SLOVENSKI STANDARD
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Katodna zaščita ladij

Cathodic protection of ships

Kathodischer Korrosionsschutz von Schiffen

Protection cathodique des coques de bateaux

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Cathodic protection of ship hulls

Protection cathodique des coques de bateaux

Kathodischer Korrosionsschutz von Schiffen

This European Standard was approved by CEN on 25 August 2012.

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Foreword

This document (EN 16222:2012) 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of an identical text or by endorsement, at the latest by April 2013, and conflicting national standards shall be withdrawn at the latest by April 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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Introduction

Cathodic protection is usually applied, mostly as a complement to protective coatings, to protect the external surfaces of ship hulls and immersed appurtenances from corrosion due to seawater.

Cathodic protection works by supplying sufficient direct current to the immersed external 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

1.1 General

This European Standard defines the general criteria and recommendations for cathodic protection of immersed external ship hulls and appurtenances.

This European Standard does not cover safety and environmental protection aspects associated with cathodic protection. Relevant national or international regulations and classification society requirements apply.

1.2 Structures

This European Standard covers the cathodic protection of the underwater hulls of ships, boats and other self propelled floating vessels generally used in seawater together with their appurtenances such as rudders, propellers, shafts and stabilisers.

It also covers the cathodic protection of thrusters, sea chests and water intakes (up to the first valve).

It does not cover the protection of internal surfaces such as ballast tanks.

It does not cover steel offshore floating structures which are covered in EN 13173.

1.3 Materials

This European Standard covers the cathodic protection of ship hulls fabricated principally from carbon manganese steels including appurtenances of other ferrous or non-ferrous alloys such as stainless steels and copper alloys, etc.

This European Standard applies to both coated and bare hulls; most hulls are coated.

The cathodic protection system should be designed to ensure that there is a complete control over any galvanic coupling.

This European Standard does not cover the cathodic protection of hulls principally made of other materials such as aluminium alloys, stainless steels or concrete.

1.4 Environment

This European Standard is applicable to the hull and appurtenances in seawater and all waters which could be found during a ship's world-wide deployment.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 12496, *Galvanic anodes for cathodic protection in seawater and saline mud*

EN 13509, *Cathodic protection measurement techniques*

EN 50162, *Protection against corrosion by stray current from direct current systems*

EN ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions (ISO 8044)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 8044, EN 12473 and the following apply.

3.1
immersed zone
zone located below the water line at draught corresponding to normal working conditions

3.2
underwater hull
part of the hull vital for its stability and buoyancy of a ship

Note 1 to entry: Part of the underwater hull might include that below the light water line.

3.3
boot topping
section of the hull between light and fully loaded conditions which may be intermittently immersed

3.4
cathodic protection zone
part of the structure which can be considered independently with respect to cathodic protection design

Note 1 to entry: A single zone may comprise a variety of components with differing design parameters.

3.5
submerged zone
zone including the immersed zone and the boot topping

3.6
driving voltage
difference between the structure/electrolyte potential and the anode/electrolyte potential when the cathodic protection is operating

3.7
closed circuit potential
potential measured at a galvanic anode when a current is flowing in between the anode and the surface being protected

4 Competence of personnel

Personnel who undertake the design, supervision of installation, commissioning, supervision of operation, measurements, monitoring and supervision of maintenance of cathodic protection systems shall have the appropriate level of competence for the tasks undertaken. This competence should be independently assessed and documented.

EN 15257 constitutes a suitable method of assessing and certifying competence of cathodic protection personnel which may be utilised.

Competence of cathodic protection personnel to the appropriate level for tasks undertaken should be demonstrated by certification in accordance with EN 15257 or by another equivalent prequalification procedure.

5 Design basis

5.1 General

The 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 structure to electrolyte potential of each part of the structure is within the limits given by the protection criteria (see 5.2).

Potentials should be as uniform as possible over the whole submerged surfaces. This objective may only be approached by adequate distribution of the protective current over the structure during its normal service conditions. This may be difficult to achieve in some areas such as water intakes, thrusters, sea chests, where specific provisions should be considered.

The cathodic protection system for a ship is generally combined with a protective coating system, even though some appurtenances such as propellers are generally not coated.

Electrochemical anti-fouling systems are often used within sea chests to prevent fouling of seawater intake systems. The possibility of interaction between the anti-fouling system and the cathodic protection system should be considered in the design and installation of the anti-fouling system.

Cathodic protection within sea chests may adversely affect, by stray current interaction, box coolers in sea chests (typically copper nickel alloy tubes) if the box coolers are electrically isolated from the sea chest. The possibility of interaction should be taken into account in designing the cathodic protection requirements for the sea chest.

The cathodic protection system should be designed either for the life of the ship or on the basis of the dry-docking intervals.

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

The design, the installation, the energising, the commissioning, the long-term operation and the documentation of all of the elements of cathodic protection systems shall be fully recorded.

EN ISO 9001 constitutes a suitable Quality Management Systems Standard which may be utilised.

Each element of the work shall be undertaken in accordance with a fully documented quality plan.

Each stage of the design shall be checked and the checking shall be documented.

Each stage of the installation, energising, commissioning and operation shall be the subject of appropriate visual, mechanical and/or electrical testing and all testing shall be documented.

All test instrumentation shall have valid calibration certificates traceable to national or European Standards of calibration.

The documentation shall constitute part of the permanent records for the works.

5.2 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 follows.

The accepted criterion for protection of steel in aerated seawater is a protection potential more negative than – 0,80 V measured with respect to Ag/AgCl/seawater reference electrode. This corresponds approximately to + 0,23 V when measured with respect to pure zinc electrode (e.g. alloy type Z2 as defined in EN 12496) or

+ 0,25 V when measured with respect to zinc electrode made with galvanic anode alloy types Z1, Z3 or Z4 as defined in EN 12496.

A negative limit of – 1,10 V with respect to Ag/AgCl/seawater reference electrode is generally recommended in order to avoid coating disbondment and / or increase in fatigue propagation rates.

Where there is a possibility of hydrogen embrittlement of steels or other metals which may be adversely affected by cathodic protection to excessively negative values, an additional less negative potential limit shall be adopted. If insufficient documentation is available for a given material, this specific negative potential limit relative to the metallurgical and mechanical conditions shall be determined by mechanical testing at the limit polarised potential. For conventional steels, this limit is – 1,10 V (Ag/AgCl/seawater reference electrode). Refer to EN 12473 for more details.

The above potential criteria and limit values are “polarised” and are expressed without IR errors. IR errors, due to cathodic protection current flowing though resistive electrolyte and surface films on the protected surface, are generally considered insignificant in marine applications. Potential measurements using “Instant OFF” techniques or “coupon Instant OFF” techniques may be necessary in applications described in this European Standard in order to adequately demonstrate the achievement of the above protection criteria (see EN 13509). Particular attention should be given to this in brackish waters and close to impressed current anodes.

5.3 Design process

The design of a cathodic protection system shall be conducted according to the following different stages:

a) the structure is divided into various cathodic protection zones which will be considered independently with respect to cathodic protection design (see 5.4.2);

b) each component included in a cathodic protection zone is fully described (see 5.4.3);

c) the service conditions are well established (see 5.4.4);

d) the current demand is determined for each cathodic protection zone from (see 5.5):

   1) areas of components;

   2) current densities regarding the state of components and service conditions;

Two different approaches may be considered concerning the choice of current densities:

   3) From current densities of bare metal (see 5.5.2) introducing a breakdown factor for the coating (see 5.5.3) taking into consideration physicochemical ageing and mechanical damage versus time;

   4) From a global approach (see 5.5.3) based on experience.

When the first approach is selected, two types of current demands are determined (see 5.5.4):

   5) maximum current demand (I_{max});

   6) mean current demand (I_{mean}),

e) the cathodic protection system is determined for each cathodic protection zone (see 5.6);

f) an electrical continuity is planned between all components of a cathodic protection zone (see 5.7);

g) the appropriate cathodic protection system dedicated to a cathodic protection zone is designed (see Clauses 6 and 7).

NOTE The design of impressed current systems is based on maximum current demand. The design of galvanic anodes systems is based on maximum current demand and mean current demand.

5.4 Design parameters

5.4.1 General

The design of a cathodic protection system takes into consideration the following parameters: structure subdivision, components characteristics and service conditions.

5.4.2 Structure subdivision

The submerged surfaces of a ship hull can be divided into different cathodic protection zones which are then considered independently with respect to cathodic protection design although they are not electrically isolated.

For instance, the underwater hull can be divided into two main cathodic protection zones: the forward (or bow) zone and the aft (or stern) zone illustrated by the drawing in Annex A. This subdivision is related to the higher current demand of the aft zone due to high water flow rates, turbulence and the presence of dissimilar metals due to the propeller(s). The aft cathodic protection zone includes the following appurtenances: the aft part of the hull, propeller(s), shaft(s), rudder(s), etc.

Some specific components may constitute a cathodic protection zone by themselves (e.g. openings of sea chests, thrusters, rudders etc).

5.4.3 Components characteristics

Each component of a cathodic protection zone as mentioned above shall be fully detailed in the design including: material, specific potential limit (where applicable) area and coating characteristics (type, lifetime and coating breakdown factor).

5.4.4 Service conditions

The design of cathodic protection system(s) shall be related to the service conditions which include: lifetime, environment and operating conditions.

a) Lifetime

Either the whole design life or dry-docking intervals should be considered.

b) Environment

The characteristics of seawater should be established. Refer to EN 12473 General principles of cathodic protection in seawater. Particular attention is required for vessels anticipated to operate in ice conditions or estuarine/freshwater conditions.

c) Operating conditions

The average and the maximum speeds should be considered combined with the percentages of lifetime associated to static (berthed) and dynamic (sailing) conditions.

5.5 Current demand

5.5.1 General

To achieve protection criteria for the conditions outlined in 5.2 it is necessary to select the appropriate design current density for each component with respect to the environmental and service conditions.

The current demand of each metallic component of the structure is the result of the product of its surface area multiplied by the protection current density for the bare steel and by the coating breakdown factor.

See Annexes B and C for design current density and anode resistance calculation guidance.

5.5.2 Design current density for bare steel

The selection of design current densities may be based either on experience gained from similar ships operating in a similar manner or from specific tests and measurements.

The protection current density of bare steels and other bare metals depends on the kinetics of electrochemical reactions. It varies with parameters such as the material, potential, surface condition, dissolved oxygen content in seawater, flow rate or speed, temperature.

For each particular environmental and service conditions mentioned in 5.4.4 c), protection current density shall be evaluated.

Typical values of design current densities as used for bare steel are given in Annex B.

5.5.3 Design current density for coated steel

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

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

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

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

Guidelines for the values of coating breakdown factors are given in Annex B.

The design current density required for the protection of coated steel is equal to the product of the current density for bare steel (see 5.5.2) and the coating breakdown factor:

$$J_c = J_b \cdot f_c$$

where

J_c is the protection current density for coated metal in A/m^2;

J_b is the protection current density for bare metal in A/m^2;

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 properties (equivalent to bare metal).

This formula should be applied for each individual component or cathodic protection zone as defined in 5.3 where the coating or current density for bare metal can be different.