INTERNATIONAL STANDARD

ISO 15589-2

Second edition
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Petroleum, petrochemical and natural gas industries — Cathodic protection of pipeline transportation systems —

Part 2:
Offshore pipelines

Industries du pétrole, de la pétrochimie et du gaz naturel — Protection cathodique des systèmes de transport par conduites — Partie 2: Conduites en mer

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 offhore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

This second edition cancels and replaces the first edition (ISO 15589-2:2004), which has been technically revised as follows:

— In Clause 6 recommendations for isolating joints are included.

— In Clause 7 a subclause on hydrogen-induced stress cracking evaluation is included.

— In Clause 7 coating breakdown factors have been reorganized by splitting into “with” and “without” concrete coating. More conservative values for some coating systems have been selected based on feedback from daily practice in industry.

— In Clause 8 recommendations on anode electrochemical properties for seawater with low salinity are included.

— Design values for electrochemical capacity in Clause 8 have been reduced. Higher values are permitted if properly documented.

— Quality control of anodes has been adjusted regarding tolerances, straightness, mass, surface irregularities and cracking (Clause 10).

— The guidance on attenuation calculation has been significantly extended. A new Annex B has been introduced and includes several examples and alternative methods.

— Regarding anode testing, only free-running testing is accepted (see Annex C).

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

— *Part 1: On-land pipelines*

— *Part 2: Offshore pipelines*

Introduction

The technical revision of this part of ISO 15589 has been carried out in order to accommodate the needs of industry and to move this International Standard to a higher level of service within the petroleum, petrochemical and natural gas industry.

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 on all the surface 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.

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 prevent alternative equipment or engineering solutions from being used for individual applications. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is intended that any variations from this part of ISO 15589 be identified and documented.

This part of ISO 15589 can also be used for offshore pipelines outside the petroleum, petrochemical and natural gas industries.

Petroleum, petrochemical 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 (CP) systems for offshore pipelines for the petroleum, petrochemical and natural gas industries as defined in ISO 13623.

This part of ISO 15589 is applicable to carbon steel, stainless steel and flexible 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.

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 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels*

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

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

ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ASTM D1141[1)], *Standard Practice for the Preparation of Substitute Ocean Water*

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

EN 10025 (all parts)[3)], *Hot rolled products of structural steels*

EN 10204:2004, *Metallic products — Types of inspection documents*

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

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

3) European Committee for Standardization, Management Centre, Avenue Marnix 17, B-1000, Brussels, Belgium.

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
anode sled
anodes installed on a structure and connected to the pipeline by a cable

3.3
closed-circuit anode potential
anode potential while electrically linked to the pipeline to be protected

3.4
coating breakdown factor
f_{c}
ratio of current density required to polarize a coated steel surface as compared to a bare steel surface

3.5
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

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

3.7
electric field gradient
change in electrical potential per unit distance through a conductive medium, arising from the flow of electric current

3.8
electrochemical capacity
ε
total amount of electric charge that is produced when a fixed mass (usually 1 kg) of anode material is consumed electrochemically

NOTE Electrochemical capacity is expressed in ampere hours.

3.9
final current density
estimated current density at the end of the lifetime of the pipeline

NOTE Final current density is expressed in amperes per square metre.

3.10
hydrogen-induced stress cracking
HISC
cracking due to a combination of load and hydrogen embrittlement caused by the ingress of hydrogen formed at the steel surface due to the cathodic polarization

3.11
IR drop
voltage due to any current, measured between two points of the metal of the pipe or two points of the electrolyte, such as seawater or seabed, in accordance with Ohm's law

NOTE IR drop and electric field gradient are related terms.

3.12
master reference electrode
reference electrode, calibrated with the primary calibration reference electrode, used for verification of reference electrodes that are used for field or laboratory measurements

3.13
mean current density
estimated average cathodic current density for the entire lifetime of the pipeline

NOTE Mean current density is expressed in amperes per square metre.

3.14
protection potential
structure-to-electrolyte potential for which the metal corrosion rate is considered as insignificant

3.15
pitting resistance equivalent number
PREN
number, developed to reflect and predict the pitting resistance of a stainless steel, based on the proportions of Cr, Mo, W and N in the chemical composition of the alloy

3.16
primary calibration reference electrode
reference electrode used for calibration of master reference electrodes

3.17
remotely operated vehicle
ROV
underwater vehicle operated remotely from a surface vessel or installation

[ISO 14723]

3.18
riser
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]

3.19
utilization factor
μ
fraction of the anodic material weight of a galvanic anode that can be consumed before the anode ceases to provide the minimum required current output

4 Symbols and abbreviated terms

4.1 Symbols

ε	electrochemical capacity
f_c	coating breakdown factor
μ	utilization factor

4.2 Abbreviated terms

CAT	cold-applied tape
CE	carbon equivalent
CP	cathodic protection
CRA	corrosion-resistant alloy
EPDM	ethylene propylene diene monomer
FBE	fusion-bonded epoxy
HISC	hydrogen-induced stress cracking
HSS	heat-shrinkable sleeve
PE	polyethylene
PP	polypropylene
PREN	pitting resistance equivalent number
PU	polyurethane
ROV	remotely operated vehicle
SCE	saturated calomel electrode
SMYS	specified minimum yield strength
SRB	sulphate reducing bacteria
3LPE	three-layer polyethylene
3LPP	three-layer polypropylene

5 General

5.1 Competence assurance

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

NOTE 1 EN 15257 or the NACE Cathodic Protection Training and Certification Programme constitute suitable methods that can be used to assess competence of cathodic protection personnel.

NOTE 2 Competence of cathodic protection personnel to the appropriate level for tasks undertaken can be demonstrated by certification in accordance with prequalification procedures such as EN 15257, the NACE Cathodic Protection Training and Certification Programme or any other equivalent scheme.

5.2 Compliance

A quality system and an environmental management system should be applied to assist compliance with the requirements of this part of ISO 15589.

NOTE ISO/TS 29001 gives sector-specific guidance on quality management systems and ISO 14001 gives guidance on the selection and use of an environmental management system.

6 Cathodic protection system requirements

6.1 General

The CP system shall be designed to prevent external corrosion over the design life of the pipeline and to:

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

— 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;

— ensure that anodes are installed where the possibility of disturbance or damage is minimal;

— provide adequate monitoring facilities to test and evaluate the system's performance.

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

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. Further guidance is given in Annex G.

The CP system based on galvanic anodes shall be designed for the lifetime of the pipeline system using the calculation procedure given in Annex A.

For areas with high water velocities and areas with erosion effects (e.g. from entrained sand, silt, ice particles), 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.

ISO 15589-1 should be used for the cathodic protection of short lengths of offshore pipelines and their branches that are directly connected to cathodically protected onshore pipelines.

6.2 Selection of CP systems

6.2.1 General

CP shall be achieved using either galvanic anodes or an impressed-current system. Galvanic anodes shall be connected to the pipe, either individually or in groups

NOTE 1 Galvanic anodes 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.

NOTE 2 Some 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.

Items that shall be considered in selecting the system to be used are covered in 6.2.2.

6.2.2 System selection considerations

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

— magnitude of the protective current required;

— resistivity of the seawater;

— availability and location of suitable power sources for impressed-current systems;

— existence of any stray currents causing significant potential fluctuations between pipeline and earth that can preclude the 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;

— integrity of other pipelines and/or structures existing in the same area that could be affected by impressed-current systems unless proper measures are taken to prevent these effects.

NOTE Impressed-current systems can be preferred on short pipelines which terminate at platforms that have impressed-current systems installed or where an impressed-current system is operated from the shore. Impressed-current systems can also 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 can also be the preferred method for high-resistivity water.

6.3 Isolating joints

Isolating joints should be considered at the following locations:

— at connections to onshore pipelines or onshore receiving facilities;

— at connections to pipelines that require different protection criteria;

— between cathodically protected pipelines and non-protected facilities or less protected facilities;

— between pipeline systems (or structures) protected by impressed current and galvanic anodes.

If isolating joints are used they shall be designed and installed to ensure long-term integrity and shall be positioned to allow easy access for inspection and maintenance. Detailed design requirements are given in ISO 15589-1.

7 Design parameters

7.1 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, including diurnal and seasonal variations, such as seawater salinity, temperature and resistivity, tides and seabed resistivity along the whole length of the pipeline;

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

— 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, subsea structures, 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);

— presence of fittings, J-tubes, risers, clamps, wyes, tees and other appurtenances; and

— performance data on CP systems in the same environment.

If CP performance data for similar environments is not available (for example when moving into deeper water), data on the seawater characteristics (dissolved oxygen, salinity, pH, sea currents, and fouling) shall be obtained as these can affect cathodic polarization and calcareous deposit formation. For these situations, the required information shall be obtained from field surveys and/or corrosion test data 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 flow rate 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 based on galvanic anode systems shall be in accordance with Annex A.

7.2 Protection potentials

7.2.1 Potential criteria

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

NOTE 1 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.

Table 1 — Potential criteria

Materials	Minimum negative potential V	Maximum negative potential[a] V
Carbon steels		
Immersed in seawater	− 0,80	− 1,10[b]
Buried in sediments	− 0,90[f]	− 1,10[b]
Austenitic stainless steels[g]		
PREN ≥ 40[c]	− 0,30[d]	− 1,10
PREN < 40[c]	− 0,50[d]	− 1,10
Duplex stainless steels	− 0,50[d]	[e]
Martensitic stainless (13 % Cr) **steels**	− 0,50[d]	[e]
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 (SMYS > 550 MPa), the most negative potential that can be tolerated without causing hydrogen embrittlement shall be ascertained.

[c] *PREN* = %Cr + 3,3 %(Mo+0,5W) + 16 %N.

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

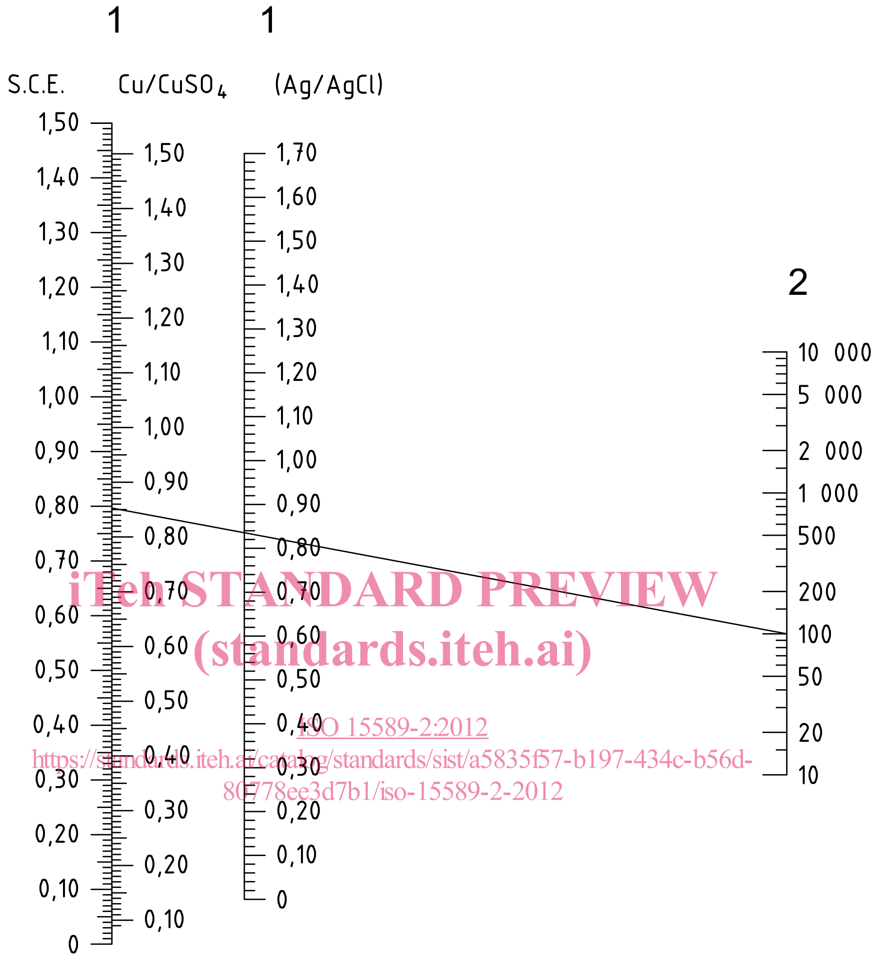
[e] Depending on the strength, specific metallurgical condition and stress level encountered in service, these alloys can be susceptible to hydrogen embrittlement and cracking. If a risk of hydrogen embrittlement exists, then potentials more negative than −0,8 V should be avoided. See also 7.2.3.

[f] This covers the possibility of SRB activity and/or high pipeline temperature (T > 60°C).

[g] If a metallurgical structure is not fully austenitic, these stainless steels can be susceptible to hydrogen-induced stress cracking (HISC) and high negative potentials should be avoided.

The potential of the Ag/AgCl/seawater reference electrode is dependent upon the concentration of chloride ions in the electrolyte, and hence 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.

NOTE 2 The term "Ag/AgCl/seawater (undersaturated) reference electrode" can be used for this electrode.



Key

1 potential, in volts

2 resistivity, in Ω·cm

Figure 1 — Nomogram for the correction of potential readings made with the Ag/AgCl/seawater electrode in waters of varying resistivity against the SCE and $Cu/CuSO_4$ reference electrodes[17]

EXAMPLE If brackish water of 100 Ω·cm resistivity exists at the pipeline potential measurement site, the least negative potential for the 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 D.3.2.

7.2.2 HISC evaluation for martensitic and duplex stainless steel materials

HISC is a non-ductile mode of failure caused by an interaction between stresses, the cathodic protection system and a susceptible material. A special assessment shall be carried out to ensure that the risk of HISC is minimized. All load contributions causing stress and strain shall be included.

For duplex stainless steels, DNV-RP-F112[8] may be used to assess acceptable stresses and strains.

