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Notranja katodna zaščita kovinskih konstrukcij

Internal cathodic protection of metallic structures

Kathodischer Korrosionsschutz für die Innenflächen von metallischen Anlagen

Protection cathodique interne des structures métalliques

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Internal cathodic protection of metallic structures

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Kathodischer Korrosionsschutz für die Innenflächen von metallischen Anlagen

This European Standard was approved by CEN on 7 November 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This document (EN 12499:2002) 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of an identical text or by endorsement, at the latest by July 2003, and conflicting national standards shall be withdrawn at the latest by July 2003.

Annex A is normative. Annex B is informative.

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

1 Scope

This European Standard specifies the structures, metals and surfaces which can be protected against corrosion by the application of internal cathodic protection, the electrolytic solutions and the conditions necessary for the application of internal cathodic protection and gives guidance on the application and operation of an effective internal cathodic protection system.

This standard applies to the internal cathodic protection of domestic water heaters, hot and cold water tanks, circulating water pipes, condensers, heat exchangers and, generally speaking, to every structure containing an electrolytic solution that it is technically possible to cathodically protect. This standard applies to metallic structures which contain stored or circulating water, which can be stagnant or renewed, cold or hot, drinking water or industrial water and also to aqueous suspension.

NOTE Electrolytic solutions are assumed to have a conductivity > 10^{-3} Siemens m^{-1}, and a pH > 4,5. Where the pH < 5,5 or the conductivity less than10^{-2} Siemens m^{-1} see 5.4 and 6.9.2.2.

This standard is applicable to metallic structures made from the following on their own or with others:

- iron and low alloy steel;
- galvanised steel;
- copper and copper alloys;
- lead;
- tin;
- stainless steels;
- aluminium and zinc;
- titanium.

This standard is applicable to the cathodic protection of uncoated metals, and of metals already coated with low or high insulation resistance coatings.

2 Normative references

This European Standard incorporates by dated or undated reference, 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 50014, *Electrical apparatus for potentially explosive atmospheres – General requirements*.

EN 60335-2-21, Safety of household and similar electrical appliances - Part 2: Particular requirements for storage water heaters (IEC 60335-2-21:1997 + Corrigendum 1998, modified).

EN ISO 8044:1999, Corrosion of metals and alloys - Basic terms and definitions (ISO 8044:1999).

3 Symbols, terms and definitions

For the purposes of this standard the symbols, terms and definitions of EN ISO 8044:1999 and the following apply.

3.1 Symbols

I	Current
R	Resistance
J	Current density
U	Voltage
a	Year
E_{Ag}	Metal-to-electrolytic solution potential with respect to a silver/silver chloride reference electrode
E_{l}	Limiting critical potential
E_{n}	Free corrosion potential
E_{off}	Instantaneous off potential
E_{on}	On potential
E_{p}	Protection potential
E_{H}	Metal-to-electrolytic solution potential with respect to a standard hydrogen electrode
E_{Zn}	Metal-to-electrolytic solution potential with respect to a zinc electrode
I_{a}	Anode current output
I_{p}	Protection current
J_{p}	Protection current density (A/m^2)
r_{c}	Specific coating resistance (Ω·m^2)
T	Temperature
t	Time
ρ	Resistivity (Ω·m)

3.2 Terms and definitions

3.2.1
anaerobic
without free oxygen in the electrolytic solution adjacent to a metallic structure

3.2.2
anodic area
part of a structure surface which acts as an anode

3.2.3
cathodic area
part of a structure surface which acts as a cathode

3.2.4
cathodic protection system
entire installation, including passive and active elements, that provides cathodic protection to a structure

3.2.5
coating defect
discontinuity in the protective coating

3.2.6
coating resistance
electrical resistance between a coated metal and the electrolytic solution

NOTE It is determined largely by the size and number of coating defects and coating pores and is therefore indicative of the condition of the coating (see also specific coating resistance).

3.2.7
continuity bond
bond designed and installed specifically to ensure electrical continuity

3.2.8
continuous anode
long flexible anode

3.2.9
coupon
representative metal sample of known weight and dimensions used to quantify the extent of corrosion or the effectiveness of applied cathodic protection

3.2.10
drinking water
water in conformity with European directive 98/83/CE from November 3, 1998

3.2.11
electrical continuity
state within a protected structure in which the circulating current does not produce a significant voltage drop

3.2.12
electrical isolation
state in which there is no metallic electrical path between structures or components

3.2.13
electrical shielding
intervening objects that prevent the flow of the current through the electrolytic solution to a structure

3.2.14
equalising current
current that flows between two separate points after interruption of the protection current

NOTE Equalising currents can flow, for example, as a result of removing cathodic protection current from a structure with components exposed to different depolarisation conditions.

3.2.15
foreign cathode
metal part fitted in the protected structure which has a more positive free corrosion potential than the protected structure and which requires a greater current density than the protected structure to achieve cathodic polarisation

NOTE Foreign cathodes can seriously impair the cathodic protection of the rest of the structure.

3.2.16
impressed current anode
anode in an impressed current station

NOTE Impressed current anodes can be permanent anodes or soluble anodes.

3.2.17

impressed current station

equipment and materials required to provide cathodic protection by impressed current

NOTE Such materials and equipment will include impressed current anodes, cables, sensing electrodes, and transformer rectifiers.

3.2.18

off potential

structure to electrolytic solution potential measured immediately after synchronous interruption of all sources of applied cathodic protection current

3.2.19

IR drop

voltage developed across a resistance, or resistive path, in accordance with Ohm’s Law ($U = I \times R$ V)

3.2.20

IR -free potential

potential measured without the voltage error caused by the IR drop ($E_{\text{IR FREE}}$)

3.2.21

isolating joint

electrically discontinuous joint or coupling between two lengths of pipe, inserted in order to provide electrical discontinuity between them

3.2.22

measuring point

point at which the actual measurement takes place

NOTE In the case of structure to electrolytic solution potentials this refers to the location of the reference electrode.

3.2.23

on potential

structure to electrolytic solution potential measured with the structure cathodic protection current flowing

3.2.24

overprotection

state in which the structure to electrolytic solution potentials are more negative than those recommended for satisfactory cathodic protection

NOTE Overprotection provides no useful function and can cause damage to the structure by excessive production of gases which can constitute an explosion hazard, embrittlement of metals, or protective coating damage.

3.2.25

permanent anodes

impressed current anodes for which the rate of corrosion is much smaller than the rate calculated in accordance with Faraday’s Law

3.2.26

permanent reference electrode

permanent installed reference electrode designed for a long life

3.2.27

potential gradient

difference in potential between two separate points in the same electrolytic solution

3.2.28
potentiostat
protection current device by means of which the structure/electrolytic solution potential is brought and maintained to a prescribed level despite variations in polarisation conditions

NOTE The current delivered by the generator, the protection current, is controlled by the structure potential measured by a reference electrode.

3.2.29
protected structure
structure to which cathodic protection is effectively applied

3.2.30
protection current (I_p)
current made to flow into a metallic structure from its electrolytic environment in order to effect cathodic protection of the structure

3.2.31
resistance bond
bond with significant resistance to limit the flow of current to within prescribed limits

NOTE Resistance can be achieved by the insertion of resistors into the bond connection.

3.2.32
soluble anode
impressed current anode which is consumed in accordance with Faraday's Law by the impressed anodic current

NOTE The adjectives soluble and sacrificial used alone do not specify if anodes are working by galvanic action or by impressed current. To avoid confusion it is proposed to apply the following convention: "galvanic anode" for sacrificial galvanic anode; "soluble anode" for soluble impressed current anode.

3.2.33
standard reference electrode
reference electrode whose potential does not depend on the concentrations of various elements in the electrolytic solution of the corrosion system

3.2.34
sensing electrode
permanently installed reference electrode used to measure the structure to electrolytic solution potential and to provide a signal to control the protection current of an automatic impressed current system

3.2.35
silver/silver chloride reference electrode
Ag/AgCl reference electrode
electrode consisting of silver, coated with silver chloride, in an electrolytic solution containing chloride ions

NOTE The potential of this electrode changes when the electrolytic solution concentration of the chloride ions changes (see annex B).

3.2.36
silver/silver chloride standard electrode
Ag/AgCl standard electrode
reference electrode consisting of silver, coated with silver chloride, in an electrolytic solution containing a fixed concentration of chloride ions

3.2.37
specific coating resistance
measurement derived from the variation of potential induced by a variation of the protection current i.e. the absolute value of the variation of potential divided by the corresponding variation of current density (see 7.4)

NOTE This is expressed in $\Omega \cdot m^2$.

3.2.38
standard hydrogen electrode
reference electrode consisting of platinum, in an electrolytic solution containing hydrogen ions at unit activity and saturated with hydrogen gas at one standard atmosphere

3.2.39
structure (to electrolytic solution) potential
corrosion potential of a structure in a given corrosion system

NOTE The contact of the reference electrode with the electrolytic solution must be close to the structure to minimise errors due to the voltage drop associated with any current flowing in the electrolytic solution.

3.2.40
sulphate reducing bacteria
bacteria which reduce sulphates in their environment, producing sulfides which accelerate the corrosion of structural materials

NOTE This group of bacteria is found in most soils and natural waters, but is active only under anaerobic conditions of near neutrality and free of oxygen.

3.2.41
transformer-rectifier
device that transforms the alternating voltage and then rectifies it to direct current

NOTE Direct current derived in this way is used as a power source for impressed current cathodic protection systems.

3.2.42
utilisation factor
proportion of a galvanic anode that may be consumed before the anode ceases to provide a current output in accordance with the cathodic protection design

4 Principle and criteria for internal cathodic protection

4.1 Principle

The decrease of the corrosion rate is achieved by lowering the corrosion potential to reach the protection potential range. Cathodic protection is achieved when all the metallic surfaces to be protected have reached the protection potential range.

The lowering of the potential is achieved by means of a protection current passing from the electrolytic solution to the metal surface. This current enters the electrolytic solution from the surface of an anode.

Throughout clause 4 all electrode potentials are IR-free potentials.

4.2 Criteria

The protection potential depends on the physical and chemical conditions at the interface between the metal and the electrolytic solution. The coverage of the metal by calcareous deposits and the rate of diffusion of ions issuing from metal are different according to the medium.

Protection potential values are determined by practical experience.

One single potential criterion cannot cover the range of different situations that arise in internal cathodic protection applications.

The only criterion that cannot be disputed is a lack of corrosion established by inspection.

Some practical values are listed in Table 1. Precautions additional to those listed may need to be taken to protect against effects caused by the simultaneous presence of different metals or by the precipitation of some ions.

Overprotection needs to be avoided on internal cathodic protection. Overprotection will result in the formation of gases. Some metal may be subject to specific damages at very negative potentials. It is essential that their potential is not brought to values lower than the limiting critical potential given in Table 1.

Table 1 — Guidance values of protection potential range with respect to the standard hydrogen electrode

Metal	Electrolytic solution	Protection potential, E_H	Limiting critical potential
		V	
Iron and low alloy steel	Neutral cold water	- 0,55	
	Hot water	- 0,65	
	Acid water or presence of bacteria	- 0,65	
Low alloy steel coupled with stainless steel	Cold or hot water	- 0,55	See footnote [a]
Stainless steel	Cold or hot water	-0,1	See footnote a
Copper and copper alloy	Cold or hot water	- 0,20	
Tin	Cold or hot water	- 0,35	- 1,0
Zinc	Cold or hot water	- 0,90	- 1,0 [b]
Lead	Neutral cold water	- 0,33	- 0,65
Aluminium and alloys with Magnesium or Manganese	Cold or hot water	- 0,45	- 0,80 [b]
	Sea water	- 0,55	- 0,80 [b]
Aluminium zinc alloys	Cold or hot water	- 0,60	- 0,80
	Sea water	- 0,70	- 0,90
Titanium	Sea water		-0,75

[a] Protection potentials shall be determined by testing in each case as well as the limiting critical potentials for ferritic and martensitic steel. There is no limiting critical potential for austenitic steel.

[b] Aluminium and zinc cannot be polarised to such a negative potential that the anodic reaction rate becomes negligible. These metals are self protected by their oxidation products. Cathodic polarisation can regularise this initial oxidation.

When the metal potential is measured between the metal and a reference electrode other than a standard hydrogen electrode, the E_H metal potential with respect to the standard hydrogen electrode is calculated as follows:

$E_H = E_M + E_R$; or

$E_M = E_H - E_R$ (see annex B)

where

E_M is the measured algebraic value of the potential difference between the metal and the reference electrode;

E_R is the measured algebraic value of the potential difference between the reference electrode and a standard hydrogen electrode.

Table 2 — Potentials of some electrodes with respect to the standard hydrogen electrode

Electrode type	Electrolytic solution	Electrode potential, E_R V	Field of use
Standard electrode			
Copper/copper sulphate	Saturated copper sulphate	+ 0,32	Soil
Silver/silver chloride (saturated)	Saturated potassium chloride	+ 0,20	Sea water – Fresh water
Thallium/thallium chloride	3.5 M potassium chloride	- 0,57	Hot water
Permanent reference electrode			
Zinc/sea water	Sea water	- 0,77 approx.	Sea water
Silver/silver chloride	Sea water	+ 0,25 approx. [a]	Sea water
	Fresh water	+ 0,35 approx. [a]	Fresh water containing chlorides

[a] These potentials change with chloride concentration; the variation is about 60 mV at 30 °C for each ten-fold change in concentration (see annex B).

5 Factors affecting design and application

5.1 Different metals

It is necessary to consider all the possible operating conditions and then determine whether or not a range of protection criteria can be established.

If different metals are protected by cathodic protection, then the least noble metal needs to reach its protection potential. It is essential that the protection potential ranges of the various metals are not incompatible.

5.2 Electrolytic solution conductivity

There needs to be a continuous electrolytic contact between the surfaces of the protected structure and the protective anodes ensuring a sufficient distribution of current. Internal cathodic protection is not possible when the liquid on the whole is non-conductive.

5.3 Electrical continuity

The structure to be protected needs to be electrically continuous. Individual components of the structure need to be connected with low resistance metallic bonds.

5.4 Current distribution

The current distribution needs to be able to achieve the protection potential range on each point of the entire structure.

The factors improving current distribution are the following:

- high electrolytic solution conductivity;
- high polarisation resistance (the polarisation resistance can be improved by coating);
- surface and positioning of the anodes;
- design of the structure to be protected.