INTERNATIONAL STANDARD

ISO 15589-2

First edition
2004-05-01

Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems —

Part 2: Offshore pipelines

Industries du pétrole et du gaz naturel — Protection cathodique des systèmes de transport par conduites —

Partie 2: Conduites en mer

Reference number
ISO 15589-2:2004(E)

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 15589-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

ISO 15589 consists of the following parts, under the general title *Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems*:

— *Part 1: On-land pipelines*

— *Part 2: Offshore pipelines*

Introduction

Pipeline cathodic protection is achieved by the supply of sufficient direct current to the external pipe surface, so that the steel-to-electrolyte potential is lowered to values at which external corrosion is reduced to an insignificant rate.

Cathodic protection is normally used in combination with a suitable protective coating system to protect the external surfaces of steel pipelines from corrosion.

External corrosion control in general is covered by ISO 13623.

Users of this part of ISO 15589 should be aware that further or differing requirements may be needed for individual applications. This part of ISO 15589 is not intended to inhibit alternative equipment or engineering solutions to be used for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, any variations from this part of ISO 15589 should be identified.

Deviations from this part of ISO 15589 may be warranted in specific situations, provided it is demonstrated that the objectives expressed in this part of ISO 15589 have been achieved.

Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems —

Part 2:
Offshore pipelines

1 Scope

This part of ISO 15589 specifies requirements and gives recommendations for the pre-installation surveys, design, materials, equipment, fabrication, installation, commissioning, operation, inspection and maintenance of cathodic protection systems for offshore pipelines for the petroleum and natural gas industries as defined in ISO 13623.

This part of ISO 15589 is applicable to carbon and stainless steel pipelines in offshore service.

This part of ISO 15589 is applicable to retrofits, modifications and repairs made to existing pipeline systems.

This part of ISO 15589 is applicable to all types of seawater and seabed environments encountered in submerged conditions and on risers up to mean water level.

NOTE Special conditions sometimes exist where cathodic protection is ineffective or only partially effective. Such conditions can include elevated temperatures, disbonded coatings, thermal insulating coatings, shielding, bacterial attack, and unusual contaminants in the electrolyte.

2 Normative references

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

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

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

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 10474:1991, *Steel and steel products — Inspection documents*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 15589-1, *Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems — Part 1: On-land pipelines*

ASTM D 1141[1)], *Standard practice for the preparation of substitute ocean water*

1) American Society for Testing and Materials, 100 Barr Harbour Drive, West Conshohocken, PA 19428-2959, USA.

AWS D1.1/D1.1M[2)], *Structural Welding Code — Steel*

EN 287-1[3)], *Approval testing of welders — Fusion welding — Part 1: Steels*

EN 288-1, *Specification and qualification of welding procedures for metallic materials — Part 1: General rules for fusion welding*

3 Terms and definitions

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

3.1
anode potential
anode-to-electrolyte potential

3.2
closed-circuit anode potential
anode potential while electrically linked to the pipeline to be protected

3.3
coating breakdown factor
f_c
ratio of current density required to polarize a coated steel surface as compared to a bare steel surface

3.4
cold shut
horizontal surface discontinuity caused by solidification of the meniscus of the partially cast anodes as a result of interrupted flow of the casting stream

3.5
electric field gradient
change in electrical potential per unit distance through a conductive medium, arising from the flow of electric current

3.6
electrochemical capacity
ε
total amount of electricity that is produced when a fixed mass (usually 1 kg) of anode material is consumed electrochemically

NOTE It is expressed in ampere hours.

3.7
final current density
estimated current density at the end of the lifetime of the pipeline

3.8
IR drop
voltage, due to any current, developed between two points in the metallic path or in the lateral gradient in an electrolyte such as seawater or seabed, measured between a reference electrode and the metal of the pipe, in accordance with Ohm's Law

cf. **electric field gradient** (3.5)

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2) The American Welding Society, 550 NW Le Jeune Road, Miami, FL 33126, USA.

3) The European Committee for Standardization, Management Centre, Rue de Stassart, B-1050, Brussels, Belgium.

3.9
mean current density
estimated average cathodic current density for the entire lifetime of the pipeline

NOTE It is expressed in amperes per square metre.

3.10
protection potential
structure-to-electrolyte potential for which the metal corrosion rate is insignificant

3.11
remotely operated vehicle
ROV
underwater vehicle operated remotely from a surface vessel or installation

[ISO 14723]

3.12
riser
that part of an offshore pipeline, including any subsea spool pieces, which extends from the seabed to the pipeline termination point on an offshore installation

[ISO 13623]

3.13
utilization factor
u
fraction of the anodic material that can be used in the cathodic protection process

4 Symbols and abbreviated terms

CE carbon equivalent

CP cathodic protection

N_{PRE} pitting resistance equivalent number

ROV remotely operated vehicle

SCE calomel reference electrode

σ_{SMY} specified minimum yield strength

5 CP system requirements

5.1 General

The main objectives and requirements of CP systems are to

— prevent external corrosion over the design life of the pipeline,

— provide sufficient current to the pipeline to be protected and distribute this current so that the selected criteria for CP are effectively attained,

— provide a design life of the anode system commensurate with the required life of the protected pipeline, or to provide for periodic rehabilitation of the anode system,

— provide adequate allowance for anticipated changes in current requirements with time,

- install anodes where the possibility of disturbance or damage is minimal,
- provide adequate monitoring facilities to test and evaluate the system performance.

Design, fabrication, installation, operation and maintenance of CP systems for offshore pipelines shall be carried out by experienced and qualified personnel.

The CP system shall be designed with due regard to environmental conditions, neighbouring structures and other activities.

Offshore pipelines that are protected by galvanic anode systems should be electrically isolated from other pipelines and structures that are protected by impressed-current systems. Offshore pipelines shall be isolated from other unprotected or less protected structures, which could drain current from the pipeline's CP system. If isolation is not practical or stray current problems are suspected, electrical continuity should be ensured.

Care shall be taken to ensure that different CP systems of adjacent pipelines or structures are compatible and that no excessive current drains from one system into an adjacent system.

The pipeline CP design shall take into account the pipeline installation method, the types of pipeline and riser and the burial and stabilization methods proposed (see Annex F).

The CP system shall be designed for the lifetime of the installation using the calculation procedure given in Annex A. In the design calculation, data given in Clause 6 of this part of ISO 15589 shall be used.

For areas with high water velocities and areas with erosion effects from entrained sand, silt, ice particles, etc., the design of the CP system needs special attention and additional design criteria shall be considered.

Installation of permanent test facilities should be considered taking into account specific parameters such as pipeline length, water depth and underwater access related to the burial conditions.

For the cathodic protection of short lengths of submarine pipelines and their branches that are directly connected to cathodically protected onshore pipelines, ISO 15589-1 shall be used.

5.2 Selection of CP systems

5.2.1 General

CP can be achieved using either galvanic anodes or an impressed-current system. Clause 6 covers the design parameters to be used for both systems. An overview of these systems and items to be considered in selecting the system to be used are covered in 5.2.2 to 5.2.5.

5.2.2 Distributed galvanic anode systems

Galvanic anodes are connected to the pipe, either individually or in groups. They are limited in current output by the anode-to-pipe driving voltage and the electrolyte resistivity. Generally, anodes are attached directly to the pipe as bracelets. Sleds of anodes can also be placed at regular intervals along the pipeline.

5.2.3 Galvanic anode systems installed at ends of pipeline

Shorter pipelines can be protected by anodes located at each end. Typically, this type of installation is used on inter-platform pipelines. Anodes for the pipeline can be attached to the platform if the pipeline is electrically connected to the platform.

5.2.4 Impressed-current anode systems

Impressed-current anodes can be of materials such as graphite, high-silicon cast iron, lead-silver alloy, precious metals or steel. They are connected with an insulated cable, either individually or in groups, to the positive terminal of a direct-current source, such as a rectifier or generator. The pipeline is connected to the negative terminal of the direct-current source.

5.2.5 System selection considerations

Selection of the CP system shall be based on the following considerations:

- impressed-current system can protect a length of pipeline, depending on
  - practical limitations on the locations for impressed-current anode and rectifier installations, e.g. at either one or both ends of the pipeline, such as at landfalls and platforms,
  - insulation resistance of the coated pipeline to the surrounding electrolyte at end of design life,
  - longitudinal resistance of the pipeline;
- impressed-current systems can be more practical in high resistivity waters (e.g. large estuaries and brackish water bays);
- lack of a source of external power can preclude the use of impressed-current systems;
- galvanic anode systems require minimal control and maintenance during the service life of the pipeline, whereas impressed-current systems require regular control and maintenance;
- galvanic anode systems seldom cause serious interference problems on foreign neighbouring structures, whereas impressed-current systems can have a significant effect;
- magnitude of the protective current required;
- existence of any stray currents causing significant potential fluctuations between pipeline and earth that can preclude use of galvanic anodes;
- effects of any CP interference currents on adjacent structures that might limit the use of impressed-current CP systems;
- limitations on the space available, due to the proximity of foreign structures, and related construction and maintenance concerns;
- future development of the area and any anticipated future extensions to the pipeline system;
- cost of installation, operation and maintenance;
- reliability of the overall system;
- galvanic anode systems have shown reliable performance for long-term protection;
- impressed-current systems located offshore are capable of providing long-term protection but are less tolerant to design, installation and maintenance shortcomings than galvanic anode systems. Good service can be expected if proper attention is paid to mechanical strength, connections, cable protection (particularly in the wave or splash zone), choice of anode type and integrity of power source. Adequate system monitoring should be provided;
- impressed-current systems may be preferred on short pipelines which terminate at platforms that have impressed-current systems installed;
- impressed-current systems may be preferred as a retrofit system on pipelines with galvanic anode failures, excessive anode consumption, operation beyond original design life or excessive coating deterioration;
- impressed-current systems may be preferred on short pipelines where an impressed-current system is operated from shore;
- impressed-current systems can cause detrimental effects on the integrity of other pipelines and/or structures existing in the same area unless proper measures are taken to prevent these effects.

6 Design parameters

6.1 General

The design of a pipeline CP system shall be based on

— detailed information on the pipeline to be protected, including material, length, wall thickness, outside diameter, pipe-laying procedures, route, laying conditions on the sea bottom, temperature profile (operating and shut in) along its whole length, type and thickness of corrosion-protective coating(s) for pipes and fittings, presence, type and thickness of thermal insulation, mechanical protection and/or weight coating,

— environmental conditions, such as seawater composition, temperature and resistivity, at the seabed along the whole length of the pipeline,

— burial status (extent of backfilling after trenching or natural burial) and soil resistivity,

— the design life of the system,

— information on existing pipelines in close proximity to or crossing the new pipeline, including location, ownership and corrosion-control practices,

— information on existing CP systems (platforms, landfalls, etc.) and electrical pipeline isolation,

— availability of electrical power, electrical isolating devices, electrical bonds,

— applicable local legislation,

— construction dates, start-up date (required for hot lines),

— pipe, fittings, J-tubes, risers, clamps and other appurtenances, and

— performance data on CP systems in the same environment.

At water depths greater than 500 m and sometimes at shallower depths, seawater characteristics (dissolved oxygen, salinity, pH, sea currents, and fouling) can vary significantly from shallower depths and affect cathodic polarization and calcareous deposit formation. For these situations, the required information shall be obtained from field surveys, corrosion test data or a review of operating experience, including the following:

— protective current requirements to meet applicable criteria;

— electrical resistivity of the electrolyte, including seasonal changes if relevant;

— pipe burial depth (if buried) and identification of exposed span lengths and locations;

— water temperature at the seabed;

— oxygen concentration at the seabed;

— water flowrate at the seabed, including seasonal changes if relevant;

— seabed topography.

When reviewing operating experience, the following additional data should be considered:

— electrical continuity;

— electrical isolation;

— external coating integrity;

— deviation from specifications;

— maintenance and operating data.

Design procedures for the CP systems shall be in accordance with Annex A.

6.2 Protection potentials

6.2.1 Introduction

The potential criteria and other measurements and observations that indicate whether adequate CP of a pipeline is being achieved are listed in 6.2.2. The effectiveness of CP or other external corrosion control measures can be confirmed by direct measurement of the pipeline potential. However, visual observations of progressive coating deterioration and/or corrosion, for example, are indicators of possible inadequate protection. Physical measurements of a loss of pipe wall thickness, using divers, or using internal inspection devices such as intelligent pigs, can also indicate deficiencies in the level of corrosion protection.

6.2.2 Potential criteria

To ensure adequate CP of a pipeline is being achieved, the measured potential shall be in accordance with Table 1.

Table 1 — Recommended potential criteria

Material	Minimum negative potential V	Maximum negative potential [a] V
Carbon steel		
Aerobic environment	– 0,80	– 1,10 [b]
Anaerobic environment	– 0,90	– 1,10 [b]
Austenitic stainless steel		
$N_{PRE} \geqslant 40$ [c]	– 0,30 [d]	– 1,10
$N_{PRE} < 40$ [c]	– 0,50 [d]	– 1,10
Duplex stainless steel	– 0,50 [d]	[e]
Martensitic stainless (13 % Cr) steel	– 0,50 [d]	[e]

The potentials given in Table 1 apply to saline mud and normal seawater compositions (salinity 3,2 % to 3,8 %).

The potentials are referenced to an SCE reference electrode, which are equivalent to a silver/silver chloride reference electrode (Ag/AgCl/seawater) in 30 Ω·cm seawater.

[a] These negative limits also ensure negligible impact of CP on pipeline coatings.

[b] Where pipeline systems are fabricated from high strength steel ($\sigma_{SMY} > 550$ MPa), the most negative potential that can be tolerated without causing hydrogen embrittlement shall be ascertained.

[c] N_{PRE} = %Cr + 3,3 %(Mo+0,5W) + 16 %N.

[d] For stainless steels, the minimum negative potentials apply for aerobic and anaerobic conditions.

[e] Depending on strength, specific metallurgical condition and stress level encountered in service, these alloys can be susceptible to hydrogen embrittlement and cracking. If a risk of hydrogen embrittlement exists, then potentials more negative than –0,8 V should be avoided.

6.2.3 Thermally sprayed aluminium

For a structure with thermally sprayed aluminium which is cathodically protected at potentials more negative than – 1,15 V, the thermally sprayed aluminium can suffer corrosion as a consequence of the build-up of alkali at the metal/electrolyte interface. A polarized potential more negative than – 1,15 V should not be used unless previous test results or operating experience indicate that no significant corrosion will occur.

6.2.4 Other factors

The potential of the Ag/AgCl/seawater reference electrode is dependent upon the concentration of chloride ions in the electrolyte, and hence by the seawater resistivity. If the chloride concentration and hence the resistivity is known to differ significantly from that of ordinary seawater (typically 3,5 % and 30 Ω·cm, respectively), the protection potential criteria shall be adjusted in accordance with Figure 1.

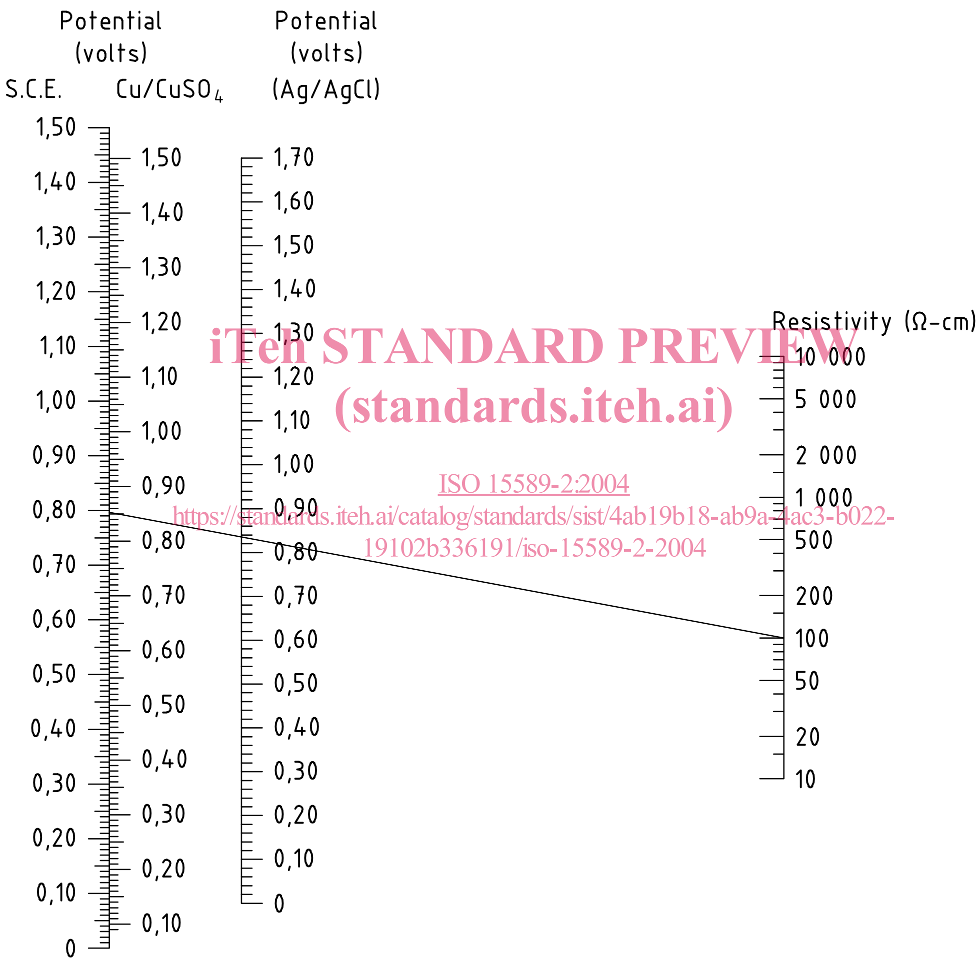


Figure 1 — Nomogram for the correction of potential readings made with the Ag/AgCl/seawater electrode in waters of varying salinity and resistivity against the SCE and $Cu/CuSO_4$ reference electrodes [5]

EXAMPLE If brackish water of 100 Ω·cm resistivity exists at the pipeline potential measurement site, the least negative potential for effective corrosion protection electrode will be – 0,84 V and not – 0,80 V as given in Table 1, with reference to the Ag/AgCl/seawater reference electrode.

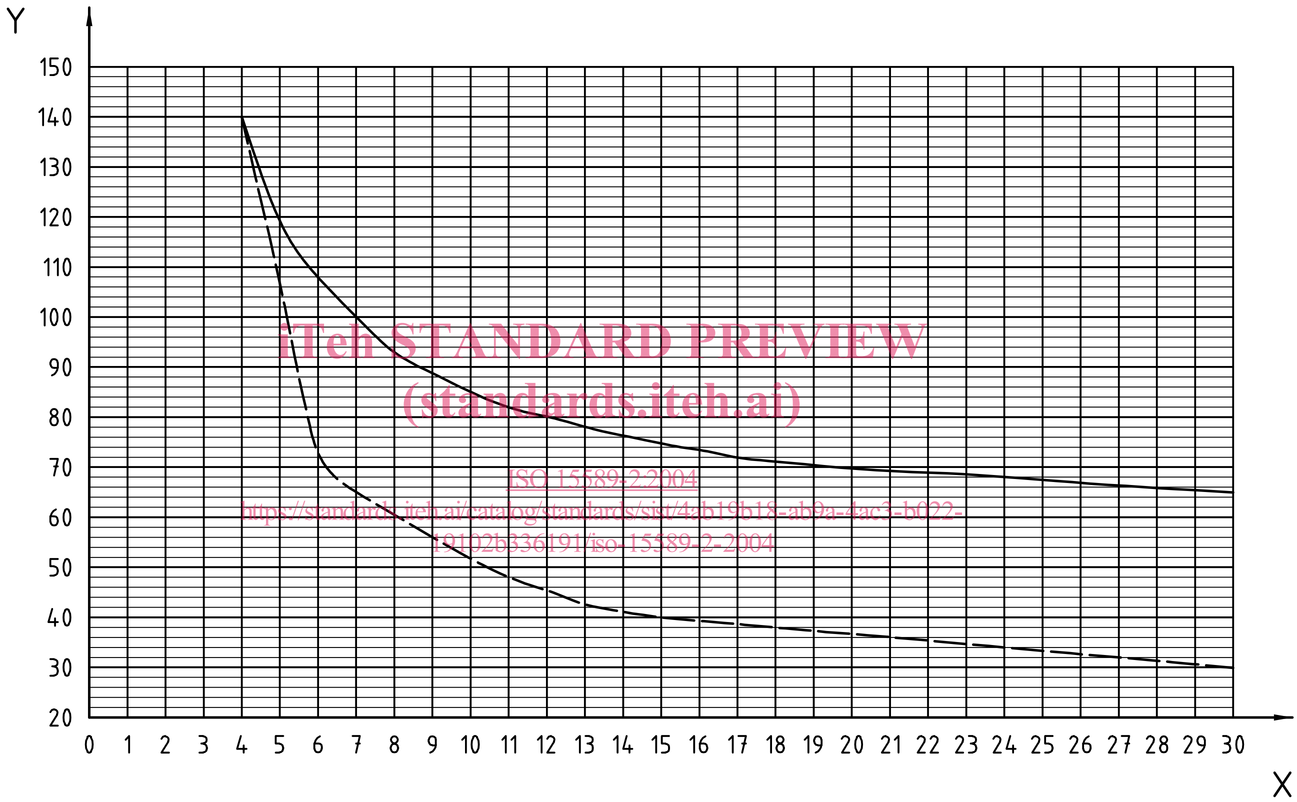
Alternative reference electrodes for specific conditions are given in C.4.2.

6.3 Design life

The design life of the pipeline CP system shall cover the period from installation to the end of pipeline operation.

6.4 Design current densities

The design current densities depend upon the seawater temperature, oxygen content, the seawater velocity and the ability to build up protective calcareous films on bare metal surfaces. For most applications in water depth of less than 500 m, the design current densities are dependent only on the seawater temperature, and the current densities for non-buried pipeline can be assessed from Figure 2.



Key

X seawater temperature, °C

Y current density, mA/m^2

NOTE The lower curve was published in [2]. This curve is based on test and field data from many platform and pipeline locations world-wide, collected over a number of years. The upper curve is a conservative curve fit of the data published in [3] and [4].

Figure 2 — Mean current density for non-buried pipeline

In Figure 2, the lower current-density curve may be used where there are no significant changes in oxygen content from surface to seabed, no problems building up protective calcareous films, and low to moderate seabed currents (up to 2 knots). The upper curve represents the highest current density values reported, which are required where oxygen content, calcareous films and seabed currents have to be considered.

If no other data are known, the upper curve in Figure 2 should be used.