BRITISH STANDARD

BS EN 12954:2001

Cathodic protection of buried or immersed metallic structures — General principles and application for pipelines

The European Standard EN 12954:2001 has the status of a British Standard

ICS 23.040.01; 77.060

National foreword

This British Standard is the official English language version of EN 12954:2001.

Reference should also be made to BS 7361, *Code of practice for land and marine applications*, which will eventually be withdrawn when all the CEN Standards relating to cathodic protection currently being prepared, are published.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

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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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English version

Cathodic protection of buried or immersed metallic structures - General principles and application for pipelines

Protection cathodique des structures métalliques enterrées ou immergées - Principes généraux et application pour les canalisations

Kathodischer Korrosionsschutz von metallenen Anlagen in Böden oder Wässern - Grundlagen und Anwendung für Rohrleitungen

This European Standard was approved by CEN on 1 December 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.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EUROPÄISCHES KOMITEE FÜR NORMUNG

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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.

Annex A is informative.

Introduction

This standard is applicable to the protection of all types of buried or immersed metallic structures especially pipelines. However, in order to allow for structures having specific features with regards to construction, commissioning or operation, provision has been made for complementary standards to be used in conjunction with this one to deal with the peculiarities of such structures.

Cathodic protection is a technique based on the application of electrochemical principles and covers a wide range of materials and equipment together with a variety of measurement techniques. In order to achieve effective and efficient cathodic protection, the design, installation, commissioning, inspection and maintenance should be performed by adequately trained, experienced and responsible personnel.

This standard aims to ensure effective cathodic protection and is therefore directed primarily to the above personnel.

1 Scope

This European Standard specifies the general principles for the implementation of a system of cathodic protection against corrosive attacks on buried or immersed metal structures with and without the influence of external electrical sources.

NOTE 1 The protection against stray current from direct current system influences is dealt in prEN 50162:2000.

This standard indicates conditions and parameters that should be met to achieve cathodic protection as well as rules and procedures that should be followed for design, installation, commissioning and maintenance of the protective systems.

NOTE 2 Clauses 5 to 10 deal mainly with the cathodic protection of pipelines but they are applicable to other structures

This standard is applicable to external surfaces of buried or immersed structures. It is not applicable to the protection of internal parts of structures containing corrosive liquids.

NOTE 3 This is covered by prEN 12499:1996.

When cathodic protection is necessary, this standard is applicable to structures covered with concrete which are then buried or immersed. It is not applicable to the protection of steel in reinforced concrete which is buried or immersed.

NOTE 4 This is covered by EN 12696

This standard is applicable only to those constructions in sea water for which the protective systems would be installed and can be inspected on land.

NOTE 5 Such constructions in sea water are generally of smaller length, whether or not they form a part of a larger underground network.

NOTE 6 Other constructions in sea water are dealt with in other standards, e.g. for submarine pipelines see EN 12473.

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 revision of any of these publications apply to this standard only when incorporated in this standard by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

prEN 50162:2000, *Protection against corrosion by stray current from DC systems*

EN 12696, *Cathodic protection of steel in concrete*

prEN 13509:1999, *Cathodic Protection Measurement Techniques*

EN 60079-10, *Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas* (IEC 60079-10:1995)

EN 60079-14, *Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)* (IEC 60079-14:1996)

EN ISO 8044, *Corrosion of metals and alloys; vocabulary*

3 Symbols, terms and definitions

3.1 Symbols

I	Current
E	Potential
R	Resistance
J	Current density
U	Voltage
a.c.	Alternating current
d.c.	Direct current
E_{Ag}	Metal or structure to electrolyte potential with respect to a silver/silver chloride reference electrode
E_{Cu}	Metal or structure to electrolyte potential with respect to a copper/saturated copper sulphate reference electrode
$E_{IR\,free}$	IR free potential
E_{KCl}	Metal or structure to electrolyte potential with respect to a silver/silver chloride/saturated potassium chloride electrode
E_l	Limiting critical potential
E_n	Free corrosion potential
E_{off}	Off potential
E_{on}	On potential
E_p	Protection potential
E_{Hg}	Metal or structure to electrolyte potential with respect to a mercury/calomel/saturated potassium chloride electrode
E_H	Metal or structure to electrolyte potential with respect to a standard hydrogen electrode
E_{Zn}	Metal or structure to electrolyte potential with respect to a zinc electrode
I_a	Anode current output
I_p	Protection current
I_s	Stray current
$J_{a.c.}$	Alternating current density
J_p	Protection current density
R_{co}	Coating resistance or structure to soil resistance (Ω)
r_{co}	Average coating resistance or average structure to soil resistance ($\Omega \cdot m^2$)
T	Temperature
t	Time
ρ	Resistivity ($\Omega \cdot m$)

3.2 Terms and definitions

For the purposes of this European Standard the following terms and definitions apply.
For other terms and definitions related to corrosion refer to EN ISO 8044.

3.2.1
anaerobic
lack of free oxygen in the electrolyte adjacent to a metallic structure

3.2.2
anode backfill
material with a low resistivity, which may be moisture-retaining, immediately surrounding a buried anode for the purpose of decreasing the effective resistance of the anode to the electrolyte

3.2.3
average coating resistance or average structure to soil resistance(r_{co})
value derived from the ratio of the difference between the ON and OFF potentials to the protection current and the surface area of the structure in question. It is usually expressed in Ohm.square meter ($\Omega \cdot m^2$)

3.2.4
backfill
see anode backfill

3.2.5
blistering
formation of swellings on the surface of an unbroken thin coating caused by permeation of water, gases and by migration of ions in the presence of an electric field between the metal and the coating

3.2.6
bond
metal conductor, usually of copper, connecting two points on the same or on different structures usually with the intention of making the points equipotential

3.2.7
buried structure
any metal construction built or laid beneath ground level or built on ground level and then covered with earth

3.2.8
cathodic protection station
impressed current or galvanic anode station

3.2.9
cathodic protection system
entire installation, including active and passive elements, that provides cathodic protection

3.2.10
coating defect
deficiency in the protective coating (e.g. holidays, porosity)

3.2.11
coating resistance or structure to soil resistance(R_{co})
electrical resistance between a coated metal and the electrolyte expressed in ohms. It is determined largely by the size and number of coating defects, coating pores and the electrolyte resistivity

3.2.12
continuity bond
bond designed and installed specifically to ensure electrical continuity of a structure

3.2.13
copper/saturated copper sulphate reference electrode
reference electrode consisting of copper in a saturated solution of copper sulphate

3.2.14
coupon
representative metal sample used to quantify the extent of corrosion or the effectiveness of applied cathodic protection

3.2.15
d.c. decoupling device
protective device that will conduct when pre-determined threshold voltage levels are exceeded

NOTE Some of these devices permit the discharge of a.c. currents to earthing systems. Polarization cells, spark gaps, and diode assemblies are examples of such devices.

3.2.16
d.c. traction system
electrical traction system powered by direct current

NOTE If these systems have the return circuit earthed at more than one point or are not completely isolated they can generate stray currents which may cause corrosion damage.

3.2.17
d.c. industrial plant
electrical system, other than a traction system, powered by direct current

NOTE If these systems use the earth as part of the return circuit they can generate stray currents which may cause corrosion damage. Cathodic protection systems use the earth as a part of the circuit.

3.2.18
drain point
location of the negative cable connection to the protected structure through which the protection current returns to its source

3.2.19
drainage (electrical drainage)
transfer of stray current from a current source to another structure by means of a deliberate bond.

NOTE For drainage devices (direct drainage bond, resistance drainage bond, unidirectional drainage bond and forced drainage bond) see prEN 50162:2000.

3.2.20
drainage station
A station which comprises the equipment and materials required to provide drainage of stray currents from affected systems by various means.

3.2.21
earthed system
An earthed system is a system that is in electrical connection with the earth

NOTE Such connection may be intentional or unintentional.

3.2.22
earthing
system that is bedded in an electrolyte and is in electrical contact with it

3.2.23
electrical continuity
physical state of a structure such that a current circulating within it does not produce a significant voltage drop

3.2.24
electrical interference
See interference.

3.2.25
electrical isolation
electrical isolation exists when there is no electrical path between structures or components

3.2.26
electrolyte
liquid, or the liquid component in a medium such as soil, in which electric current flows by the movement of ions

3.2.27

electrolyte resistivity (ρ)

The specific electric resistance of the electrolyte assuming that the electrolyte is homogenous

NOTE Usually expressed in Ohm.meter ($\Omega \cdot m$).

3.2.28

external potential test probe

installation comprising a coupon with an associated reference electrode to provide structure to electrolyte potential measuring facilities devoid of IR drop errors

3.2.29

foreign electrode

an electrode in contact with the structure under consideration

3.2.30

forced drainage or forced drainage bond

a form of drainage in which the connection between a protected structure and a traction system includes an independent source of direct current

3.2.31

foreign structures

any neighbouring structure other than the structure that is under consideration

3.2.32

galvanic anode

electrode that provides current for cathodic protection by means of galvanic action

3.2.33

galvanic anode station

station which comprises the equipment and materials required to provide cathodic protection by the use of galvanic anodes. Such materials and equipment will include galvanic anodes, cables, and test facilities.

3.2.34

groundbed

system of buried or immersed galvanic or impressed current anodes

3.2.35

holiday

defect in a protective coating at which metal is exposed to the environment

3.2.36

immersed structure

any metal construction, or part of a construction laid in a liquid environment such as fresh water (rivers, lakes), brackish water (estuaries), or sea water

3.2.37

impressed current anode

electrode that supplies current for cathodic protection by means of an impressed current source

3.2.38

impressed current station

station which comprises the equipment and materials required to provide cathodic protection by impressed current. Such materials and equipment will include impressed current anodes, cables, and a d.c. source.

3.2.39
insulated flange
flanged joint between adjacent lengths of pipe in which the nuts and bolts are electrically insulated from the flange(s) and the gasket is non-conducting, so that there is an electrical discontinuity in the pipeline at that point

3.2.40
interference
any change of the structure to electrolyte potential which is caused by foreign electrical sources

3.2.41
interference test
test to determine the severity of corrosion interaction between two buried or immersed structures

3.2.42
***IR* drop**
voltage, due to any current, developed in an electrolyte such as the soil, between the reference electrode and the metal of the structure, in accordance with Ohm's Law ($U = I \times R$)

3.2.43
***IR* free potential ($E_{IR\ free}$)**
structure to electrolyte potential measured without the voltage error caused by the *IR* drop due to the protection current or any other current

3.2.44
isolating joint
electrically discontinuous connection between two lengths of pipe, inserted in order to provide electrical discontinuity between them, e.g. monobloc isolating joint, insulated flange

3.2.45
measuring point
the point at which the actual measurement takes place.

> NOTE In the case of structure to electrolyte potentials this refers to the location of the reference electrode.

3.2.46
off potential(E_{off})
structure to electrolyte potential measured immediately after synchronous interruption of all sources of applied cathodic protection current

3.2.47
on potential (E_{on})
structure to electrolyte potential measured with the cathodic protection current flowing

3.2.48
permanent reference electrode
permanently buried or immersed reference electrode designed for a long life and installed close to the structure

3.2.49
polarization
change in the potential of an electrode as the result of current flow to or from that electrode

3.2.50
polarization cell or a.c. discharge device
device that blocks d.c. current at low voltage and provides a low resistance path for a.c. current at higher voltage (e.g. lightning discharge)

3.2.51
potential gradient
difference in potential between two separate points in the same electric field

3.2.52
potential test probe
see external potential test probe.

3.2.53
protected structure
structure to which cathodic protection is effectively applied

3.2.54
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

3.2.55
protection potential
structure to electrolyte potential for which the metal corrosion rate is acceptable

3.2.56
remote earth
that part of the electrolyte in which no noticeable voltages, caused by current flow, occur between any two points

NOTE This situation generally prevails outside the zone of influence of an earth electrode, an earthing system, an impressed current groundbed or a protected structure.

3.2.57
resistance bond or resistance drainage bond
a bond with significant resistance to limit the flow of current to within prescribed limits

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

3.2.58
sensing electrode
permanently installed reference electrode used to measure the structure to electrolyte potential and to provide a reference signal to control the protection current of an automatically controlled impressed current system

3.2.59
standard hydrogen electrode
reference electrode, used as a standard in laboratories, consisting of an inert metal, such as platinum, in an electrolyte containing hydrogen ions at unit activity and saturated with hydrogen gas at one standard atmosphere

3.2.60
structure
metallic construction, whether coated or not, which is in contact with an electrolyte (e.g. soil, water)

NOTE The structure may represent a construction of great length, such as pipeline, pipe networks, underground electric cables, or well casings as well as constructions on a smaller scale such as piles, sheet pilings, tanks or other underground constructions.

3.2.61
structure to electrolyte potential (also called electrode potential)
difference in potential between a structure and a specified reference electrode in contact with the electrolyte at a point sufficiently close to, but without actually touching, the structure.

3.2.62
sulphate reducing bacteria
group of bacteria found in most soils and natural waters, but active only in conditions of near neutrality and freedom from oxygen. They reduce sulphates in their environment, with the production of sulphides and accelerate the corrosion

3.2.63
test point
location of a test station

3.2.64
test probe
see external potential test probe.

3.2.65
test station
installation that provides measuring and test facilites for the buried structure.

NOTE Such installations will include cabling and structure connections.

3.2.66
transformer rectifier
device that transforms the a.c. voltage to d.c. voltage. D.c. voltage derived in this way is used as a power source for impressed current cathodic protection systems

3.2.67
unidirectional bond or unidirectional drainage bond
A bond that will only permit current flow in one direction

NOTE This may be achieved by the use of active devices such as relays or passive devices such as diodes.

4 Principle and criteria of cathodic protection

4.1 Principle of cathodic protection

The corrosion rate of a metal in soil or water is a function of the potential, E, of the material in its surrounding media. In general, the corrosion rate decreases as the potential is shifted in the more negative direction. This negative potential shift is achieved by feeding direct current from anodes via the soil or water to the metal surface of the structure to be protected. In the case of coated structures, the current mainly flows to the metal surface at coating pinholes and holidays. The protection current may be provided by impressed current systems or galvanic anodes.

4.2 Criteria of cathodic protection

The metal to electrolyte potential at which the corrosion rate is < 0,01 mm per year is the protection potential, E_p. This corrosion rate is sufficiently low so that during the design life time corrosion damage cannot occur. The criterion for cathodic protection is therefore:

$$E \leq E_p \tag{1}$$

The protection potential of a metal may depend to some extent on the corrosive environment (electrolyte), but it is mainly dependent on the type of metal used (see Table 1).

The protection potential criterion applies at the metal/electrolyte interface, i.e. a potential which is free from the IR drop in the corrosive environment.

Some metals may be subject to corrosion damage at very negative potentials. For such metals, the potential shall therefore not be more negative than a limiting critical potential E_l. In such cases the criterion for cathodic protection is:

$$E_l \leq E \leq E_p \tag{2}$$

Procedures for measuring the metal to electrolyte potential are laid down in prEN 13509:1999. The protection potentials of the most common metals are listed in Table 1 below. For all materials not listed in Table 1, the protection and limiting critical potentials shall be determined by way of experiment.

NOTE In the case of thin protective coatings without holidays with an average coating resistance (r_{CO}) of less than 10^8 $\Omega \cdot m^2$, very negative potentials may have a detrimental impact on the coating, such as blistering. In order to minimise any detrimental effects, IR free potentials should not be more negative than a limiting critical potential of E_l = -1,1 V, measured by reference to a copper/ saturated copper sulphate reference electrode, except if the coating manufacturer gives another documented value. Very negative potentials may also cause gradual cathodic disbonding at faults in thick as well as in thin protective coating.

Table 1 — Free corrosion potentials, protection potentials and limiting critical potential of some common metals in soil and in fresh and salt water

Metal or metal alloy	Medium		Free corrosion potential: E_n (without cell formation) Indicative value V	Protection potential: E_p V	Limiting critical potential: E_l V
Non alloy and low alloy Fe materials with yield strength ≤ 800 N·mm^{-2}	Water and soil aerobic conditions	Normal condition T < 40°C	-0,65 to -0,40	-0,85[a]	-
		T > 60°C	-0,80 to -0,50	-0,95[a]	[b]
		Aerated sandy soil 100<ρ<1000 Ω·m	-0,50 to -0,30	-0,75	-
		Aerated sandy soil ρ>1000 Ω·m	-0,40 to -0,20	-0,65	-
	Water and soil anaerobic conditions		-0,80 to -0,65	-0,95	-
Ferritic or austenitic stainless steels with yield strength < 800 N·mm^{-2}	Neutral and alkaline fresh water and soil	at ambient temperatures	- 0,10 to + 0,20	- 0,45	-
	Acid fresh water and soil	at ambient temperatures	- 0,10 to + 0,20	[c]	[c]
	Sea and brackish water	at ambient temperatures	- 0,10 to + 0,20	- 0,45	-
Ferritic or austenitic stainless steels with yield strength <800 N·mm^{-2} with ≥ 16% Cr	Neutral and alkaline fresh water and soil	at ambient temperatures	- 0,10 to + 0,20	- 0,20	-
Ferritic/martensitic stainless steels with yield strength >800 N·mm^{-2}	Water	at ambient temperatures	- 0,10 to + 0,20	- 0,45	[c]
Copper, cupronickel alloys	Water and soil		- 0,20 to ± 0,00	- 0,20	-
Lead	Water and soil		- 0,50 to - 0,40	- 0,65	- 0,95
Aluminium alloys [d]	Fresh water		- 0,70 to - 0,50	-0,80	-1,15[e]
	Sea and brackish water		- 0,80 to - 0,50	-0,90	-1,15[e]
Steel in concrete	Water and soil [f]		- 0,60 to - 0,10	- 0,75	[g]
Galvanized steel	Water and soil		- 1,10 to - 0,90	- 1,20	-

NOTE 1 All potentials are IR free and refer to a copper/saturated copper sulphate reference electrode, $E_{Cu} = E_H - 0,32$ V.

NOTE 2 During the lifetime of the structure any possible changes of resistivity of the medium around the structure are to be taken into account. For high strength steels there is a risk of hydrogen embrittlement when the potential is more negative than the start of hydrogen evolution.

[a] For temperatures 40°C ≤ T ≤ 60°C the protection potential may be interpolated.
[b] The risk of NaOH-induced stress corrosion cracking increases with increase of temperature.
[c] Protection potential should be determined by testing in each single case as well as the limiting critical potential for ferritic and martensitic stainless steels
[d] These values are only valid for aluminium alloys without Zn and Cu (e.g. AlMgSi-alloys). For all other aluminium alloys the protection potential may be different.
[e] Corrosion risk in stagnant conditions because of alkalinity caused by cathodic protection which dissolves the passive layer.
[f] For structures in the air in accordance with EN 12696
[g] Limiting critical potential should be determined by testing in each single case for pre- and post-tensioned steels with yield strength > 700 N·mm^{-2}. In any case, potentials lower than -1,1 V should be considered dangerous.

4.3 Influence of alternating current on cathodically protected structures

In the case of long term a.c. interference on metallic structures the possibility of corrosion induced by a.c. current needs to be taken into account (see annex A).

An exchange of alternating current is possible between the soil and the bare metal at coating defects on metallic structures. This applies particularly to carbon steel pipelines for which the level of a.c. interference can be significant in the proximity of high voltage electrical power lines, power stations, or traction systems.

In these conditions care should be taken in the choice of measurement equipment and methods as well as in the interpretation of the measurements on cathodically protected structures.

5 Prerequisites for application of cathodic protection

5.1 General

The adoption of cathodic protection depends on the size and shape of the structure, the type of coating, the aggressive action of soil and its resistivity, d.c. and a.c interference, national regulations, and also on the technical and economic criteria.

None of the recommendations in this standard shall have an adverse effect on the safe operation of the structure in question.

To achieve cathodic protection the following conditions shall be satisfied.

5.2 Electrical continuity

The structure, or a section of the whole structure, to be protected shall be electrically continuous. The continuity shall achieve a low longitudinal resistance and the components which may increase the longitudinal resistance of the structure shall be short-circuited e.g. by using cables with a suitable cross section area (see **7.11.3**).

5.3 Electrical isolation

In the case of coated structures to be protected it is essential that there are no metal contacts with parts of the structure not to be protected, or with other buried structures. Direct bonds with earthing systems should be avoided (see clause **7**). If this condition cannot be met, then it is required to properly design the cathodic protection system considering the structure as a complex structure.

5.4 External coating

The structures to be protected should normally be provided with a suitable external coating.

A good external coating reduces protection current demand (I_p), improves current distribution, extends the protected area and reduces interference to other foreign structures.

On structures which may be either bare or inadequately coated, cathodic protection shall be applied with care to avoid electrical interference.

6 Base data for design

6.1 General

Effective design of cathodic protection systems is highly dependent upon correct information concerning the proposed structure to be protected. Structure details, service conditions and design lifetime are necessary to establish the correct method of protection and the correct materials to achieve and sustain cathodic protection.

6.2 Structure details

The surface area of the structure shall be ascertained either by calculation from dimensional drawings, or by advice from the manufacturer of the structure.

Details of neighbouring buried or immersed structures should be obtained.

Such information may include the following items :

- location (e.g. map, site layout);
- principal dimensions and characteristics;
- cathodic protection details;
- coating details;
- date of construction.

Such information will help in the design of methods to prevent adverse effects to the structure to be protected and to neighbouring structures.

6.3 Coating

Details of the coating characteristics before and after installation, the average coating resistance or the protective current requirements shall be taken into consideration

The average coating resistance may be determined by the method described in prEN 13509:1999.

6.4 Environment

Environmental conditions will have a major impact on the application of cathodic protection and shall be fully considered during the design phase.

The following environmental conditions should be taken into account:

- electrolyte resistivities at suitable depths and locations;
- particular soil conditions (e.g. ground frost depth);
- possibility of electrical influence (a.c. or d.c.);
- anaerobic conditions and probability of sulphate reducing bacteria activity.

In the case of new constructions it should be borne in mind that the stray current interference may change when the structure is completed.

6.5 Pipelines specific data

6.5.1 Special considerations also need to be taken into account for buried widely dispersed structures and particularly pipelines since they may encounter a wide variety of conditions.

6.5.2 For new pipelines, or extensions to existing pipelines, maps and descriptions of the entire pipeline route should be prepared which should clearly indicate the following items :

- topographical details;
- elevations;
- high voltage overhead power lines;
- known buried cables and structures, including other pipelines;
- details of any known neighbouring cathodic protection systems;
- valves and regulating stations;
- river crossings;
- road and railway crossings;
- sleeve pipes that will remain after construction;
- types of bedding material;
- length, diameter, wall thickness and type of pipe connections;
- factory and field applied coatings;
- bridge suspensions;

- isolating joints;
- characteristics of a.c. and d.c. traction systems (e.g. sub-stations, operating voltages and polarities);
- characteristics of d.c; industrial plants
- any electrically operated equipment (e.g. emergency shut down valves);
- any earthing systems or earthed systems;
- any telemetry systems;
- details of the medium to be transported.

6.5.3 For existing pipelines the design may be undertaken using the information from 6.5.2 in conjunction with field tests.

In the case of some pipelines the only meaningful data that can be collected may be restricted to soil resistivities, soil analysis, stray current measurements, and the results obtained from a temporary impressed current cathodic protection system.

7 Design and prerequisites

7.1 General

In order to design a cathodic protection system the prerequisites described in 7.2 to 7.13 should also be taken into account.

7.2 Electrical isolation

Structures to be protected shall be isolated from foreign structures by suitable devices such as isolating joints. In the case of pipelines, for example, foreign structures may include compressor, pressure reducing and delivery stations, and domestic installations.

Isolating joints may also be installed, after proper design, to divide the system into sections, e.g. in stray current areas. In the case of distribution systems they shall be installed in all service pipes.

Isolating joints shall be designed to withstand service conditions (e.g. medium, temperature, pressure) and need to have a high dielectric strength and electrical resistance.
In underground pipelines they shall be coated with materials compatible with the coating applied to the structure. In all cases, the design and the installation shall be such that accidental bonding is avoided.

To avoid damage to isolating joints resulting from high voltage due to lightning or earth currents caused by electric power lines, installing protective devices (e.g. appropriate spark gap) should be considered.

If an isolating joint is to be installed in areas classified as hazardous in accordance with EN 60079-10, it is essential that it conforms to the certification and operational requirements of the zone.

In the case of pipelines carrying electrolytic solutions, there is a risk of internal corrosion on the unprotected side of isolating joints. This is mainly dependent on the conductivity rather than on the corrosiveness of the liquid.
For corrosion protection, the pipeline on the cathodically protected side of an isolating joint should be lined with an electrically isolating material.
The length of the section to be coated internally increases with increasing electrolyte conductivity, increasing pipeline diameter and decreasing polarisation resistance of the pipe material and electrolyte solution. If empirical values are not available, the length of pipeline to be coated internally should be determined by tests. The coating should be of a type which does not deteriorate in contact with internal aqueous media, especially in the case of coating exposed to salt water.
Alternatively, cathodic protection may be applied inside the pipe.

7.3 Test stations

Installation of test stations should be considered for the measurement of structure-to-electrolyte potentials, currents and resistances.

In the case of pipelines, it is sufficient to install test stations at suitable intervals, preferably not more than 3 km apart, along the pipeline route. Where necessary, test stations may be equipped for line current measurements in accordance with prEN 13509:1999. In built-up areas, test station spacing should be reduced to less than 1 km. Installation of test stations shall be considered in the following situations:

- crossing with traction systems;
- crossings with other buried pipelines or cables;
- parallelisms with other buried pipelines or cables;
- metal sleeve pipes;
- isolating joints;
- large road and embankment (dyke) crossings;
- river crossings;
- bond connections;
- connections with coupons, earthings and earthed systems.

In special cases, e.g. under tarmac surfaces, test stations may be provided with extra equipment, e.g. a permanent reference electrode, an external potential test probe.

7.4 Bonding

Low-resistance metal bonds should be provided across components which may increase the longitudinal resistance of the structure.

7.5 Buried sleeve pipes for pipelines

7.5.1 *General*

Sleeve pipes may have a detrimental impact on the cathodic protection of the carrier pipes. The use of sleeve pipes should therefore be avoided where possible.

In every case the carrier pipe inside the sleeve should have a high quality coating for protection against corrosion.

Where the use of sleeve pipes is unavoidable, isolating spacers should be installed and the annular space between the carrier pipe and the sleeve pipe should be sealed at the ends of the sleeve pipe. In practice it is almost impossible to achieve a water-tight seal.

The corrosion prevention measures to be taken for different types of sleeve pipe are described in **7.5.2 and 7.5.3.**

7.5.2 *Sleeve pipes that shield cathodic protection current*

Sleeve pipes that shield cathodic protection current include plastic, coated concrete, and coated steel sleeve pipes.
External corrosion protection of the carrier pipe inside the sleeve is often achieved by the use of galvanic anodes or by filling the annular space with appropriate material with adequate long-term corrosion protection properties.

7.5.3 *Sleeve pipes that pass cathodic protection current*

Sleeve pipes that pass cathodic protection current include bare or poorly coated steel pipes and uncoated concrete pipes that are sufficiently conductive.
In these cases, the external cathodic protection of the carrier pipe may be effective in protecting the carrier pipe inside the sleeve provided there is no contact between the carrier pipe and the sleeve

pipe, and there is an electrolyte in the annular space. Without any electrolyte in the annular space, there is only a risk of atmospheric corrosion.

7.6 Wall entries, restraints, saddles and anchors for pipelines

Where entries, restraints, saddles and anchors are made of concrete, it is necessary that there is no metallic contact between reinforcing steel and the protected structure. For this reason, an adequate wall entry fitting made of insulating material should be provided and a high-quality coating should be applied to the protected structure. In other cases, the structure shall be considered as a complex structure.

7.7 Bridges

Near the conductors of electric traction systems, adequate measures shall be taken to prevent an inadmissible touch voltage.

In the case of pipelines one of the following measures should be taken as appropriate:

a) *Pipes equipped with above ground isolating joints at each end of the bridge*
The section of the pipe which runs on the bridge shall be connected to the metallic parts of the bridge. If necessary, the cathodic protection continuity of the pipeline should be assured by an equipotential bond.

b) *Pipes without isolating joint*
The pipe shall be isolated from the metallic parts of the bridge.

7.8 Electrically operated equipment

When the protective earth is connected to electrically operated equipment, e.g. valves or pumps on buried tanks, the resistance to earth is decreased at these points, impeding or preventing cathodic protection.

In order to prevent shock hazards and at the same time maintain effective cathodic protection, one of the measures listed below shall be taken in accordance with national relevant safety standards:

a) isolation of the electrically operated equipment from the protected structure;
b) isolation of the part of the pipeline (e.g. the valve) connected with the electrical operated equipment from the rest of the pipeline by means of isolating joints. Install a continuity bond between the two parts of the pipeline. Provide corrosion protection to the valve;
c) installation of isolation transformers;
d) installation of fault current circuit breaker in conjunction with a local earthing system made of galvanised steel, zinc or magnesium;
e) if permitted by national safety regulations, install d.c. decoupling devices between the electrically operated equipment and the general earthing system.

7.9 Lightning protection

Cathodically protected structures shall only be connected to a lightning protection system or to a structure itself bonded with this system through a suitable device (e.g. spark gap).

7.10 Equipment for the reduction of a.c. interference

There are two basic types of a.c. interference on buried structures:

a) short term interference caused by a.c. high voltage power line failure and operational changes (ohmic and inductive effects);
b) long term interference caused by induction during operation (inductive effect).

Mitigation of these effects may require the addition of earthing systems. These earthing systems may be constructed using a wide variety of electrodes (e.g. galvanised steel, zinc, magnesium) and some earthing systems will have an adverse effect on the effectiveness of the cathodic protection.

To avoid adverse effects on the cathodic protection, any additional earthing systems are connected to the structure via appropriate devices (e.g. spark gaps, d.c. decoupling devices).

7.11 Cathodic protection systems

7.11.1 *Impressed current stations*

7.11.1.1 *General - site selection*

Impressed current installations mainly consist of the following items :

- transformer rectifier units or other d.c. power supply units;
- groundbeds.

The site for the installation of impressed current systems should be selected taking due account of the following factors:

- availability of low-voltage power supply;
- level of protective current requirement;
- lowest possible soil resistivity in the area of the groundbed;
- minimum impact on third party interests;
- good access to installations;
- sufficient distance between groundbeds and foreign installations to minimise interference;
- sufficient distance between groundbeds and the structure to be protected;
- hazardous areas.

It is strongly recommended that impressed current installations are set up outside hazardous areas. If in exceptional cases this is not possible, these installations shall meet the requirements of EN 60079-14.

In order to protect against accidental contact with components which carry voltage when in operation and for protection from unduly high contact voltages (above 50 V) which may persist in the event of a fault, precautionary measures should be taken.

7.11.1.2 *Protective housings*

Protective housings ensure adequate protection from the expected external influences, such as moisture, dust, wind pressure, shock and ingress of foreign matter, provide adequate ventilation for the dissipation of waste heat. Protective housings shall be lockable and should if possible, be provided with the following items:

- means of fitting a connection box;
- means of fitting an electricity board with adequate safety devices and sockets;
- means of fitting a transformer rectifier unit or other power supply units;
- means of connecting and identifying cables.

7.11.1.3 *Transformer rectifier units, or other power supply units*

Transformer rectifier units or other power supply units are specified for each application. The specification should take into account the following items :

- connection to incoming a.c. supply;
- type of rectification;
- measuring devices, e.g. voltmeter, ammeter;
- output control;
- removable link to allow insertion of cyclical switch;
- appropriate electrical and safety requirements;
- protection measures against possible high voltage interference;
- a.c. content of d.c. output (ripple factor);
- identification and rating plate details;
- environmental protection (e.g. IP rating).

7.11.1.4 *Impressed current groundbeds*

Groundbeds for impressed current installations may be either of the following types :
- shallow type; or
- deep type.

They consist of one or more impressed current anodes. The materials commonly used are the following :
- silicon iron alloy;
- graphite;
- metallic oxides;
- conductive polymers;
- steel.

The connection between the cable and the anode head shall be insulated with particular care to prevent penetration of moisture and hence corrosion damage.

The insulating materials used shall have long-term resistance to the chemical and physical effects of the electrolyte. At the anode head, the cable shall be protected against kicking. The anodes should be provided with suitable backfill. Groundbeds should generally be laid in low resistivity soils. Venting should be considered for shallow groundbeds with high current output and for deep groundbeds.

The environmental impact of dissolving anodes and backfill should be taken into account in the choice of materials for anodes and backfill

7.11.2 ***Galvanic anode stations***

As a rule, galvanic anodes can only be used economically for structures with a small protection current requirement (Ip) and for low soil resistivities. They are also suitable whenever a power supply does not exist or can be provided only at uneconomical costs.

Suitable materials for anodes in soil and fresh water are primarily magnesium and zinc. In brackish water zinc and aluminium alloys are considered as suitable. To keep the current output as constant as possible and obtain a low ground resistance, galvanic anodes shall be installed in a suitable low resistivity non-carbonaceous backfill.

In order to enable the measurement of off potentials and anode current, galvanic anodes shall be connected via a test station. As a general rule galvanic anodes are not suitable for use in areas with d.c. interference and/or continuous a.c. interference.

The environmental impact of dissolving anodes and backfill should be taken into account in the choice of materials for anodes and backfill.

7.11.3 ***Cables***

The cable insulation shall be selected to meet requirements imposed by the environment for instance for buried or immersed conditions.

Cables fit for buried service shall be used for the connection of protected structures, impressed current anodes, galvanic anodes and test stations. Such cables should not have a metal armouring. Conductors marked for use as a protective earth conductor shall only be used for that purpose.

Cable cross sections are determined on the basis of the following criteria :
- voltage drops which are technically admissible;
- mechanical strength;
- economics.

The total cross sections of any cables used shall not be less than those specified below:

a) Impressed current systems
   - cable to protected structure: 10 mm² Cu;
   - cable to groundbed: 4 × 2,5 mm² Cu or 10 mm² Cu.

b) Galvanic anode systems
   - cable to protected structure: 4 mm² Cu;
   - cable to single anode: 2,5 mm² Cu.

c) Other installations
   - cable for potential measurement: 2 × 2,5 mm² Cu or 6 mm² Cu;
   - cable for current span measurements: 4 × 2,5 mm² Cu;
   - cable for continuity bond: 4 × 2,5 mm² Cu or 10 mm² Cu.

Separate connections are required to the structure for each core or cable with a separate function.

7.12 Drainage stations

A drainage station comprises the equipment and materials to provide drainage of stray currents from the affected structure towards the stray current d.c. source. Drainage stations may be considered at the time of design, but in general their necessity and specification are determined only at the time of the commissioning and during the life time of the cathodic protection system.

7.13 Design and design documents

Design is achieved in accordance with the following criteria:
- prerequisite for application of cathodic protection;
- base data for design;
- design prerequisites.

Design documents should be prepared in sufficient details to satisfy the requirements of design verification, installation procedures and future inspection.

Design may also consider temporary measures to prevent corrosion during the construction of the structure and until the commissioning of the permanent cathodic protection system.

Temporary cathodic protection can be achieved by either of the following methods:
- the application of separate temporary systems (usually galvanic anodes); or
- the activation of parts of the permanent CP system.

8 Installation of cathodic protection systems

8.1 General

This chapter concerns the main aspects that should be considered during the installation of cathodic protection components.

The other equipment determined by the design, such as isolating joints and sleeves, are integral parts of the structure and are therefore installed at the same time as the main structure to be protected.

Usually the installation work is undertaken, as soon as possible, after the completion of the main structure. In particular cases, temporary cathodic protection systems should be installed and activated (see **9.3**).

As a general rule, the following points shall be considered:

a) Before the beginning of the work, it shall be verified that:
   - the equipment and the materials to be installed are in conformity with those indicated in the design;

- the local conditions are the same as those used for the design.

b) During the work, it is necessary to verify that the installation and materials are in conformity with the appropriate regulations, including safety.

c) Deviations from the design shall be justified for approval, then documented and later reported on as-built documentation.

8.2 Cables

Cable installations are to be carried out in accordance with the appropriate electrical and safety regulations and to the text of **7.11.3**.

Cables used for potential measurement should be separate from those carrying current to avoid errors due to voltage drop.

In all cathodic protection installations, cables shall be installed with great care to avoid damage to the insulation. It is preferable to place them within protective sleeves or to protect them with a sufficient coverage and warning tapes.

The method used to connect the cable to the structure shall ensure that:

- the mechanical properties of the structure are not adversely affected;
- the mechanical and electrical characteristics of the connection are suitable for the intended purpose;
- all coating repairs are carefully carried out to ensure that the performance of the coating is not impaired.

As far as possible cable joints should be avoided. Buried and immersed cable joints should be suitable for permanent burial or immersion.

8.3 Galvanic anodes

At the time of installation of galvanic anodes checks should be carried out to ascertain, by reference to the design file (plans, specifications and procedures) whether or not the following points are covered:

- the electrolyte condition and resistivity where the anodes are to be located corresponds to the design;
- there is no isolating shielding between the anode and the structure to be protected;
- if there is any risk of interference, corrective measures have been taken ;
- anodes conform to the specifications;
- for buried anodes the anode backfill material used is of the correct type for the anodes concerned, and that the homogeneous backfill mixture is evenly distributed around the anode (minimum 50 mm);
- the prepackaged anodes have been thoroughly wetted before burial;
- the electrical circuit between the anode and the structure has been left open at the test station until the commissioning (see clause **9**).

8.4 Impressed current systems

8.4.1 *General*

At the time of installation checks should be carried out to ascertain, by reference to the design file (plans, specifications and procedures) whether or not the following points are covered:

- the electrolyte condition and resistivity where the anodes are to be placed correspond to the design;
- there is no isolating shielding between the anodes and the structure to be protected;
- there is no risk of interference to other buried or immersed metal structures from the anodes, or that if there is a risk corrective measures have been taken.

8.4.2 *Impressed current stations*

Impressed current stations should be located where they are easily assessible and where they are protected against environmental damage, electrical damage and vandalism.

The installation shall be carried out in accordance with the national appropriate electrical and safety regulations. In particular, attention is drawn to the following recommendations:
- location of the station outside hazardous areas or alternatively by installing suitable safety devices (e.g.flameproof materials, pressurised enclosures);
- the earthing of all metal components of the impressed current station that are not subject to electrical power.

For an automatically controlled impressed current station, the location of the sensing electrode shall be carefully selected and recorded.

The following labels should be on the housing:
- safety signs concerning the dangers of electricity;
- identification signs concerning the owner/operator and the installation.

8.4.3 *Groundbed*

The dimensions of the anodic mass should be checked to see if they correspond to those indicated in the design. The backfill, if any, should be checked to verify if it is suitable and that it has been correctly prepared. It is particularly important to check that the backfill is both sufficient in quantity and homogeneous, and meets the requirements of the project specification.

8.4.4 *Cables to groundbed*

The integrity of the insulation of the cable connection between the groundbed (or an element of the groundbed) and the impressed current station is essential. If not, moisture ingress and subsequent, oxidation of the conductor can lead to the premature failure of the groundbed.

The electrical circuit between the groundbed and the structure, through the transformer rectifier, should be left open at the transformer rectifier until the commissioning period (see clause 9).

8.5 Test stations

Test stations should be located in easily accessible places, protected against risk of damage (falling rocks, shocks) and set up in such a way as to make them easy to find. They should be outside hazardous areas in order to avoid any risk due to sparking. If a test station is to be installed in areas classified as hazardous in accordance with EN 60079-10, it shall conform to the certification and operational requirements of the zone.

8.6 Drainage stations

The drainage stations should be located in an easily accessible place and be protected against environmental damage.

For personnel safety, drainage stations shall be placed in areas of permitted access.

The cable connection to the traction system is the responsibility of the traction system operator.

8.7 As built documentation

Electrical and installation drawings shall be made for all cathodic protection components.

9 Commissioning

9.1 Preliminary checking

When temporary cathodic protection has been used, the system shall be switched off before the commissioning.

Before a cathodic protection system is activated, care should be taken to check that all installations are in accordance with the design. In particular, cable connections and safety measures (contact protection, lightning protection, explosion proofing) where necessary shall be checked.
D.c. connections to the transformer rectifier shall be checked for correct polarity.

Further, the following measurements may be made and readings compared with the design requirements:

a) Resistance measurements
   - resistance against remote earth of the groundbed or the galvanic anode;
   - resistance between the structure to be protected and the groundbed.

b) Electrical isolation of the structure
   - at isolating joints;
   - at metal sleeve pipes.

c) Potential measurements
   - free corrosion potential E_n of the structure;
   - interference due to suspected stray currents;
   - anode to electrolyte potential of galvanic anodes;
   - structure to electrolyte potential of nearby structures.

9.2 Start up

a) Switch on the impressed current station and confirm that it is functioning correctly.

b) Adjust station settings to conform to the potential design requirements. If major deviations occur, the causes should be ascertained by measurements.

c) When necessary, connect galvanic anodes to the protected structure via a variable resistor for current limitation.

d) Next make the following measurements:
   - rectifier output voltage on impressed current station;
   - protective current output;
   - on potential at drain point (outside the anode voltage cone);
   - on potential at the extremities of the parts of the structure protected by each rectifier;
   - on potentials and current requirements of foreign electrodes ;
   - possible a.c (see annex A). or d.c. interference.

e) If stray currents are present, make measurements to determine the interference level in order to achieve the effectiveness of cathodic protection. These measurements shall be made with and without the cathodic protection stations in operation.

9.3 Verification of the cathodic protection effectiveness

Once the protected structure has sufficient ground contact and after a suitable polarisation period, the effectiveness of cathodic protection needs to be checked in accordance with prEN 13509:1999.

9.4 Installation and commissioning documents

After the successful commissioning of the cathodic protection installations, the following documents shall be prepared:

a) as built layout drawings of the structure including neighbouring structures that are relevant to the cathodic protection;
b) cathodic protection design with as built installation drawings and all details pertaining to the cathodic protection of the structure;
c) results of interference tests carried out on neighbouring installations;
d) details of equipment operation and adjustment and the results of all measurements carried out before and after commissioning;
e) description of the installations with details and references to materials as well as all information useful for the correct operation and maintenance of the installations e.g. frequency of system checks.

The final data are the basis for subsequent system checks to be performed on the structure and therefore need to be filed and retained.

10 Inspection and maintenance

10.1 General

The aim of inspection and maintenance is to ensure the effectiveness of cathodic protection throughout the life of a structure. For this to be achieved, the required structure to electrolyte potential shall be maintained, which generally requires continuous operation of the cathodic protection system.

Subsequent to commissioning (see clause 9), regular inspection is necessary to approved procedures, appropriate to the type of structure and its cathodic protection system. The procedures should be subject to review to reflect operating experience and new technology.

Record systems for both operation and maintenance are essential. Manual systems may be acceptable for some data, but for large volumes of data, computer based systems are preferred.

Procedures for maintaining the accuracy and safety of measuring equipment and instrumentation are also necessary.

10.2 Factors influencing inspection frequency

10.2.1 *Structure environment*

The following factors influence inspection frequency:

- corrosive nature of the electrolyte (soil or water);
- susceptibility of structure to mechanical damage;
- d.c. or a.c. interference currents;
- susceptibility of cathodic protection installations to damage by lightning or mechanical means;
- risks associated with the contents of a containing structure (e.g. buried fuel tank).

10.2.2 *Structure design*

The following factors influence inspection frequency:

- extent and complexity of structure;
- constructional features critical to maintaining effective cathodic protection (e.g. sleeve pipes on pipelines);
- quality and type of applied protective coating.

10.2.3 ***Cathodic protection system design***

The following factors influence inspection frequency:

In case of galvanic anode:

- directly attached e.g. welded fixings to jetty piles or connected via cables e.g. magnesium alloy anodes on urban pipelines;

In case of impressed current :

- power supply method e.g. transformer rectifier, solar panel, wind powered or thermo electric generator and whether control is manual or automatic;
- data collection method;
- automated via a communication system or manually recorded e.g. measurements at test stations by technicians entered onto record sheets or portable data logger.

10.3 Inspection

10.3.1 ***General***

The inspection of the effectiveness of an applied cathodic protection system can be conveniently divided into two areas: equipment checks and structure measurements.

The procedures used and the results obtained shall be reviewed and approved by cathodic protection personnel with adequate theoretical and practical knowledge.

Examples of measurements that should be undertaken by adequately qualified cathodic protection personnel are structure to electrolyte potentials, functional checks of the applied cathodic protection, and functional checks of drainage equipment.

Examples of equipment checks are transformer rectifier visual observations, transformer rectifier metered outputs, and test station mechanical integrity.

10.3.2 ***Implementation of inspection***

In general, the effectiveness of cathodic protection is assessed by comparing actual measurement values with reference values or protection criteria. Measured values established at cathodic protection stations and test points in line with state of the art at the time of commissioning as well as in subsequent years are used as reference values.
If there are indications that cathodic protection is not fully effective throughout the structure, investigations should be carried out and appropriate corrective action taken to restore the effectiveness of cathodic protection. The measured values established from this exercise are then be used as the new reference values.

10.3.3 ***Inspection procedures***

Specific procedures may be defined in an operating manual or laid down by statutory regulations.

10.3.3.1 *Inspection of cathodic protection system*

Unless telemetric methods are used and regularly verified, functional checks (e.g. voltage and current readings) should be carried out at the typical frequencies described in Table 2.

Table 2 — Frequency of functional checks

Functional check	Frequency
Galvanic anode stations	Annually or more frequently if required by operational conditions
Impressed current station	Every 3 months or more frequently if required by operational conditions
Drainage stations	Every month or more frequently if stray current is severe
Connections to foreign structures	Annually or more frequently if required by operational conditions
d.c. decoupling devices and earthing systems	Annually or more frequenlty if required by operational conditions
Safety and protection devices	Annually or more frequently if required by operational conditions
Test stations	Annually at selected locations and every three years at all locations (see **10.3.3.2**)

In the case of pipelines, local or general inspection of the cathodic protection system may also be achieved by using "over the line" survey techniques.

10.3.3.2 *Cathodic protection measurements*

a) Potential measurements
For proving the effectiveness of cathodic protection, a structure to electrolyte potential in accordance with Table 1 shall be achieved. The methods of measurement of the structure to electrolyte potential are described in prEN 13509:1999.

1) *For general assessment of cathodic protection,* on potential measurement is usual, and carried out annually.
   Dependent on the type of structure, all or selected test stations may be measured. Selected test stations could be those at the limits of the structure e.g. isolating joints, test stations where the least negative potentials were measured during commissioning, critical points or those shown to be representative of the cathodic protection system. Test stations associated with foreign structures should be included, so that any changes may be detected.

2) *For detailed and comprehensive assessment of the effectiveness of cathodic protection*, the measurement methods adopted shall be appropriate to the structure.

   For structures not significantly affected by stray current, possible measurement methods include off potentials and test probe or coupon potentials, carried out typically every 3 years, preferably at all test stations (see prEN 13509:1999).

   Where stray currents are significant, on potential measurements of the structure over a sufficient period of time and external test probe measurements may be required (see prEN 13509:1999).
   Detailed investigations to prove the effectiveness of cathodic protection should also be carried out in the following circumstances:
   - after foreign construction work in the area of the coated structure, if any damage to the protective coating or metallic contact is suspected;
   - in the event of any indications of structure movement e.g. in areas of subsidence or changes in operating conditions;
   - any other changes to the structure environment;
   - in cases of a.c. interference;
   - when there are long term changes to the electrical interference.

b) *Current measurements*
Using suitable external meters (see prEN 13509:1999) current measurements for galvanic anodes, impressed current stations, bonds, drainage stations, and line currents in pipelines are necessary to establish whether or not significant changes have occurred.

10.3.3.3 *Remote control*

Functional checks :
If the cathodic protection system is monitored by remote control, such that equipment malfunctions can be immediately detected, then the frequency of functional checks laid out in Table 2 do not apply.

Effectiveness of cathodic protection :
it is possible to have a better overview of the cathodic protection system if the effectiveness of cathodic protection is monitored by remote control. In this case potential and current measurements may be performed on demand, automatically at pre-set intervals, or when an alarm condition exists.

10.4 Maintenance

10.4.1 *Cathodic Protection equipment*

Maintenance on impressed current and drainage stations is recommended to be carried out annually.
When functional or visual checks indicate that it is necessary, maintenance on test stations shall be carried out.
Electrical safety has to be checked in accordance with national regulations.

10.4.2 *Instrumentation*

Instrumentation used for measurements shall be kept in good working order and shall be subjected to periodical calibration and safety checks.

10.5 Results of inspection

The results of inspection work shall be recorded and evaluated. These records should be kept for the lifetime of the structure, but always for a sufficient period to provide detailed information on the cathodic protection effectiveness and to allow comparative checks to be carried out. In addition, it is recommended that a cathodic protection history should be maintained for reference purposes.

Annex A (informative)

a.c. interference

At the time of publication, the corrosion mechanism in the presence of alternating current interference is not fully understood. Nevertheless, the following points represent the best available knowledge to assess the risk of corrosion induced by alternating current on carbon steel structures and to perform measurements.

a) Structure to electrolyte potential measurements should be performed using suitable equipment to ensure that potential criteria of Table 1 are met in the presence of a.c. current on the structure.

b) Corrosion likelihood may be negligible if alternating current density referred to a 1 cm^2 bare surface (e.g. an external test probe) is lower than 30 A/m^2 and the structure to electrolyte potential meets the cathodic protection criteria.

c) On cathodically protected structures and in the presence of alternating current the protection current density may need to be higher to meet the protection potential.

d) Structures with a small number of small holidays may present a higher risk of corrosion due to alternating current.

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