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Petroleum, petrochemical and natural gas industries — Prevention of corrosion on pipeline systems influenced by stray currents

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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 documents 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, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

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

This document has been developed to provide guidance for the prevention of external corrosion when a pipeline is influenced by electrical interference. Electrical interference can be from stray currents (defined in ISO 8044) and from naturally occurring interference caused by geomagnetic or tidal activity.

Cathodic protection standards (e.g. ISO 15589-1 and 15589-2) make reference to a structure-to-electrolyte potential value that is considered to indicate that cathodic protection is effective. When the potential is influenced by stray currents, however, it is not always possible to obtain a meaningful structure-to-electrolyte potential and other methods of assessment are required. These other methods can include mathematical analysis of the potentials and/or direct assessment of the corrosion rate using electrical resistance probes.

Users of this document should be aware that further or differing requirements from those provided in this document may be required for individual applications. This document is not intended to prevent alternative or differing analysis, measurement techniques or mitigation systems being used for individual applications. Where an alternative is offered, it is intended that any variations from this document be identified and documented.

This document can also be used for pipeline systems outside of the petroleum, petrochemical and natural gas industries.

Petroleum, petrochemical and natural gas industries — Prevention of corrosion on pipeline systems influenced by stray currents

1 Scope

This document establishes the general principles to be adopted to minimize the effects of stray current corrosion on external surfaces of buried or immersed pipeline systems caused by direct-current (d.c.).

ISO 18086 provides detailed information on the effects of alternating current on bubried or immersed pipelines. A brief description of alternating current (a.c.) effects is provided in this document.

The document is intended to offer guidance for:

— the design of cathodic protection systems which may produce stray currents;

— the design of pipeline systems, or elements of pipeline systems, which are to be buried or immersed and which may be subject to stray current corrosion;

— the selection of appropriate protection or mitigation measures.

The effects of a.c. induced voltages are not dealt with in detail in this document because they are covered in ISO 18086. General principles and guidelines are, however, provided.

Stray current corrosion can also occur internally in systems containing a conducting electrolyte e.g. near insulating joints or high resistance pipe joints in pipelines transporting conductive fluids.

Internal corrosion risks from stray currents are not dealt with in detail in this document but principles and measures described here can be applicable for minimizing the interference effects.

Stray currents can also cause other effects such as overheating. These other effects are not covered in this document.

A.C. currents can induce voltages on above-ground appurtenances of pipeline systems. These are not covered in detail in this document. They are covered in EN 50443, EN 61140, IEC 60364-4-41, IEC/TS 60479-1, IEC 60364-5-52, IEC /TS 61201, and IEC/TR 60479-5. EN 50122-1 gives guidance on d.c. touch potential limits.

Systems which may be affected by stray currents include buried or immersed metal structures such as:

a) pipeline systems;

b) metal sheathed cables;

c) tanks and vessels;

d) earthing systems;

e) steel reinforcement in concrete;

f) sheet steel piling.

This document provides details only for pipeline systems, although the principles can be applied to other buried structures. The EN 50162 series of standards also provide guidance for railway related structures.

An affected structure carrying stray currents, e.g. a pipeline or cable may itself affect other nearby structures.

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.

IEC 62128-2:2013, *Railway applications - Fixed installations - Part 2: Protective provisions against the effects of stray currents caused by d.c. traction systems*

ISO 15589-1:2001, *Cathodic protection of buried or immersed metallic structures – General principles and application for pipelines*

ISO 8044:2015, *Corrosion of metals and alloys — Basic terms and definitions*

EN 50122-2:2010, *Railway applications. Fixed installations. Electrical safety, earthing and the return circuit. Provisions against the effects of stray currents caused by d.c. traction systems*

EN 14505:2005, *Cathodic protection of complex structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15589-1, IEC 62128-2:2013, ISO 8044 and the following apply.

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
coating
electrically insulating covering bonded to a metal surface for protection against corrosion by preventing contact between the electrolyte and the metal surface

3.2
remote earth
theoretical concept that refers to a ground electrode of zero impedance placed an infinite distance away from the ground under test

Note 1 to entry: In practice, remote earth is approached when the mutual resistance between the ground under test and the test electrode becomes negligible. Remote earth is normally considered to be at zero potential. [IEEE Std 81-1983].

3.3
conductive coupling
occurs when a part of the current belonging to the interfering system returns to the system earth via the interfered system

Note 1 to entry: Also, when the voltage to the reference earth of the ground in the vicinity of the influenced object rises because of a default in the interfering system, and the results of which are conductive voltages and currents.

3.4
drainage (electrical drainage)
transfer of stray current from an affected structure to the current source by means of a deliberate bond

Note 1 to entry: For drainage devices see direct drainage bond, unidirectional drainage bond and forced drainage bond.

3.5
direct drainage bond
device that provides electrical drainage by means of a direct bond between an affected structure and the stray current source

Note 1 to entry: The bond can include a series resistor to limit current.

3.6
forced drainage bond
device that provides electrical drainage by means of a bond between an affected structure and the stray current source

Note 1 to entry: The bond includes a separate source of d.c. power to augment the transfer of current.

3.7
unidirectional drainage bond
device that provides electrical drainage by means of a unidirectional bond between the affected structure and the stray current source

Note 1 to entry: The bond includes a device such as a diode to ensure that current can only flow in one direction.

3.8
telluric interference
voltages generated by geomagnetic field variations that cause variations in the observed pipe-to-soil-potentials

3.9
electrical resistance probe
metal loss is measured by comparison of the calibrated resistance value of a piece of metal with known physical characteristics

3.10
sampling rate
measuring interval set by the operator

4 Abbreviations and symbols

a^{-1}	per annum
A.C. (a.c.)	Alternating current
CP	Cathodic protection
D.C. (d.c.)	Direct current
E	Structure/soil potential for non cathodically protected structures
E_a	Anodic potential
E_c	Cathodic potential
$E_{IR\text{-}free}$	Structure-to-electrolyte soil IR Free (instant off) potential for cathodically protected structures
E_{off}	Structure-to-electrolyte soil OFF potential for cathodically protected structures
E_{on}	Structure-to-electrolyte soil ON potential for cathodically protected structures
ΔE	Potential difference due to operation / non-operation of the interfering source

ΔE_a	Anodic potential shift (IR drop included)
$\Delta E_{a,avg}$	Average anodic potential shift
$\Delta E_{a,IR free}$	Anodic potential shift (IR drop excluded)
ΔE_c	Cathodic potential shift
$\Delta E_{c,avg}$	Average cathodic potential shift
Δv_{corr}	Corrosion rate difference due to operation / non-operation of the interfering source
$E_{IR-free}$	IR free potential
E_{on}	ON potential
$E_{on,avg}$	Average ON potential
E_p	Protection potential according to ISO 15589-1
E_{ref}	Reference potential: E_{on}-E_{ref}>0 => anodic interference, E_{on}-E_{ref}<0 => cathodic interference
EMI	Electromagnetic Interference
ER probe	Electrical resistance probe
GIC	Geomagnetically induced currents
HVAC	High voltage alternating current
HVDC	High Voltage Direct Current
IR	Product of the current and resistance (I and R) that indicates the voltage drop error in a potential measurement
J_a	Anodic current density
J_c	Cathodic current density
J_{ref}	Reference value for current density
PV	Photovoltaic
Q_a	Anodic charge during the period of anodic interference
Q_c	Cathodic charge during the period of cathodic interference
r.m.s.	Root mean square
ρ	Soil resistivity [Ω.m]
s	Second (unit of time)
R_{iso}	Isolation resistance, usually of a cable insulation
t	Time
T_a	Interval when the structure is anodic with respect to the selected value of E_{ref} or I_{ref}
$T_{a,max}$	Maximum duration of the anodic period
T_c	Interval when the structure is cathodic with respect to the selected value of E_{ref} or I_{ref}

5 Information exchange and co-operation

Common sources of interference that can cause stray current corrosion are given in Clause 6. During the design stage of buried or immersed metallic pipeline systems the possibility of both causing and suffering from stray current interference shall be taken into consideration. It is required to meet the criteria mentioned in Clause 8. Construction work, major changes on existing structures, regenerative braking etc. can require a detailed consideration of the interference situation.

Electrical interference problems on buried or immersed metallic pipeline systems shall be considered with the following points in mind:

— The operator of the pipeline system can protect a structure against corrosion with the method that the operator considers to be the most suitable. However, electrical interference to neighbouring structures shall be maintained within the defined limits given in Clause 8.

— Stray currents, especially from d.c. traction systems, are directly related to the design of the return circuits. This means that it is possible to limit the stray current by design but not to remove it entirely.

— Where other structures that may be affected are present, the requirement to maintain interference within the defined limits applies to all affected structures.

— Utility-scale photovoltaic (PV) installations can develop a steady state d.c. interference to adjacent buried pipelines. It is expected that the operator of the PV installation will maintain constant monitoring of the R_{iso} value to verify the isolation resistance between the PV panels and the earth. The pipeline operator should be informed of any earth leakages.

— The operating characteristics of HVDC systems can change under fault and maintenance conditions. These changes can affect the corrosion risk to buried pipelines and such changes should be communicated in a timely manner to the pipeline operator.

These goals are best achieved by agreement, co-operation and information exchange between the parties involved. Information exchange and co-operation are important and shall be carried out both at the design stage and during operation of the systems. In this way possible effects, suitable precautions and remedies can be assessed.

The following information is required to make a sound engineering judgement:

— details of buried metallic structures;

— cathodic protection installations or significant modifications to existing installations;

— d.c. traction system installations or significant modifications to existing installations;

— HVDC transmission line installation or modification to existing installations or modes of operation;

— details of any sources of d.c. installations that can cause interferences to buried pipelines;

— utility scale photovoltaic systems.

Agreement and co-operation may be more effectively achieved and maintained by periodic meetings between interested parties, committees or other associations who can establish information exchange procedures and protocols.

6 Common sources of interference that can affect corrosion

6.1 General

D.C. systems that can cause currents to flow in the earth or any other electrolyte, whether intentional or unintentional, include:

— d.c. traction systems;

— overhead lines for vehicles;

— trolley bus systems;

— d.c. power systems;

— d.c. equipment at industrial sites e.g. welding;

— d.c. communication systems;

— cathodic protection systems;

— high voltage d.c. (HVDC) transmission systems;

— d.c. track circuit signalling systems. (For stray currents from traction systems IEC 62128-2gives requirements for minimizing their production and for the effects within the railway system);

— photovoltaic power systems;

— offshore wind farm power systems;

— geomagnetic interference (telluric currents);

— tidal fluctuations.

A.C. systems that can induce voltages into buried structures include:

— three phase power transmission overhead cables;

— buried three phase power cables;

— a.c. operated railways.

6.2 Alternating Current (a.c.)

6.2.1 General

A.C. powered systems can cause interference on pipelines due to inductive, conductive and capacitive coupling mechanisms, which are described in EN 50443.

It is possible that the voltage resulting from interference on the pipe can exceed acceptable levels of touch-potential and/or current densities that will lead to corrosion damage of exposed steel surfaces.

The potentials and current densities that are used to determine the risk of corrosion from a.c. interference are detailed in ISO 18086.

Annex F (informative) provides additional information and one method to calculate the induced voltage in a section of pipe.

6.2.2 Overhead and buried power lines

6.2.2.1 General

Overhead power lines can generate unacceptable voltages onto buried pipelines, primarily by induction. The induction is a result of magnetic coupling. The magnitude of the induced voltage depends on the distance, length of parallelism, inducing current magnitude, frequency and phase relationship.

6.2.2.2 Buried power cables

Buried power lines can generate unacceptable voltages onto buried pipelines, primarily by induction, in the same way as overhead power lines. It is preferable if buried cables are laid with the phase cables close to each other and formed in a trefoil configuration. Trefoil formation refers to a method of arranging the individual phase cables to reduce the net inductance because the phases are in anti-phase and cancel each other.

6.2.2.3 Railway systems

A.C. railway systems can be a source of interference. Where the pipeline is parallel to the railway the coupling is primarily inductive. The rails of a.c. powered railways are earthed, and this can also result in conductive coupling to adjacent buried structures. A.C. railways can operate at 60 Hz, 50 Hz and 16.67 Hz. When evaluating the risks resulting from the effects of electromagnetic interference (EMI) on buried pipelines running near a.c. electrified traction systems, the harmonic distortion in railway systems should be considered. The presence of harmonics can exacerbate voltages accumulating on buried pipelines [REF].

6.3 Direct current (d.c.)

6.3.1 General

Sources of d.c. that can affect the structure-to-electrolyte potentials on pipelines can either originate from industrial or natural sources.

6.3.2 Traction systems

There are various configurations of d.c. traction systems that are in common use. They generally differ in respect of the way that the current is returned to the substation(s). Whichever system configuration is used there will be some current that returns via the earth. EN 50122-2 gives guidance on permissible limits.

6.3.3 Industrial systems

6.3.3.1 General

Industrial systems that use, or generate, d.c. should be provided with earthing systems that do not rely upon long earth return paths or deliberately utilize third party structures for earthing purposes.

6.3.3.2 Welding

Welding return circuits should be configured to ensure that the return paths are as short as possible and do not exacerbate the risk of currents returning via third party structures.

6.3.3.3 Photovoltaic Interference on Buried Pipelines

Leakage currents in photovoltaic (PV) systems originate from a fault or from the systematic and inevitable flow of direct current (d.c.) where there is cable insulation damage, PV modules and other array components. Under certain conditions, the d.c. leakage currents, if left unattended, or not detected