistance	Size: Length Colour coding Insulation / sheathing checked Cable connection checked Cable resistance		mm ² m ohm
Check the feeder system and splicing materials	None/single anode Central distribution, distribution box Ring feeder, size		mm ²
Check groundbed location Excavate trench to required depth for horizontal installation. Auger or drill holes for vertical anode installation Check soil resistivity	Location correct Measure depth + length Spacing anode holes Depth holes Resistivity at anode depth		m m m ohm.cm
Horizontal: Install anodes on layer of backfill and cover anodes. Backfill acc. to specification. Vertical: Poor backfill material in hole (bottom) and centre anode in hole in tamped backfill. Cover anode with backfill material.			
Connections to feeder cable connections to junction box	Line taps, C-crimps, other, splice kits type		
Commissioning			
Measure anode groundbed resistance to remote earth.	Anode groundbed resistance to remote earth		ohm
Update as-built information	Location, station name as built drawings		
Finish trench with native soil	Cable warning tape/tiles, groundbed markers		

APPENDIX 3 INSTALLATION CHECKLIST FOR IMPRESSED CURRENT DEEP GROUND BED

Procedure	Activity / Property	Result / Check	Unit
Check anode materials and dimensions, check for damage. Use suitable centralisers and suspension ropes.	Material: Silicon Iron / Magnetite / graphite / Pt-Ti / Pt-Nb / MMO Dimensions, Weight: Damage: Spacers, suspension rope		cm, kg
Check anode backfill type, quality, volume and weight	Type: Coke breeze / other / fine/course backfill slurry / dry Backfill, volume, weight		m ³ , tons
For each anode check cable dimensions and check for damage of sheathing and anode connection. Measure cable resistance	Size, length Colour coding Insulation / sheathing checked Cable connection checked Cable resistance		mm ² , m ohm
Check the feeder cable and splicing materials	None Single via junction box Size		mm ²
Check borehole details. Check borehole location Drill 5 m depth and set surface casing. Drill hole to total depth and log hole using borehole checklist. Check total depth and water level in hole	Drilling equipment suitable Location correct Surface casing, dia, length Hole diameter Total depth Water table		mm, m mm m m
Set casing according to design, record casing details, cut casing above grade	Casing diameter / uncased Active section: steel / perforated plastic, isolating top section, steel (coated) / plastic, length		mm m m
Install headworks with cable conduit, anode suspension system, distribution box, vent pipe	shunts calibrated		A/mV
Remove anode protection, lower anodes in centre of hole and fix suspension rope Install vent pipe with lower anode Record installation details on "Anode log sheet" Pour coke backfill (slurry) in hole. Record backfill used, record level of backfill. Backfill with gravel above active length	Number of anodes per hole <i>Use centralizers and suspension rope</i> Vent pipe material, diameter, length Perforated over length Coke Used Final level Backfill gravel, particle size, max min volume, weight		mm, m m tons m mm m ³ , tons
Commissioning			
Measure each anode to remote earth resistance Measure total groundbed to remote earth resistance	Anode resistance to remote earth Groundbed resistance		Ohm ohm
Update as-built information	Location, Station name		

APPENDIX 4 DEEP GROUND BED DRILLING RECORD (BOREHOLE CHECKLIST)

[illegible]

APPENDIX 5 CHECKLIST FOR ANODE INSTALLATION IN DEEP GROUND BED

[illegible]

APPENDIX 6 INSTALLATION CHECKLIST FOR UNDERGROUND SACRIFICIAL ANODES

Procedure	Activity / Property	Result / Check	Unit
Check anode materials and dimensions, check for damage.	Material: Magnesium / Zinc / Aluminium Dimensions: Weight: Potential: Damage:		cm kg mV (ref)
Check anode backfill	Type: Gypsum-Bentonite / other Pre-packaged / separate:		
Check anode cable dimensions and check for damage	Size: Length Colour coding Insulation / sheathing checked Cable connection checked Cable resistance		mm ² , m ohm
Check the feeder cable and splicing materials	None(one anode) Single via junction box ring Splice kits		
Check installation details. Take soil sample if required. Remove protection, install anode in centre of hole, water down and compact backfill. Backfill with native soil. Install cable.	Horizontal/vertical Soil sample, Resistivity: Depth bottom Hole diameter Spacing Waterproof container removed depth top of anode backfill watered down loose backfill compacted Cable depth		ohm.cm m mm m m m
Install distribution box	No of anodes No of feeders shunts calibrated Marker post		A/mV
Commissioning			
Measure anode free potential and resistance Make connection to the structure, measure anode current, adjust resistor, measure structure potential	Anode-to-soil potential Anode resistance to remote earth Connection to structure made resistors installed anode current structure-to-soil potential		mV (ref) ohm ohm mA mV (ref)
Update as-built information	Location Station name/number		

APPENDIX 7 INSTALLATION CHECKLIST FOR SACRIFICIAL ANODES (MARINE, SUBSEA, INTERNAL)

Procedure	Activity / Property	Result / Check	Unit
Check anode materials and dimensions, check for damage.	Material: Magnesium / Zinc / Aluminium Dimensions: Weight: Potential: Damage:		kg mV (ref)
Check anode supports and support dimensions	Distance to structure Installation by bolts / U-bolts / welding bolt holes matching		cm
Check coating if specified	Coating bottom of anode		
Check and mark anode locations	Anode locations Marked		
Install anodes in correct orientation, secure bolts. tack weld bolted supports coat supports/anode cores Repair structure coating	Orientation vs. Structure (coating) Bolts / U bolts secure Welded / tack welded Supports / cores coated Structure coating repaired		
Commissioning			
Measure anode-to-structure resistance (spot check). Measure structure to soil potential (if possible)	Anode-to-structure resistance structure-to-soil potential		ohm mV (ref)
Update as-built information	Number of anodes, size, location Drawings updated		

APPENDIX 8 EXAMPLES OF TEST FACILITY WIRING DIAGRAMS

Figure A.8-1 Standard potential test station

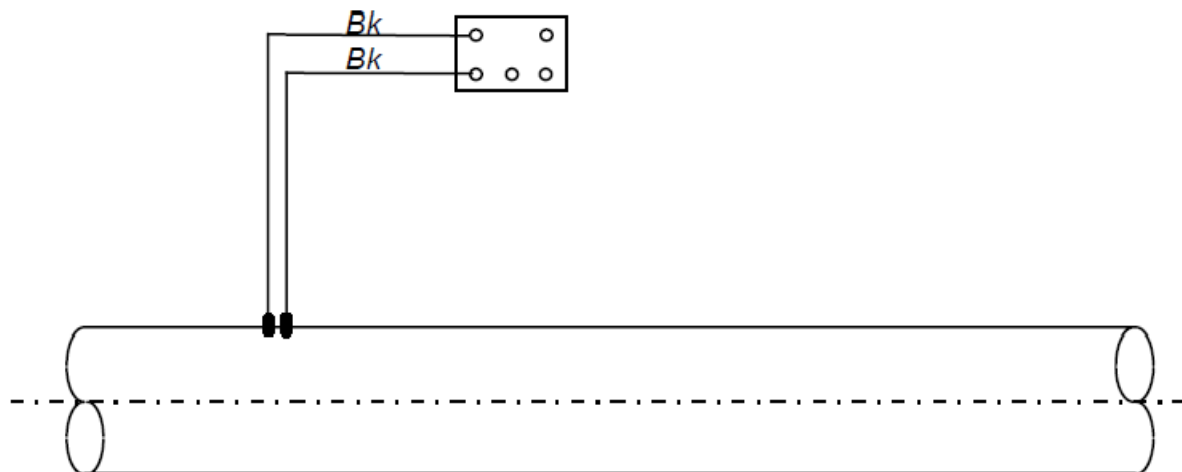


Figure A.8-2 Drainpoint / potential test station

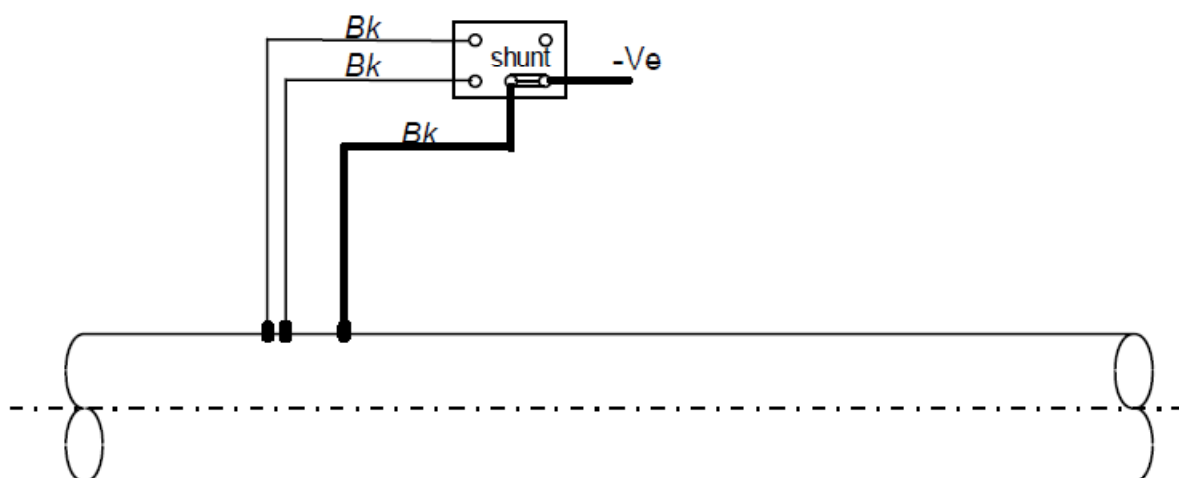


Figure A.8-3 Potential test station at pipeline crossing

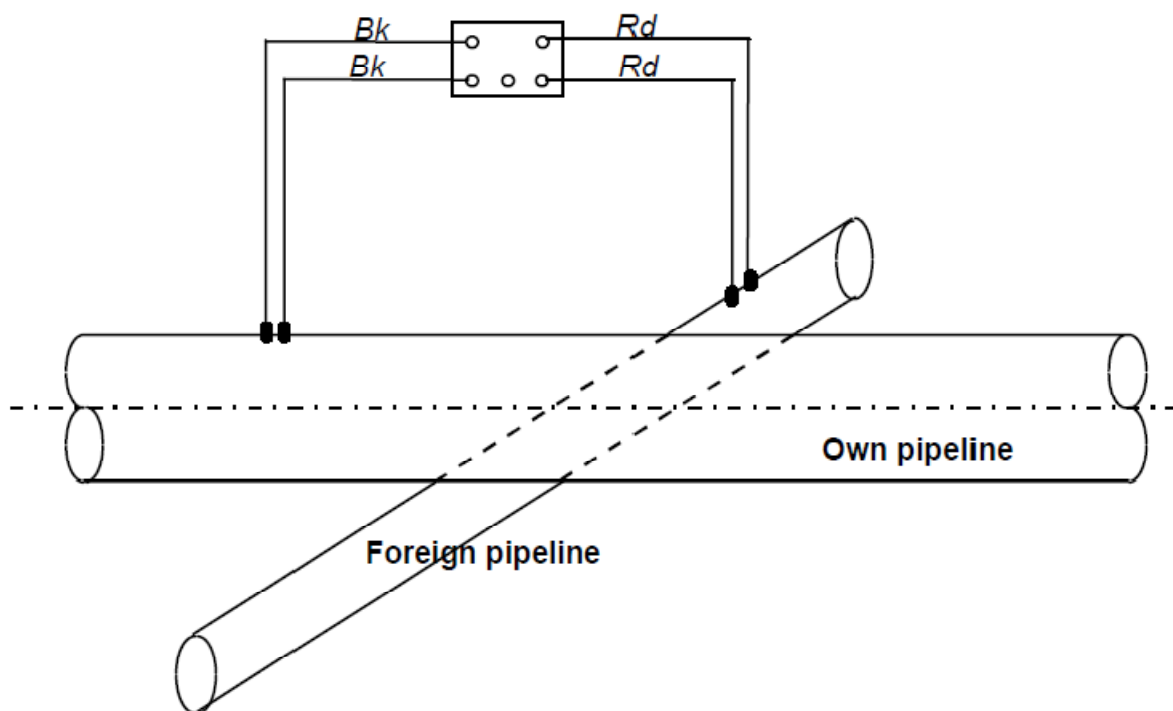


Figure A.8-4 Test station at isolating flange / joint

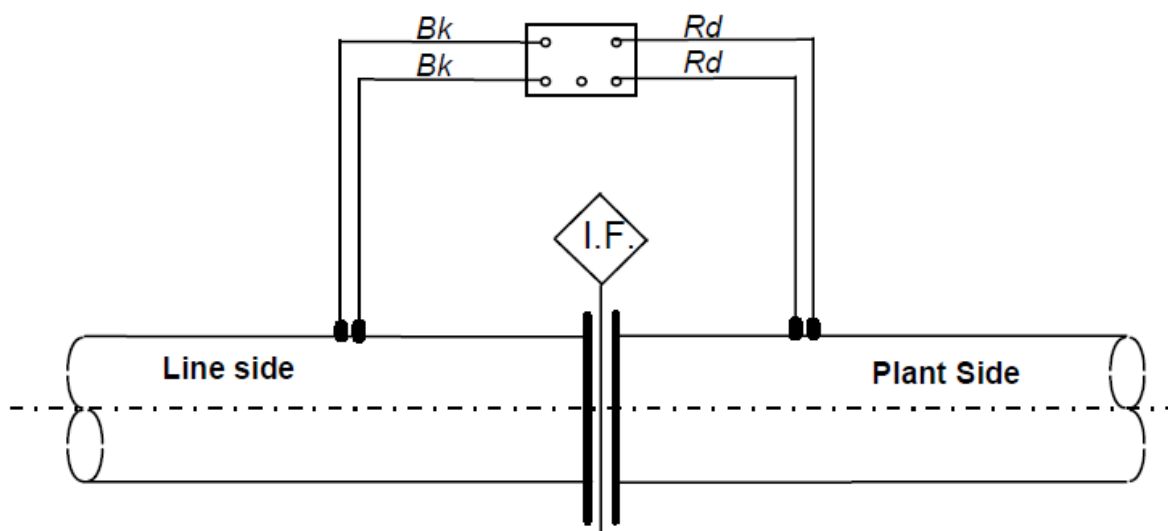


Figure A.8-5 Test station at steel casing

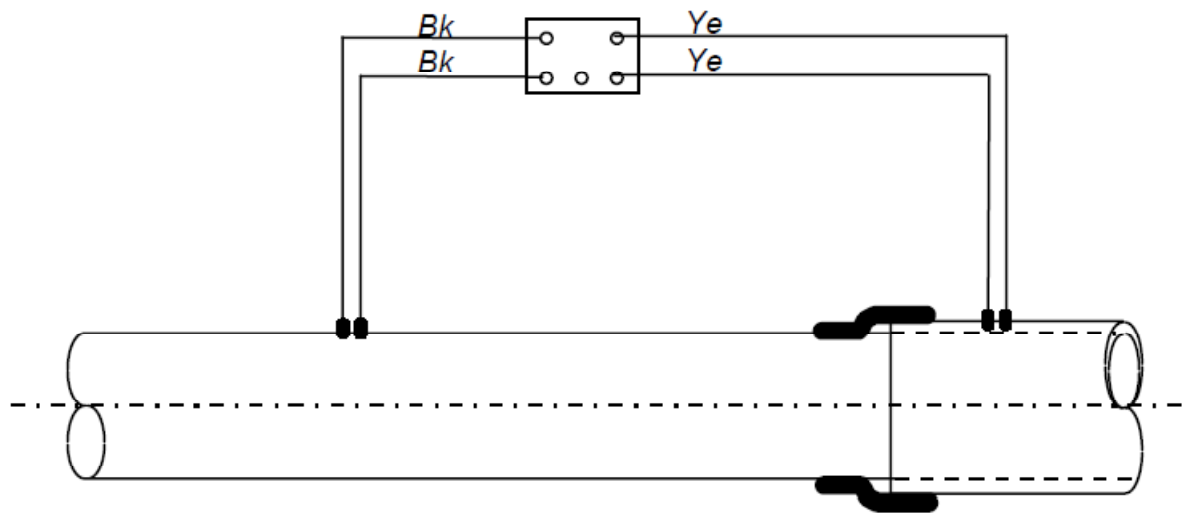


Figure A.8-6 Test station at non-metal casing

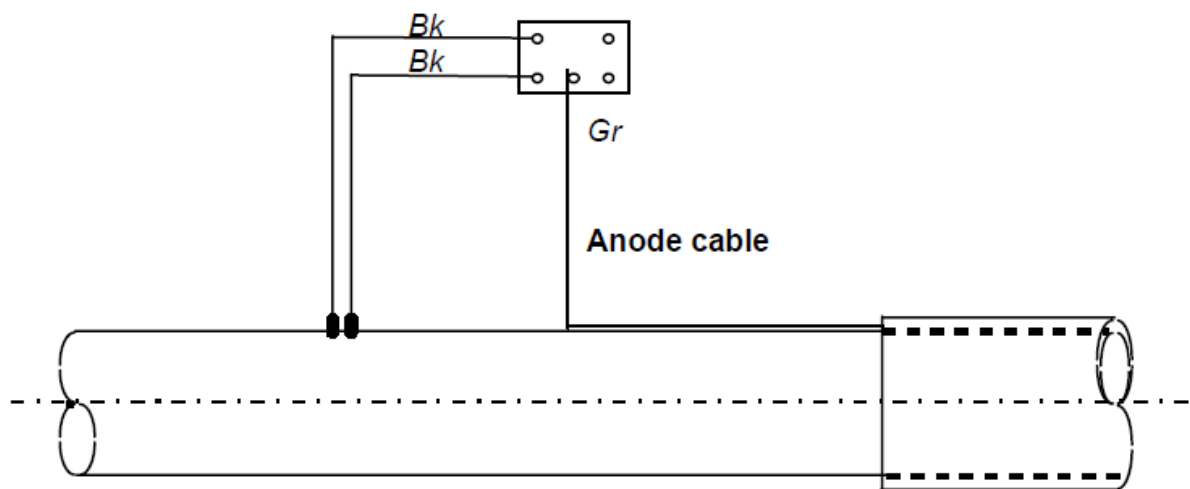


Figure A.8-7 Sacrificial anode connection

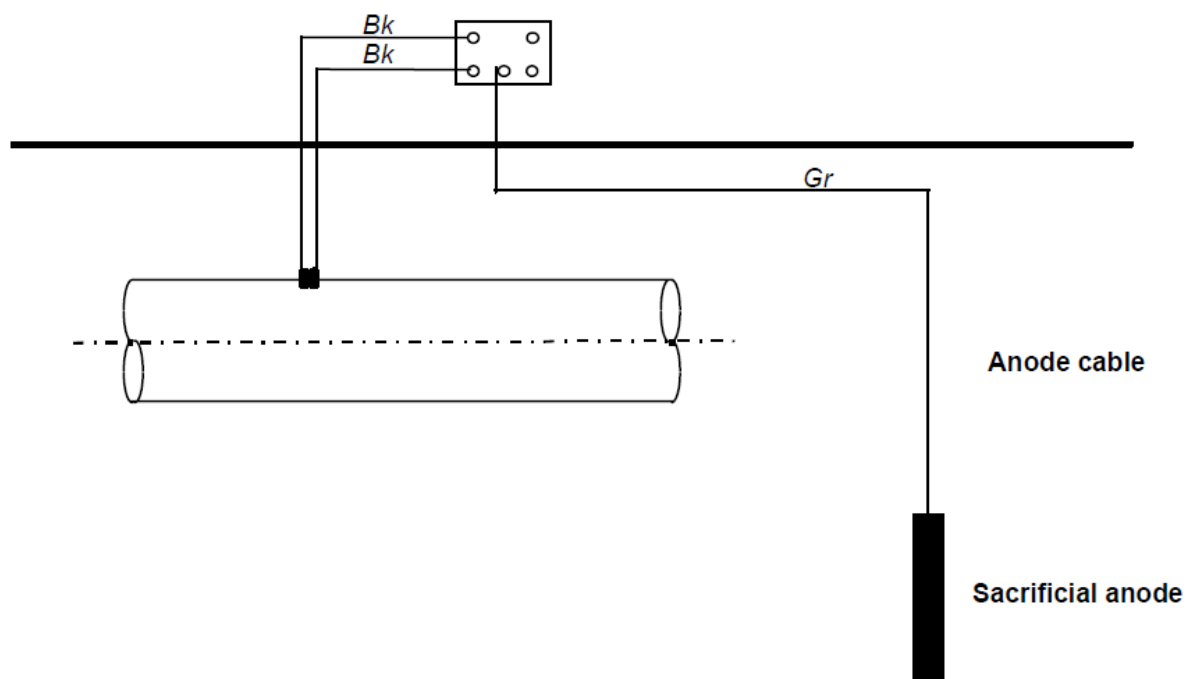


Figure A.8-8 Line current / potential test station

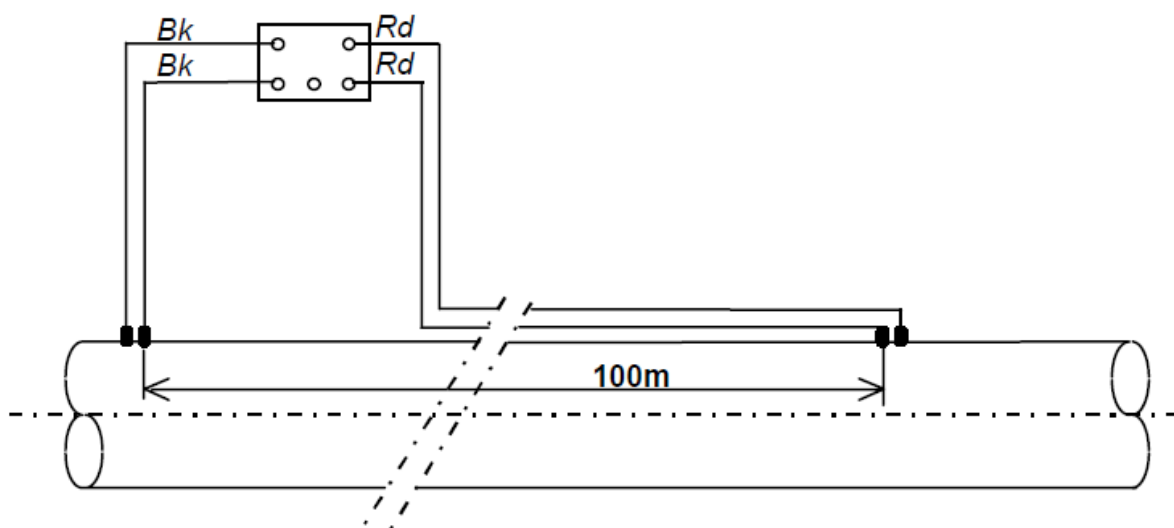


Figure A.8-9 Permanent reference electrode

