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

Part 2: Offshore pipelines

Industries du pétrole et du gaz y compris les énergies à faible teneur en carbone — Protection cathodique des systèmes de transport par conduites —

Partie 2: Conduites en mer

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Foreword

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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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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.

— 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