BRITISH STANDARD

BS EN 13173:2001

Cathodic protection for steel offshore floating structures

The European Standard EN 13173:2001 has the status of a British Standard

ICS 75.180.10; 77.060

National foreword

This British Standard is the official English language version of EN 13173:2001.

Reference should also be made to BS 7361, Code of practice for land and marine applications, which will eventually be withdrawn when all the CEN standards relating to cathodic protection currently being prepared, are published.

The UK participation in its preparation was entrusted to Technical Committee GEL/603, Cathodic protection, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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This British Standard, having been prepared under the direction of the Electrotechnical Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 June 2001

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EUROPEAN STANDARD

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EN 13173

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English version

Cathodic protection for steel offshore floating structures

Protection cathodique des structures en acier flottant en mer

Kathodischer Korrosionsschutz für schwimmende Offshore-Anlagen aus Stahl

This European Standard was approved by CEN on 6 July 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 219 "Cathodic protection", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2001, and conflicting national standards shall be withdrawn at the latest by July 2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Cathodic protection is usually applied, mostly as a complement to protective coating or paint, to protect the external surfaces of steel offshore floating structures and appurtenances from corrosion due to sea water or saline mud.

Cathodic protection works by supplying sufficient direct current to the immersed surface of the structure in order to change the steel to electrolyte potential to values where corrosion is insignificant.

The general principles of cathodic protection are detailed in EN 12473.

1 Scope

This European Standard defines the means to be used to cathodically protect the submerged metallic surfaces of steel offshore floating structures and appurtenances in sea water and saline mud.

1.1 Structures

This European Standard covers the cathodic protection of the external surface of offshore floating structures which are static during their usual operating conditions. This essentially includes: barges, jack-ups, semi-submersible platforms, storage tankers, buoys, etc.

It also covers the submerged areas of appurtenances, such as chains, attached to the structure, when these are not electrically isolated from the structure.

It does not cover the cathodic protection of ships, fixed offshore structures, elongated structures (pipelines, cables) or harbour installations, which are covered by other standards.

This European Standard concerns only the cathodic protection of external surfaces immersed in sea water, including sea chests and water intakes up to the first valve.

This European Standard does not include the internal protection of surfaces of any components such as ballast tanks and hull internals of floating structures.

1.2 Materials

This European Standard covers the cathodic protection of structures fabricated principally from bare or coated carbon manganese steels

As some parts of the structure may be made of metallic materials other than carbon manganese steels, the cathodic protection system should be designed to ensure that there is a complete control over any galvanic coupling and minimise risks due to hydrogen embrittlement or hydrogen induced cracking (see EN 12473).

This European Standard does not cover concrete structures.

1.3 Environment

This European Standard is applicable for the whole submerged zone in sea water, brackish waters, saline mud which can normally be found where the floating structure is anchored, moored or moving.

This European Standard is also applicable to appurtenances which may be in contact with muds (e.g. chains).

For surfaces which are alternately immersed and exposed to the atmosphere, the cathodic protection is only effective when the immersion time is sufficiently long for the steel to become polarised.

1.4 Safety and environment protection

This European Standard does not cover safety and environmental protection aspects associated with cathodic protection. The relevant national or international regulations shall apply.

2 Normative references

This European Standard incorporates, by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 12473, *General principles of cathodic protection in sea water.*

prEN 12496, *Galvanic anodes for cathodic protection in sea water.*

3 Terms and definitions

For the purposes of this European Standard the terms and definitions in EN 12473 and the following apply:

3.1
atmospheric zone
zone located above the wetted zone; that means above the level reached by the normal swell, whether the structure is moving or not

3.2
boot topping
section of the hull between light and fully loaded conditions, which may be intermittently immersed

3.3
Cathodic Protection zone
that part of the structure which can be considered independently with respect to cathodic protection design

3.4
immersed zone
zone located below the water line at draught corresponding to normal working conditions

3.5
submerged zone
zone including the immersed and the buried zones

3.6
underwater hull
part of the hull vital for its stability and buoyancy of a floating structure, i.e. below the light water line

4 Design basis

4.1 Objectives

The major objective of a cathodic protection system is to deliver sufficient current to protect each part of the structure and appurtenances and distribute this current so that the potential of each part of the structure is within the limits given by the protection criteria (see 4.2).

Potentials should be as uniform as possible over the whole structure. This objective may only be approached by an adequate distribution of the protective current over the structure during its normal service conditions. However, it may be difficult to achieve in some areas such as chains, water intakes, sea chests, when supplementary cathodic protection systems should be considered.

The cathodic protection system for a floating structure is generally combined with a coating system, even though some appurtenances, such as chains, may not benefit from a coating protection.

Dielectric shields may be used in conjunction with anodes to minimise the risk of local over-protection.

The cathodic protection system should be designed either for the life of the structure or for a period corresponding to the maintenance dry-docking interval.

The above objectives should be achieved by the design of a cathodic protection system using galvanic anodes or impressed current systems or a combination of both.

4.2 Cathodic protection criteria

The criteria for cathodic protection are detailed in EN 12473.

To achieve an adequate cathodic protection level, steel structures should have potentials as indicated hereafter.

The accepted criterion for protection of steel in aerated sea water is a potential more negative than -0,80 V measured with respect to Ag/AgCl/sea water reference electrode.

A negative limit of -1,10 V (Ag/AgCl/sea water reference electrode) is generally recommended.

Where there is a possibility of coating disbondment and corrosion fatigue, the negative limit should be more positive. This negative limit should be documented.

4.3 Design parameters

The design of a cathodic protection system should be made in accordance with the following parameters: structure subdivision, components description and service conditions.

4.3.1 Structure subdivision

A floating structure can be divided into different Cathodic Protection zones, (CP zones), which are then considered independently with respect to cathodic protection design, although they may not necessarily be electrically isolated.

EXAMPLE 1 For a storage tanker, some specific components may not be included in the underwater hull CP zone and therefore constitute a CP zone by themselves (e.g. : seachests).

EXAMPLE 2 For buoys, a single zone is generally considered, including two components: the body of the buoy and the influenced part of the mooring chain(s).

4.3.2 Description of CP zones

Each C.P. zone may consist of several components which should be fully described including material, surface area and coating characteristics (type, lifetime and coating breakdown factor).

4.3.3 Service conditions

The design of the cathodic protection system(s) will depend on service conditions which include: expected life time, environment and operating conditions.

- Life time: either the whole design life or dry-docking interval(s) should be considered.
- Environment: the sea water properties should be established (see EN 12473).
- Operating conditions: the cathodic protection design normally considers only the static conditions of the structure because the durations when dynamic conditions prevail are generally negligible.

4.4 Electrical current demand

4.4.1 General

To achieve the criteria for protection for the conditions outlined in 4.3, it is necessary to select the appropriate current density for each component.

The current demand of each metallic component of the structure is the result of the product of its surface area multiplied by the required current density.

4.4.2 Protection current density for bare steel

The current density required may not be the same for all components of the structure as the environmental and service conditions are variable.

The selection of design current densities may be based on experience gained from similar structures in a similar environment or from specific tests and measurements.

The current density depends on the kinetics of electrochemical reactions and varies with parameters such as the protection potential, surface condition, dissolved oxygen content in sea water, sea water velocity at the steel surface, temperature.

The following should be evaluated for each design:

- initial current density required to achieve the initial polarisation of the structure;
- maintenance current density required to maintain polarisation of the structure;
- final current density for possible repolarisation of the structure, e.g. after severe storms or cleaning operations.

As the initial polarisation preceding steady state conditions is normally short compared to the design life, the average current density over the lifetime of the structure is usually very close to the maintenance current density.

The (average) maintenance current density is used to calculate the minimum mass of anode material necessary to maintain cathodic protection throughout the design life.

Typical values of current densities as used for bare steel are given in annex A.

4.4.3 Protection current density for coated steel

The cathodic protection system is generally combined with suitable coating systems. The coating reduces current density and improves the current distribution over the surface.

The reduction of current density may be in a ratio of 100 to 1 or even more. However the current density will increase with time as the coating deteriorates.

An initial coating breakdown factor related mainly to mechanical damage occurring during the fabrication of the structure should be considered. A coating deterioration rate (i.e. an increase of the coating breakdown factor) should be selected in order to take into account the coating ageing and possible mechanical damage occurring to the coating during the life time of the structure or a period corresponding to the dry-docking interval.

These values are strongly dependent on the actual construction and operational conditions.

Guidelines for the values of coating breakdown factors (f_c) are given in annex A.

The protection current density needed for the protection of coated steel is equal to the product of the current density for bare steel and the coating breakdown factor.

$$J_c = J_b \cdot f_c$$

where:

J_c is the protection current density for coated steel in amperes per square metre,

J_b is the protection current density for bare steel in amperes per square metre,

f_c is the coating breakdown factor which varies with time due to ageing and mechanical damage:

$f_c = 0$ for a perfectly insulating coating,

$f_c = 1$ for a coating with no insulation property (equivalent to bare steel structure).

This formula should be applied for each individual component or zone as defined in 4.3 where the coating, or the current density for bare steel, may be different.

4.4.4 Protection current demand

An evaluation of the current demand required should be carried out to optimise the mass and size of galvanic anodes, or the capacity of impressed current systems.

The protection current demand I_e of each component of the structure to be cathodically protected is equal to:

$$I_e = A_e \cdot J_{ce}$$

where:

A_e is the surface area of the individual component in square metres,

J_{ce} is the individual protection current density for the component considered, in amperes per square metre.

The protection current demand I_z of each CP zone is therefore equal to the sum of current demands for each component included in the CP zone:

$$I_z = \Sigma_z(I_e)$$

where:

I_a is the protection current demand of each component included in the considered CP zone in amperes.

NOTE For current demand determination, the underwater surface area should always include the boot topping, but never the atmospheric zone.

An estimate of the current demand of chains (or cables) which are not electrically insulated from the floating structure shall be made and added to I_t when applicable. This is necessary to ensure a safe cathodic protection design, even if the potential achieved on the chains (and their protection) will depend on the actual quality of the electrical continuity between the chains and the floating structure, and between the links of each chain.

4.5 Cathodic protection systems

Two types of cathodic protection systems are used :

- impressed current system,
- galvanic anode system.

Sometimes a combination of both systems is used (hybrid).

The choice of the most appropriate system depends on a series of factors (see EN 12473). In general, impressed current systems are preferred for structures fitted with electrical power and where there is a high current demand.

For any cathodic protection system, the size of the anodes shall be determined using Ohm's law.

$$I = \Delta U / R$$

where:

ΔU is the driving potential in volts,

R is the circuit resistance in ohms.

The anodic resistance is a function of the resistivity of the anodic environment and of the geometry (form and size) of the anode. Empirical formulae may be used such as those given in annex B for the evaluation of the anode resistance.

If the anodes are grouped in arrays and close to each other, mutual interference between anodes should be considered when calculating the anodic resistance.

The number and location of the anodes shall be determined in order to achieve as far as practicable an electrical current distribution leading to an adequate uniform protection potential level over the whole steel structure surface.

Calculations can be performed using computer numerical modelling based on finite elements or boundary elements methods.

All components of the cathodic protection system should be installed at locations where the probability of disturbance or damage is minimal.

4.6 Electrical continuity

Where cathodic protection is required for appurtenances, then electrical bonding to the structure should be carried out by appropriate means except when the appurtenances are protected by an independent cathodic protection system.

The electrical resistance of the bonding should be low enough to ensure adequate protection of all the components to be protected.

The electrical continuity shall be permanently maintained.

For buoys and other moored structures, no particular continuity device with anchor chains is generally required but continuity should be assessed.

4.7 Interactions

A floating structure may be permanently or temporarily connected to other neighbouring structures. Each structure should be fitted with its own cathodic protection system which should be checked before electrically connecting it to the floating structure under consideration.

If foreign structures, not fitted with a cathodic protection system are temporarily connected to the protected structure, the potential of the protected should be measured to confirm that the protection is being maintained at an acceptable level during the period of connection.

Measures should be taken to ensure that there are no deleterious effects of electrical stray current on the protected structure (see prEN 50162).

5 Impressed current system design

5.1 Objectives

An impressed current system provides the protection using direct current (d.c) delivered by connecting the steel structure to the negative terminal of an adjustable d.c. power source and the positive terminal to the anodes.

The electrical current output delivered by the d.c. power source is controlled during the expected life time of the cathodic protection system in order to obtain and maintain an adequate protection potential level over the whole steel surface of the structure.

The design calculations and specifications should include detailed information on the following :

- design basis,
- size of equipment,
- general arrangement of the equipment,
- specification of equipment e.g. d.c.power source, anodes, connection cables, terminations and protection devices, measurement electrodes,
- installation specifications,
- monitoring specification.

5.2 Design considerations

Impressed current systems for floating structures include one or more variable d.c. power sources, several anodes and normally a number of reference electrodes.

D.c. power sources with automatic potential control can be used when the environment conditions and the structure configuration and service conditions induce large and frequent variations of the current demand necessary to maintain polarisation.

Each CP zone (see 4.3.1) shall be protected by a dedicated system. Specific areas presenting particular situations may require the consideration of a multi-zone control system in order to adapt and optimise the electrical current distribution to the cathodic protection demand.

A dielectric shield is usually used around the anodes to prevent local over-protection and improve the current distribution to the cathode.

The total maximum electrical current demand (I_z) for the protection of a CP zone of the structure should be calculated using formulae as per 4.4, with the most severe service conditions as described in 4.4.2, using the highest coating breakdown for the design life considered (see 4.4.3).

To compensate for a less efficient current distribution (small number of anodes), the cathodic protection system should be designed to be able to provide 1,1 to 1,5 times the calculated total maximum current demand, depending on the geometry and the coating of the structure:

$$I_t = (1{,}1 \text{ to } 1{,}5) \cdot I_z$$

5.3 Equipment considerations

5.3.1 Direct current power source

The d.c. power source shall be able to deliver the total maximum current I_t to the zone it is intended to protect.

The output voltage should take into account the resistance of the electric circuit (cables, anodes, back e.m.f.) and the maximum recommended operating voltage of the anodes.

The d.c. power source should be able to deliver sufficient electrical current to maintain the cathode potential within the set range.

D.c. power sources with automatic potential control shall deliver an electrical current when one of the reference electrodes used for the control of the d.c. power source leads to a potential reading less negative than the set positive limit (refer to 4.2 for the protection criteria).

This type of d.c. power source should also be able to deliver no current when all the reference electrodes used for the control of the d.c. power source lead to potential readings more negative than the set negative limit.

There should be devices to limit the output current to each anode to a pre-set value.

A d.c. power source without output current limitation circuits should have an effective shutdown in the event of an external short circuit.

5.3.2 Anodes

Anodes used for impressed current systems are generally of the inert type.

The inert anodes are generally made of titanium, niobium or tantalum with a thin layer of platinum or mixed metal oxides which permit the discharge of electric current. Some typical anodes electrochemical characteristics are given in annex C.

Anodes should be either suitable for the life of the structure, or replaceable.

Lead silver semi-inert anodes may also be used provided that initial anode current density is sufficient (20 A/m^2 to 50 A/m^2) to generate and maintain a conductive PbO_2 film. This visible brown film does not deteriorate rapidly provided the oxygen content of the water is high enough.

Generally impressed current anodes are of high current output and a small number are used compared to galvanic systems.

Therefore, the loss of an anode may significantly reduce the performance of the system. The anode assembly and its attachment should be designed to have a high resistance to mechanical damage.

All possible precautions shall also be taken in order to avoid any direct electrical contact (short circuit of the cathodic protection circuitry) between the anodes and the structure. Similarly, all precautions shall be taken to avoid any leakage of water through the hull penetration. It is usually a requirement to fit a cofferdam (see annex D).

The number, sizes and location of anode shall be determined in order to be able to deliver the electrical current distributed by the d.c. power source to which the anode are connected.

Additional calculations to assess the anodes distribution may be necessary.

5.3.3 Dielectric shields

Materials selected shall be suitable for the intended service. They shall be resistant to cathodic disbonding and to corrosive chemicals produced at the anodes.

Yard applied additional coatings, fibreglass reinforced plastic, prefabricated plastic or elastomeric sheets can be used on the structure adjacent to the anodes.

The design of the cathodic protection system should anticipate the possible deterioration and ageing of shielding materials and devices in order to obtain the system desired life duration.

5.3.4 Reference electrodes

Reference electrodes are used to measure the steel to sea water potential and are generally used to control the electrical current delivered by the cathodic protection system. They are either zinc or silver/silver chloride/sea water electrodes (see EN 12473). Zinc electrodes are more robust whereas silver/silver chloride/sea water electrodes are more accurate.

All precautions shall be taken in order to avoid any direct electrical contact between the electrodes and the structure. Similarly, all precautions shall be taken to avoid any leakage of water through the hull penetration. It is usually a requirement to fit a cofferdam (see annex D).

The location of the reference electrodes is very important, particularly when used to control the system.

Electrodes should be installed at locations where the potential of the structure may become outside the protection criteria.

5.3.5 Cables, terminations

All connecting cables shall be fitted with adequate protection systems to avoid any mechanical damage that could occur in normal service conditions.

The electrical connection between the anode lead cable and the anode body shall be watertight and mechanically secure.

The cable and connection insulation materials shall be resistant to their environmental conditions (chlorine, hydrocarbon and other chemicals).

When determining the cross section of cables, it is necessary to take into account the voltage drop for the length of cable under consideration.

The specified maximum current rating for a given size of cable should never be exceeded.

For potential measurements, dedicated cables should be used, and these should be screened in order to avoid any interference.

6 Galvanic anode system design

6.1 Objectives

Galvanic anodes are mnaufactured from electronegative alloys which corrode to provide current and are connected directly to the steel structure.

The dimensions, number and location of the anodes should be determined so that the protection potential is achieved over the whole surface of the structure for the expected life time of the cathodic protection system and under various service conditions.

6.2 Design considerations

The three design electrical current densities as defined in 4.4 shall be considered :

- the maintenance electrical current density shall be used to determine the mass of the anodes. This current density is required to maintain an adequate polarisation level of the structure during its design life;
- the initial electrical current density shall be used to verify that the output current capacity of the new anodes, i.e. their initial dimensions, is adequate to obtain a complete initial polarisation of the structure;
- the repolarisation electrical current density shall be used to verify that the output current capacity of the anodes when they are consumed to their utilisation factor, i.e. their final usable dimensions, is adequate to repolarise the structure after severe storms or marine growth cleaning operations.

Galvanic anodes are usually made of zinc or aluminium based alloys.

Magnesium based alloys may be used for short term temporary or interim protection.

A large variety of shapes and sizes can be used to deliver protective electrical current in order to optimise the electrical current distribution.

The method of attachment of the anodes to the structure depends on their type and application but low resistance electrical contact shall be maintained throughout the operating life of the anodes.

Galvanic anodes should be preferably attached by continuous welding of their steel cores to the structure in such a manner that stresses are minimised at the weldment location. The steel cores of the galvanic anodes may be bolted to separate supports which have been connected to the structure by continuous welding; a minimum of two bolts are to be used at each support.

Attachment studs 'fired' into the structure are not permitted.

When low hydrodynamic resistance has to be considered, shapes and methods of attachment of anodes should be optimised.

The performance of galvanic anodes in sea water depends essentially on the alloy composition.

The electrochemical properties of the anodic material should be documented or determined by appropriate tests.

The information required includes:

- the driving potential to polarised steel, i.e. the difference between closed circuit anode potential and the positive limit of the protection potential criterion,
- the practical electrical current capacity (A h/kg) or consumption rate (kg/A a),
- the susceptibility to passivation,
- the susceptibility to intergranular corrosion.

6.3 Factors determining the anode current output and operating life

The basic requirements for anodic materials are stipulated in EN 12496.

The environmental impact of alloy metal components released in the electrolyte should be taken into consideration.

The anode current output depends on the environment resistivity and on the anode shape and dimensions (see 4.3, 4.5 and annex B).

The anodic materials exhibit different specific consumption rates when operating in various environments.

Therefore, for a given electrical current output, the anode life duration will depend on the anodic material (consumption rate) and its mass.

The dimensions and number of anodes should be optimised in order to minimise the total mass of the galvanic anodes, and in order to provide a protective electrical current greater or equal to the protective electrical current required for the permanent protection of the structure during the life of the anodes.

The cathodic protection system shall include sufficient mass of anodic material in order to be able to supply the (average) maintenance electrical current demand during the design life time of the system.

The output current is given by Ohm's law as explained in 4.5 and annex B.

The commonly used net driving potential between an anode made of a typical aluminium or zinc based alloy and a polarised or coated structure at its minimum cathodic protection level (-0,8 V vs. Ag/AgCl/sea water) is only 0,15 V to 0,30 V.

Calculations can be performed using computer numerical modelling based on finite elements or boundary elements methods.

The anode life duration may be determined using the formula given in annex B.

6.4 Location of anodes

The galvanic anodes should be distributed to ensure the steel surface is polarised to within the recommended limits (see 4.2). Computer modelling based on finite elements or boundary elements calculation methods and/or model testing may be used.

Galvanic anodes shall not be located in areas where they can interfere with the normal operation of the structure.

They should not be installed in high stress areas or areas subject to high fatigue loads such as butts or seams.

They should not be located in areas where they could be damaged (by accidentally dropped objects or by craft coming alongside).

Galvanic anodes should preferably be located in way of local stiffenings.

7 Cathodic protection system monitoring

Cathodic protection systems should be regularly monitoring.

Fixed monitoring systems are not essential for galvanic anodes systems. However, fixed monitoring systems are essential for impressed current systems.

7.1 Objectives

The monitoring system of a cathodic protection system should be able to follow and possibly control the operating parameters and the efficiency of the cathodic protection system.

Portable equipment used for periodic inspections are not included in the monitoring system. These may be used to verify the accuracy of the permanent reference electrode and to measure potential in critical areas that are not covered by permanent electrodes.

The steel to water potential should be measured periodically during the whole life of the structure in order to verify the adequacy of the cathodic protection system.

7.2 Potential measurements

7.2.1 Potential measurement method

The potential of steel is measured using a high impedance voltmeter connected to a reference electrode which shall be located as close as possible to the steel surface to be checked.

If this measurement circuit remains permanently connected, care should be taken that it does not deliver current into the reference electrode which may become polarised and give false readings.

7.2.2 Location of the reference electrodes

Some reference electrodes should be installed at locations representative of the average potential of each CP zone. Additional reference electrodes should be installed in areas where the potential of the structure is more likely to become outside the set limits.

In the case of impressed current systems, reference electrodes should be fitted to the structure at suitable locations in order to control the output of the anodes and ensure critical areas are polarised to within the set limits.

7.2.3 Verification of the reference electrodes

The reference electrodes shall be checked, i.e. calibrated at regular intervals by measuring their potential versus a saturated calomel reference electrode or versus any other reference electrode recently calibrated.

For installations where the reference electrodes cannot be dismantled from their permanent location, a portable reference electrode shall be used for their calibration. This should be placed in close proximity to the permanent reference electrode.

7.3 Measurement of the impressed current anode electrical current output

The electrical current delivered to each anode should be measured at the corresponding output terminal of the d.c. power source or at the distribution box as applicable.

7.4 Impressed current power source control

The d.c. power source delivers the protective current to the anodes and should be equipped with the following control equipment :

- a voltmeter for the measurement of the d.c. output voltage,
- an ammeter for the measurement of the d.c.output intensity, possibly connected to a switch allowing the measurement of the electrical current output of each anode,
- protection devices against over-voltages and short circuits.

An hour meter may be installed for recording the operational periods of the d.c.power source.

7.5 Additional monitoring methods

Additional monitoring methods may include measurement of current density on the structure using fixed or portable equipment, and the installation of monitored galvanic anodes.

8 Documentation

8.1 Objectives

All information, data and results relevant to the cathodic protection system should be recorded.

This includes all data pertinent to the design, manufacture, installation, commissioning, operation and maintenance recommendations and effectiveness of the cathodic protection system.

The as-built documentation should reflect any changes from design specification. It essentially concerns the equipment location, deviation in water line which might alter protected areas.

Commissioning data should include results of surveys be conducted after energising each cathodic protection system in order to assess that it satisfies design criteria and operates effectively, including structure potential measurements to demonstrate that the protection is achieved.

8.2 Impressed current system

The following data should be kept for reference and permanently updated, if applicable:

- the design criteria including the design life, the environment characteristics (e.g. water salinity range, resistivity), the protection criteria considered, the current density requirements, the assumed values of the anode output current;

- the number of anodes, their size, specification, description of anodic equipment and connection, effective output current densities and allowable voltage, as well as the manufacturer / supplier data and documentation;

- the description and means of attachment of anodes, the composition and location of any dielectric shield (when applicable), as well as the specification, characteristics and attachment method and through wall or through hull arrangements of the connecting cables;

- the location of each and every anode as checked during construction, all discrepancies with design location being highlighted (these locations can be conveniently recorded on a specific drawing of the structure), the date of installation. This data should updated during the life of the structure;

- the location, detailed specification, drawings, and output characteristics of each d.c.power source with their factory test reports;

- the localisation, description and specification of any protection, potential control or monitoring device, including reference electrode, measuring equipment and connecting cables;

- the commissioning results including potential survey data, current and voltage output values of each d.c. power source and any adjustment made for non-automatic devices;

- the results of data recorded during periodic maintenance inspection including protection potential values, d.c. output values, maintenance data on d.c. power sources and downtime periods in order to follow the changes of the protection potential level status of the structure.

8.3 Galvanic anode systems

The following data should be kept for reference and permanently updated, when applicable :

- design criteria including the design life, the environment characteristics (e.g. water resistivity), the protection criteria considered, the current density requirements, the assumed values of the anodes output current at different periods and working conditions, and the anode theoretical efficiency and driving potential;

- the number of anodes, their size, mass, specification, alloy composition, effective consumption rate as measured during tests, in accordance with prEN 12496 and characteristics, as well as the manufacturer/supplier references and documentation;

- the location of each and every anode as checked during construction, all discrepancies with the design location being highlighted (these locations can be conveniently recorded on a specific drawing of the structure), the method of attachment, the date of installation. This data should be updated during the life of the structure;

- the location, description and specification of any current or potential control or monitoring device, including type of reference electrode, measuring equipment, and connecting cables;

- the commissioning results including potential survey data;

- the results of periodic maintenance inspection survey data including current and protection potential measurements, equipment and the measuring technique in order to follow the changes of the protection potential status of the structure.

Annex A
(informative)

Guidance for current requirements for cathodic protection of offshore floating structures

In the absence of any other documented experience, the following values may be considered:

A.1 Design current densities for the protection of bare steel in seawater

Geographic areas	Current densities (m A/m^2)		
	Initial value	Maintenance value	Repolarisation value
North sea (northern sector) above 62°N	220	100	130
55°N to 62°N	180	90	120
North sea (southern sector) below 55°N Bay of Biscay – West Portugal - West UK – West Ireland – Netherlands	150	80	100
Arabian Gulf, India, Australia, Brazil, West Africa	130	70	90
Mediterranean sea, Adriatic sea, Gulf of Mexico, Indonesia	110	60	80

A.2 Design current densities for the protection of bare steel in saline muds (ambient temperature)

Geographic areas	Current densities (m A/m^2)		
	Initial value	Maintenance value	Repolarisation value
any where	25	20	20

A.3 Values of coating breakdown factors of usual paint systems for the design of cathodic protection systems

Initial coating breakdown factor : 1 % to 2 % for immersed zone

Depletion rate : 1 % to 1,5 % per year

NOTE Usual paint systems include minimum two layers of an ambient temperature cured paint (coal tar epoxy, epoxy,...) with dry film thickness ranging from 250 µm to 500 µm.

Annex B
(informative)

Anode resistance and life determination

B.1 Anodic resistance (R_a) formulae

Slender anodes mounted at least 0,3 m offset from structure steel surface

if $L \geq 4r$

$$R_a = \frac{\rho}{2\pi L} \times \left[\ln\left(\frac{4L}{r}\right) - 1 \right]$$

if $L < 4r$

$$R_a = \frac{\rho}{2\pi L} \times \left\{ \ln\left[\frac{2L}{r} \times \left(1 + \sqrt{1 + \left(\frac{r}{2L}\right)^2} \right) \right] + \frac{r}{2L} - \sqrt{1 + \left(\frac{r}{2L}\right)^2} \right\}$$

Flat plate anodes

$$R_a = \frac{\rho}{2S}$$

Other shapes

$$R_a = 0{,}315 \frac{\rho}{\sqrt{A}}$$

where:

R_a is the anodic resistance in ohms,

is the environment resistivity in ohms metres,

L is the length of the anode in metres,

r is the radius of the anode (for other shapes than cylindrical, $r = \frac{C}{2\pi}$, where C is the cross section periphery) in metres,

S is the arithmetic mean of anode length and width in metres,

A is the exposed surface area of anode in square metres.

Without any information on the average resistivity of the environment, the following range of values can be used:

- cold sea water : 0,30 m to 0,35 m;
- warm sea water: 0,15 m to 0,25 m;
- saline mud: 0,70 m to 1,70 m.

For brackish water, the resistivity may fluctuate greatly (0,20 m to 10 m) depending on salt content.

B.2 Anodes life duration

The anode life time (T) may be determined using the following formula :

$$T = W \cdot u / (E \cdot I_s)$$

where:

T is the effective life time of the anode in years,

W is the net mass of the anodes in kilogrammes,

u is the utilisation factor determined by the portion of anodic material consumed when the remaining anodic material cannot deliver the current required. The shape of the anode will affect the utilisation factor which may be in the range of 0,7 to 0,95,

E is the consumption rate of the anodic material in the environment considered in kilogrammes per ampere and per year,

I_s is the average (mean) electrical current output during the life time in amperes.

Annex C
(informative)

Typical electrochemical characteristics of impressed current anodes

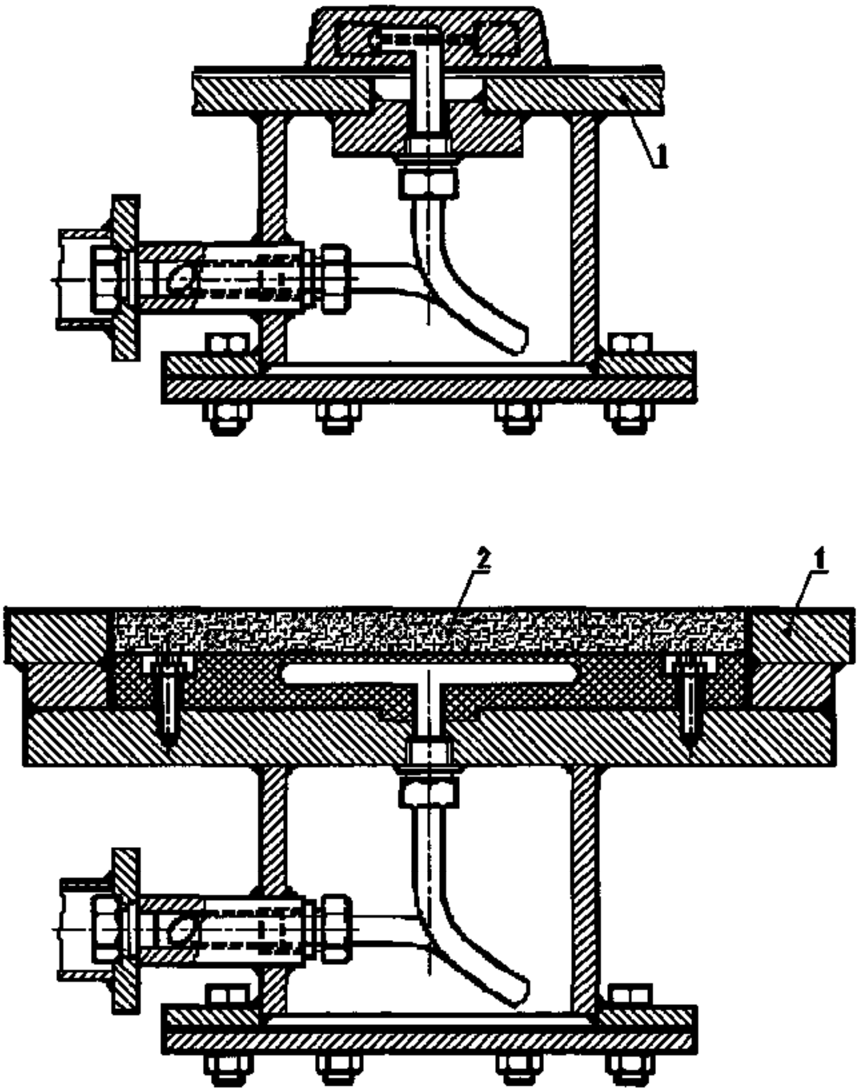
Anode materials	Consumption rate (g/A a)	Maximum current density (A/m^2)	Maximum voltage (V)
Platinised titanium	0,0012 to 0,004 [a)]	500 to 3000	8 [b)]
Platinised niobium	0,0012 to 0,004 [a)]	500 to 3000	50
Platinised tantalum	0,0012 to 0,004 [a)]	500 to 3000	100
Mixed metal oxide on titanium substrate	0,0006 to 0,006	400 to 1000	8 [b)]
Lead silver	25 to 100	250 to 300	24

a) The life of the platinum film may be affected by the electrolyte resistivity, the consumption rate increasing with resistivity. The life of the platinum film can also be affected by the magnitude and frequency of the ripple present in the d.c. supply. Ripples frequencies less than 100 Hz should be avoided.

b) In sea water, the oxide film on titanium may break down if the voltage at the anode exceeds 8 V. Higher voltages may be used with fully platinized anodes or in less saline environments.

Annex D
(informative)

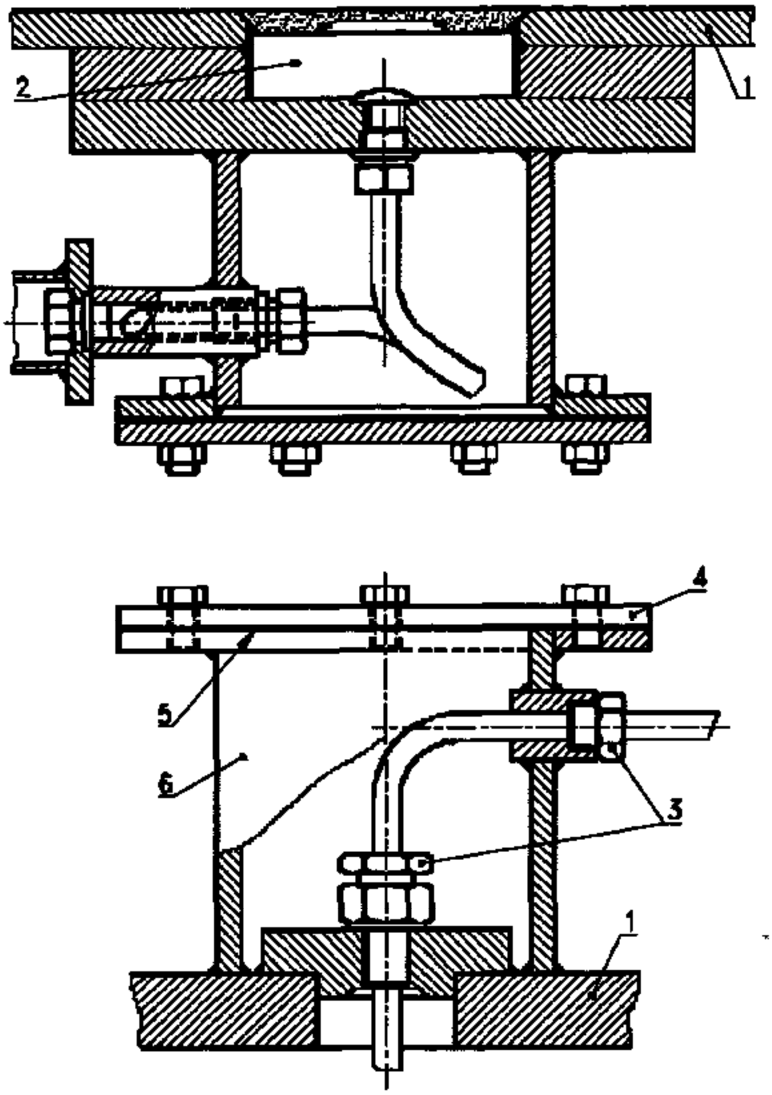
Typical cofferdam arrangements



Key

1 Hull
2 Active area (anode)

Figure D.1 – Typical anode mountings with cofferdam arrangement



Key

1 Hull
2 Reference electrode
3 Stuffing box
4 Blind flange
5 Neoprene sealer
6 Cofferdam

Figure D.2 – Typical through hull passage with cofferdam arrangement

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