



BSI Standards Publication

Oil and gas industries including lower carbon energy — Cathodic protection of pipeline transportation systems

Part 2: Offshore pipelines

National foreword

This British Standard is the UK implementation of EN ISO 15589-2:2024. It is identical to ISO 15589-2:2024. It supersedes BS EN ISO 15589-2:2014, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17/2, Transmission pipelines.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Part 2: Offshore pipelines (ISO 15589-2:2024)

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN ISO 15589-2:2024) has been prepared by Technical Committee ISO/TC 67 "Oil and gas industries including lower carbon energy" in collaboration with 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of an identical text or by endorsement, at the latest by August 2024, and conflicting national standards shall be withdrawn at the latest by August 2024.

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Endorsement notice

The text of ISO 15589-2:2024 has been approved by CEN as EN ISO 15589-2:2024 without any modification.

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 2, *Pipeline transportation systems*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 219, *Cathodic protection*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 15589-2:2012), which has been technically revised.

The main changes are as follows:

- in [Clause 6](#), recommendations for isolating joints have been expanded;
- in [Clause 7](#), NOTES to [Table 1](#) and text in [7.4](#) have been updated to avoid discrepancies with [Figure 2](#); coating breakdown factors have been revised for errors left in the previous edition and less conservative values for some coating systems have been selected based on feedback from the industry;
- in [Clause 8](#), NOTES and guidance on the design of the system have been updated including recommendations for buried pipelines; anode utilization factors have been expanded to cover additional anodes types;
- in [Clause 9](#), [Table 6](#) has been updated to reflect anode compositions in line with current industry practices and other standards;
- in [Clause 10](#), additional references have been provided for guidance on core dimensions and position as well as testing for quality control of anode electrochemical properties;
- in [Annex A](#), additional anode resistance formulae have been provided to cover different anode types.
- [Annex B](#) has been modified to present the NORSOK method as a requirement, with an alternative method given for information.
- [Annex C](#) has been updated as informative and the test method replaced with references to current test methods in line with current industry practice.

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- The previous Annex E has been removed and replaced by additional guidance on quality control testing of anodes in [10.10](#).
- In the updated [Annex E](#) (Interference), additional references for alternating current interference have been added.

A list of all parts in the ISO 15589 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 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.

This document can also be used for offshore pipelines outside the petroleum, petrochemical and natural gas industries.

Oil and gas industries including lower carbon energy — Cathodic protection of pipeline transportation systems —

Part 2: Offshore pipelines

1 Scope

This document 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. Flexible pipelines, in-field flowlines, spools and risers are included in this document. Subsea production and injection equipment and structures are not included in this document.

This document is applicable to carbon steel, stainless steel and flexible metallic pipelines in offshore service.

This document is applicable to retrofits, modifications and repairs made to existing pipeline systems.

This document 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 630, *Structural steels*

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

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

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

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

AWS D1.1/D1.1M, *Structural Welding Code — Steel*

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

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

ASTM D1141, *Standard Practice for Preparation of Substitute Ocean Water*

DNV-RP-B401, *Cathodic Protection Design*

NACE TM0190, *Standard Test Method — Impressed Current Test Method for Laboratory Testing of Aluminium Anodes*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

anode sled

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

3.2

closed-circuit potential

anode potential while electrically linked to the pipeline to be protected

3.3

coating breakdown factor

f_c
time-dependent factor to address increasing current requirements due to coating breakdown based on the 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

driving voltage

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

3.6

electric field gradient

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

3.7

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 1 to entry: Electrochemical capacity is expressed in ampere hours.

3.8

final current density

current density required to repolarise pipeline at the end of the CP design life

Note 1 to entry: Final current density is expressed in amperes per square metre.

3.9

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

3.10

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 1 to entry: IR drop and *electric field gradient* ([3.6](#)) are related terms.

3.11

master reference electrode

reference electrode, calibrated with the *primary calibration reference electrode* ([3.15](#)), used for verification of reference electrodes that are used for field or laboratory measurements

3.12

mean current density

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

Note 1 to entry: Mean current density is expressed in amperes per square metre.

3.13

protection potential

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

3.14

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

3.15

primary calibration reference electrode

reference electrode used for calibration of *master reference electrodes* ([3.11](#))

3.16

remotely-operated vehicle

ROV

underwater vehicle operated remotely from a surface vessel or installation

[SOURCE: ISO 14723:2009, 4.32]

3.17

riser

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

[SOURCE: ISO 13623:2017, 3.1.20, modified — "including any subsea spool pieces" has been added.]

3.18

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

3.19

pipeline lifetime

period that includes pipeline service life, and any prior or subsequent period planned by the operator

4 Symbols and abbreviated terms

4.1 Symbols

ΔE_A	electrolytic potential drop
ΔE_{Me}	metallic potential drop
μ	utilization factor
A	anode exposed surface area
A_c	total surface area
A_w	cross-sectional area of the pipe wall
C	anode cross-sectional perimeter
D	pipeline outer diameter
d	pipeline wall thickness
ΔE	driving voltage
D_i	pipeline internal diameter
E_0	pipe-to-electrolyte potential shift at anode
E_a	design closed-circuit potential of the anode
E_c	design protection potential
E_x	pipe-to-electrolyte potential shift at a distance x
f_c	coating breakdown factor
f_{cf}	final coating breakdown factor
I_0	current flowing onto the pipe at anode
I_{af}	individual current output at the end-of-life
I_c	current demand
i_c	current density
I_{cf}	current demand at the end of life
I_{cm}	mean current demand
I_f	end-of-life individual anode current output
I_x	current flowing onto the pipe at a distance x
L	anode length
L_d	distance between anodes
L_m	half the distance between drain points
m	net anode mass

m_a	individual net anode mass
n	number of anodes
r	anode radius
R_0	pipe-to-electrolyte insulation resistance
R_a	anode resistance /total circuit resistance
R_{af}	anode resistance at end of life
R_L	linear electrical resistance of the section of the pipeline
R_t	transverse resistance
S	arithmetic mean of anode length and width
t_{dl}	design life, expressed in years.
α	attenuation constant for the pipeline
ε	electrochemical capacity
ρ	environmental resistivity
ρ_{Me}	pipe material resistivity

4.2 Abbreviated terms

AC	alternate current
CAT	cold-applied tape
CE	carbon equivalent
CP	cathodic protection
CRA	corrosion-resistant alloy
CSE	saturated copper electrode (Cu/CuSO ₄)
DC	direct current
EPDM	ethylene propylene diene monomer
FBE	fusion-bonded epoxy
HSS	heat-shrinkable sleeve
ICCP	impressed current cathodic protection
MIC	microbially induced corrosion
PE	polyethylene
PP	polypropylene
PREN	pitting resistance equivalent number
PU	polyurethane

ROV	remotely-operated vehicle
SCE	saturated calomel electrode (KCl)
SMYS	specified minimum yield strength
SRB	sulphate reducing bacteria
TSA	thermally sprayed aluminium
3LPE	three-layer polyethylene
3LPP	three-layer polypropylene

5 General

5.1 Competence assurance

Personnel who undertake the design, supervision of installation, construction, installation supervision, 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.

Competence of cathodic protection personnel to the level appropriate for tasks undertaken should be demonstrated by certification in accordance with prequalification procedures such as ISO 15257, or by any other equivalent scheme.

5.2 Conformity

A quality system and an environmental management system should be applied to assist conformity with the requirements of this document.

NOTE ISO 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 pipeline lifetime 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 CP 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.

Electrical isolation of offshore pipelines protected by galvanic anodes from other pipelines, structures, subsea facility or floaters that are protected by impressed-current systems shall be evaluated for adverse interaction between the two systems. An assessment shall be performed to identify the cathodic protection system of these facilities and review the electrical connectivity with the proposed pipeline to ensure no detrimental effects on each side related to inadequate or excessive polarization. Offshore pipelines shall be

isolated from other unprotected or less protected structures, which can drain current from the pipeline's CP system. If stray current problems are anticipated due to interaction between offshore pipelines and other structures, providing electrical continuity of the pipelines to the other structures can be considered.

CP systems of adjacent pipelines or structures shall be verified to be compatible such that current drain from one system into an adjacent system does not adversely affect the performance of either CP 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. Guidance is given in [Annex F](#).

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](#).

The design of the CP system shall document what allowances have been made for the effects of water velocity and erosion effects (e.g. from entrained sand silt or ice particles).

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

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 or mattresses of anodes can also be placed at regular intervals along the pipeline. For these cases, an attenuation check in accordance with [Annex B](#) shall be conducted to ensure the full length of pipeline is protected.

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. For this case, an attenuation check in accordance with [Annex B](#) shall be conducted to ensure the full length of pipeline is protected.

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 can 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 can 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;
- at connections between pipelines and appurtenances constructed from dissimilar metals (e.g. pumps and valves).

Electrical isolation of submarine pipelines from onshore electrical earthing systems is essential for effective cathodic protection offshore and onshore. This isolation shall be provided using electrically isolating joints.

Where offshore submarine pipeline CP is provided using galvanic anodes and onshore sections of the pipeline are protected using either impressed current or galvanic anodes, electrical isolation is necessary in order to enable the onshore section to be subject to the performance assessment as in ISO 15589-1. This requires the measurement of IR free pipe/soil potentials on the pipeline. As current flowing to the onshore pipeline from offshore galvanic anodes cannot be interrupted, it is necessary to electrically isolate the onshore pipeline from the offshore pipeline. This is to permit the onshore pipeline CP system to be adequately performance assessed.

This isolation shall be provided using electrically isolating joints. These isolating joints are best located at the landfall or on the seaward side of any emergency shut down valves. They should be located on the seaward side of any electrical or control piping connections to the onshore pipeline, to avoid such connections short circuiting the CP current and negating the effectiveness of the isolation joints.

NOTE 1 If these requirements for isolation joints are not followed, there is a considerable threat that cathodic protection effectiveness be severely impaired and that significantly costly remedial work be necessary in order to maintain pipeline integrity.

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

ISO 15589-1 requires that monolithic isolation joints be used wherever possible, for all electrical isolation requirements. Unless these joints are exposed to unplanned forces, they have been shown to be much more reliable than the use of insulating gaskets, sleeves and washers in a conventional flange. Due to the impact of isolation failure on pipeline integrity, monolithic isolation joints should be used at the interfaces between offshore and onshore pipelines.

NOTE 2 NACE SP0286-2007, "Electrical Isolation of Cathodically Protected Pipelines", provides information on the design and application of monolithic isolation joints.

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;
- construction dates, start-up date (required for hot lines);
- presence of fittings, J-tubes, risers, clamps, wyes, tees and other appurtenances;
- performance data on CP systems in the same environment.

If CP performance data for similar environments is not available (e.g. 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 for existing CP systems, the following 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 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	−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 a silver/silver chloride reference electrode (Ag/AgCl/seawater) which are equivalent to an SCE reference electrode, 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 $F_{PREN} = w_{Cr} + 3,3(w_{Mo} + 0,5w_W) + 16w_N$, where F_{PREN} is the PREN; w_{Cr} , w_{Mo} , w_W and w_N are the mass fractions of Cr, Mo, W and N in the stainless steel respectively, expressed in per cent.

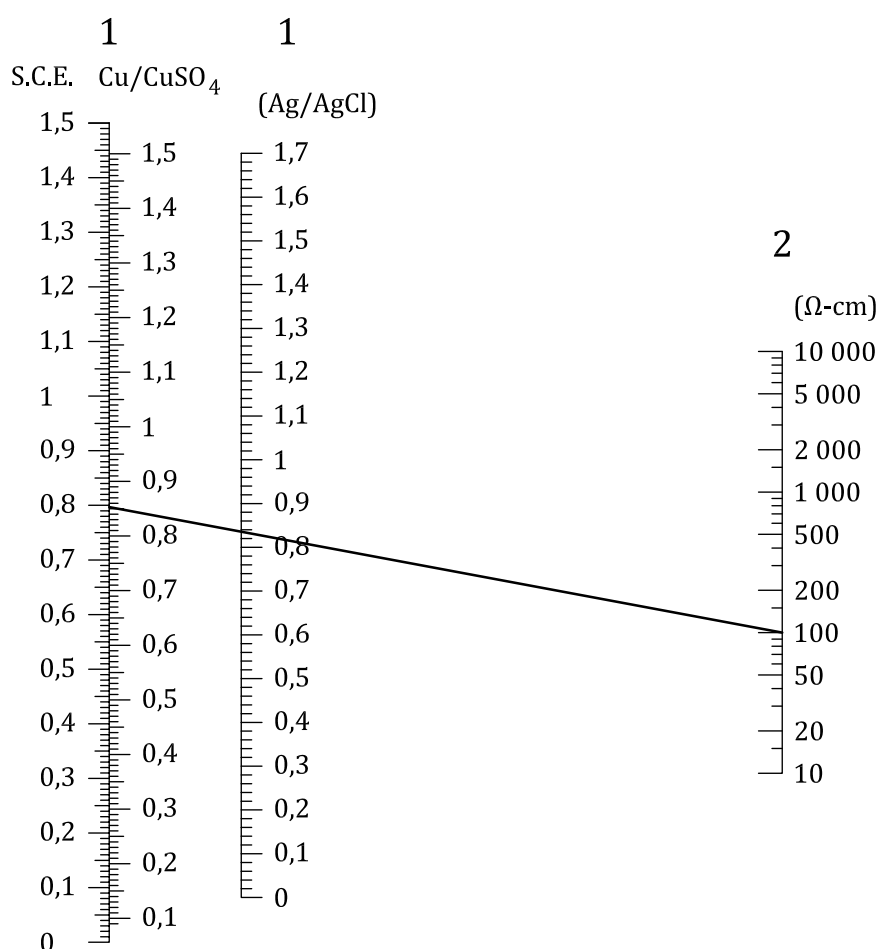
^d For stainless steels, the minimum negative potentials apply for aerobic and anaerobic conditions.

^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 [7.2.2](#).

^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 potentials more negative than −0,9 V are considered high and should be avoided, unless testing has proven a different limit is applicable.

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](#).

**Key**

- 1 potential, in negative volts
 2 resistivity, in $\Omega\cdot\text{cm}$

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/CuSO₄ (sat) reference electrodes^[17]

EXAMPLE If brackish water of 100 $\Omega\cdot\text{cm}$ resistivity exists at the pipeline potential measurement site, the least negative potential for the effective corrosion-protection electrode is -0,84 V and not -0,80 V as given in [Table 1](#), with reference to the Ag/AgCl/seawater reference electrode.

SCE are seldom used due to its Hg content. Cu/CuSO₄ electrodes should not be used in seawater as contamination by chlorides shifts the potential.

Alternative reference electrodes for specific conditions are given in [D.4.2](#).

7.2.2 HISC evaluation

HISC is a non-ductile mode of failure caused by an interaction between stresses, hydrogen produced by 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^[9] may be used to assess acceptable stresses and strains.

Fillet welds, doubler plates or aluminothermic welds should not be used directly on high-strength carbon steels (SMYS > 550 MPa), martensitic or duplex stainless steel materials. For martensitic or duplex stainless steel pipelines, installation of galvanic anode cables should be performed to special pipe joints consisting of carbon steel internally clad with CRA or made of other CRA materials which are not susceptible to HISC.