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Corrosion of metals and alloys — Determination of AC corrosion — Protection criteria

Corrosion des métaux et alliages — Détermination de la corrosion occasionnée par les courants alternatifs — Critères de protection

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 156, *Corrosion of metal and alloys*.

This second edition cancels and replaces the first edition (ISO 18086:2015), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— references cited informatively (EN 13509 and EN 15257) have been moved from Clause 2 to the Bibliography;

— in Clause 7, the two instances of the phrase "AC current density" have been changed to "AC average current density".

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 incorporated criteria and thresholds together with experience gained from the most recent data. Various countries have a very different approach to the prevention of AC corrosion depending primarily on the DC interference situation. These different approaches are taken into account in two different ways:

— in the presence of “low” on-potentials, which allows a certain level of AC voltage (up to 15 V);

— in the presence of “high” on-potentials (with DC stray current interference on the pipeline for instance), which requires the reduction of the AC voltage towards the lowest possible levels.

This document also gives some parameters to consider when evaluating the AC corrosion likelihood, as well as detailed measurement techniques, mitigation measures, and measurements to carry out for the commissioning of any AC corrosion mitigation system. Annex E proposes other parameters and thresholds that require further validation based on practical experiences.

Corrosion of metals and alloys — Determination of AC corrosion — Protection criteria

1 Scope

This document specifies protection criteria for determining the AC corrosion risk of cathodically protected pipelines.

It is applicable to buried cathodically protected pipelines that are influenced by AC traction systems and/or AC power lines.

In the presence of AC interference, the protection criteria given in ISO 15589-1 are not sufficient to demonstrate that the steel is being protected against corrosion.

This document provides limits, measurement procedures, mitigation measures, and information to deal with long-term AC interference for AC voltages at frequencies between 16,7 Hz and 60 Hz and the evaluation of AC corrosion likelihood.

This document deals with the possibility of AC corrosion of metallic pipelines due to AC interferences caused by conductive, inductive or capacitive coupling with AC power systems and the maximum tolerable limits of these interference effects. It takes into account the fact that this is a long-term effect, which occurs during normal operating conditions of the AC power system.

This document does not cover the safety issues associated with AC voltages on pipelines. These are covered in national standards and regulations (see, e.g., EN 50443).

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

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

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements*

EN 50443, *Effects of electromagnetic interference on pipelines caused by high voltage AC electric traction systems and/or high voltage AC power supply systems*

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 terminological databases for use in standardization at the following addresses:

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

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

3.1
AC electric traction system
AC railway electrical distribution network used to provide energy for rolling stock

Note 1 to entry: The system can comprise the following:

— contact line systems;

— return circuit of electric railway systems;

— running rails of non-electric railway systems, which are in the vicinity of and conductively connected to the running rails of an electric railway system.

3.2
AC power supply system
AC electrical system devoted to electrical energy transmission, which includes overhead lines, cables, substations and all apparatus associated with them

3.3
AC power system
AC electric traction system (3.1) or *AC power supply system* (3.2)

Note 1 to entry: Where it is necessary to differentiate, each *interfering system* (3.6) is clearly indicated with its proper term.

3.4
copper/copper sulfate reference electrode
CSE
reference electrode consisting of copper in a saturated solution of copper sulfate

3.5
AC voltage
voltage measured to *earth* (3.9) between a metallic structure and a reference electrode

3.6
interfering system
general expression encompassing an interfering high voltage *AC electric traction system* (3.1) and/or high voltage *AC power supply system* (3.2)

3.7
interfered system
system on which the *interference* (3.15) effects appear

Note 1 to entry: In this document, it is the *pipeline system* (3.8).

3.8
pipeline system
system of pipe network with all associated equipment and stations

Note 1 to entry: In this document, pipeline system refers only to metallic pipeline system.

Note 2 to entry: The associated equipment is the equipment electrically connected to the pipeline.

3.9
earth
conductive mass of the earth, of which the electric potential at any point is conventionally taken as equal to zero

[SOURCE: IEC 60050-826]

3.10
operating condition
fault-free operation of any system

Note 1 to entry: Transients are not to be considered as an operating condition.

3.11
fault condition
non-intended condition caused by a short-circuit to *earth* (3.9), the fault duration being the normal clearing time of the protection devices and switches

Note 1 to entry: A short circuit is an unintentional connection of an energized conductor to earth or to any metallic part in contact with earth.

3.12
conductive coupling
coupling that occurs when a proportion of the current belonging to the *interfering system* (3.6) returns to the system *earth* (3.9) via the *interfered system* (3.7) or when the voltage to the reference earth of the ground in the vicinity of the influenced object rises because of a fault in the interfering system and the results of which are conductive voltages and currents

3.13
inductive coupling
phenomenon whereby the magnetic field produced by a current carrying circuit influences another circuit

Note 1 to entry: Coupling is quantified by the mutual impedance of the two circuits. The results of which are induced voltages and, hence, currents that depend on, for example, the distances, length, inducing current, circuit arrangement and frequency.

3.14
capacitive coupling
phenomenon whereby the electric field produced by an energized conductor influences another conductor

Note 1 to entry: Coupling is quantified by the capacitance between the conductors and the capacitances between each conductor and the *earth* (3.9). The results of which are *interference* (3.15) voltages into conductive parts or conductors insulated from earth. These voltages depend, for example, on the voltage of the influencing system, distances and circuit arrangement.

3.15
interference
phenomenon resulting from *conductive, inductive or capacitive coupling* (3.12, 3.13, 3.14) between systems, which can cause malfunction, dangerous voltages, *damage* (3.17), etc.

3.16
disturbance
malfunction of a piece of equipment that loses its capability to work properly for the duration of the *interference* (3.15)

Note 1 to entry: When the interference disappears, the *interfered system* (3.7) starts working properly again without any external intervention.

3.17
damage
permanent reduction in the quality of service that can be suffered by the *interfered system* (3.7)

Note 1 to entry: A reduction in the quality of service could also be the complete cancellation of service.

EXAMPLE Coating perforation, pipe pitting, pipe perforation, permanent malfunction of the equipment connected to the pipes.

3.18
danger
state of the influenced system that is able to produce a threat to human life

3.19
interference situation
maximum distance between the *pipeline system* (3.8) and AC power system for which an *interference* (3.15) is to be considered

3.20
interference voltage
voltage caused on the *interfered system* (3.7) by the *conductive, inductive or capacitive coupling* (3.12, 3.13, 3.14) with the nearby *interfering system* (3.6) between a given point and the *earth* (3.9) or across an insulating joint

3.21
***IR* drop**
voltage due to any current, developed in an electrolyte such as the soil, between the reference electrode and the metal of the structure, in accordance with Ohm's Law ($U = I \times R$)

3.22
***IR*-free potential**
$E_{IR\text{-free}}$
pipe to electrolyte potential measured without the voltage error caused by the *IR drop* (3.21) due to the protection current or any other current

3.23
off-potential
E_{off}
pipe to electrolyte potential measured after interruption of all sources of applied cathodic protection current with the aim of approaching an *IR-free potential* (3.22)

Note 1 to entry: The delay before measurement varies according to circumstances.

3.24
on-potential
E_{on}
pipe to electrolyte potential measured while the cathodic protection system is continuously operating

3.25
spread resistance
ohmic resistance through a coating defect to *earth* (3.9) or from the exposed metallic surface of a *coupon* (3.26) towards earth

Note 1 to entry: This is the resistance which controls the AC or DC current through a coating defect or an exposed metallic surface of a coupon for a given AC or DC voltage.

3.26
coupon
metal sample of defined dimensions made of a metal equivalent to the metal of the pipeline

3.27
probe
device incorporating a *coupon* (3.26) that provides measurements of parameters to assess the effectiveness of cathodic protection and/or corrosion risk

4 Cathodic protection persons competence

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

EN 15257 or the NACE Cathodic Protection Training and Certification Programme constitute suitable methods of assessing and certifying the competence of cathodic protection personnel.

The competence of cathodic protection persons to the appropriate level for tasks undertaken should 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 Assessment of the AC influence

5.1 General

This document is applicable to all metallic pipelines and all high voltage AC traction systems and high voltage AC power supply systems and all major modifications that can significantly change the AC interference effect.

The effects are the following:

— danger to people who come in direct contact or contact through conductive parts with the metallic pipeline or the connected equipment;

— damage of the pipeline or to the connected equipment;

— disturbance of electrical/electronic equipment connected to the pipeline.

Electrical/electronic systems installed on a pipeline network shall be chosen such that they will neither become dangerous nor interfere with normal operating conditions because of short-term voltages and currents, which appear during short circuits on the AC power system.

Long-term AC interference on a buried pipeline can cause corrosion due to an exchange of AC current between the exposed metal of the pipeline and the surrounding electrolyte.

This exchange of current depends on an AC voltage of which the amplitude is related to various parameters such as the following:

— configuration of AC power line phase conductors;

— presence and configuration of the earthing conductor;

— distance between the AC power line/traction system and the pipeline;

— current flowing in the AC power line/traction system phase conductors;

— average coating resistance of the pipeline;

— thickness of the coating;

— soil resistivity;

— presence of earthing systems;

— voltage of the AC railway system or the AC power line system.

5.2 Assessment of the level of interference

Calculations can be carried out (e.g. in accordance with EN 50443) by mathematical modelling to determine the earthing requirements necessary to maintain touch voltages within acceptable safe levels. Their results can also be used to determine voltages necessary to reduce the AC corrosion likelihood.

During the design phase of new influencing systems (electricity power line or railway line) or a new influenced system (pipelines), an estimation of the level of AC voltage on the pipeline should be calculated. Calculations can be carried out by mathematical modelling to determine the level of voltage produced on the pipeline. In the case of existing structures, field measurements can also be used as an option to calculation.

According to the results of calculations or field measurements, relevant mitigation measures should be installed on the influencing systems and/or the influenced system to achieve the relevant AC voltage to reduce the AC corrosion likelihood (see Clause 7).

Guidance on calculating the AC voltage on a structure caused by an AC power system was published in Reference [8]. The algorithm determines the worst-case conditions for the input parameters used for the calculation.

Due to inconsistent load demands on AC power systems, the magnitude of operating currents in power lines varies. The fluctuations depend on daily and seasonal changes. Input data for calculation purposes should be based on the realistic operating conditions or the maximum power load of the influencing system.

NOTE Carrying out calculations with input data based on both approaches helps to estimate the range between both results and to choose the right method.

6 Evaluation of the AC corrosion likelihood

6.1 Prerequisite

6.1.1 General

The AC voltage on a pipeline is the driving force for the AC corrosion processes taking place on the steel surface at coating defects. Among other things, corrosion damage depends on the AC current density, level of DC polarization, defect geometry, local soil composition and resistivity (see Annex D).

Basically, there are three different approaches to prevent AC corrosion: to limit the AC current flowing through a defect, to control the cathodic protection level, and to ensure that any coating remains defect free. These approaches are not mutually exclusive.

The evaluation of AC corrosion likelihood should be performed by the evaluation of some or all of the following parameters:

- AC voltage on the structure;
- on-potential;
- *IR*-free potential;
- AC current density;
- DC current density;
- AC/DC current density ratio;
- soil resistivity;
- corrosion rate.

Annexes B, C and E provide further information.

6.1.2 AC voltage on the structure

The acceptable AC voltage thresholds (see Clause 7 and Annex E) depend on the chosen strategy to prevent AC corrosion. Hence, a given interference situation on the pipeline can influence the decision regarding the applicable strategy.

6.2 AC and DC current density

6.2.1 General

The AC and DC current density on a coating defect controls both the cathodic protection level and AC corrosion process. Therefore, it is a more reliable parameter for the evaluation of the AC corrosion likelihood than the on-potential or the AC voltage. However, in contrast to the voltages present on the pipeline, the current density cannot be readily determined. In principle, the current density can be calculated from the spread resistance and the geometry of the coating defect and the AC voltage. This calculation is generally not possible since the geometry of the coating fault and its surface area are generally not known. Moreover, the application of cathodic protection can significantly change the spread resistance and therefore, the current density at a given voltage.

The current density can only be estimated by means of coupons or probes. When evaluating the AC corrosion likelihood by means of a coupon or probe, it is important to consider the limitations of this technique. The calculation of the current density based upon the metallic coupon or probe surface area and on the current measured on a coupon or probe, the current is averaged over the entire coupon or probe surface. However, the current distribution on the coupon or probe can vary depending on its geometry. Typically, current densities at the edges of the coupon or probe are larger than the current averaged over the entire surface. Moreover, the often-observed formation of chalk layers can decrease the effective coupon or probe surface area. Again, this effect results in an under estimation of the current density.

6.2.2 AC current density

The AC current density results in anodic and cathodic charge transfer. A detailed explanation of the charge transfer process is given in Annex A. This current can be consumed in charging of the double layer capacitance at the steel surface, in the oxidation of hydrogen (resulting in a decreasing pH), in the oxidation of corrosion products, and in the oxidation of the metal. The oxidation of the metal results in corrosion. Generally, an increasing AC current density results in a larger amount of metal oxidation and higher corrosion rates. However, the anodic current is not the only current that can affect the corrosion process. Cathodic current can reduce oxide layers formed and increase the pH on the metal surface.

High AC current densities do not necessarily cause AC corrosion if the charge passed through the metal surface can be consumed in reactions other than metal oxidation and oxide film reduction. This is the case in the presence of low cathodic DC current densities. As a consequence, the judgment of the AC corrosion likelihood based on the AC current density requires the additional consideration of the cathodic DC current density.

Nevertheless, there is an empirically determined lower limit for the AC current density below which the probability for AC corrosion is extremely low (see Clause 7).

6.2.3 High cathodic DC current density

A high DC current density results in more negative cathodic protection levels and the formation of a high pH at the pipeline surface. However, the formation of a high pH-value, the decrease of the spread resistance, and the increased reduction of surface oxide films can result in an acceleration of the corrosion rate under simultaneous AC interference. Nevertheless, a sufficiently high DC current density can prevent any anodic metal oxidation and therefore, the occurrence of AC corrosion.