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Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production —

Part 1: General principles for selection of cracking-resistant materials

Industries du pétrole et du gaz naturel — Matériaux pour utilisation dans des environnements contenant de l'hydrogène sulfuré (H_2S) dans la production de pétrole et de gaz —

Partie 1: Principes généraux pour le choix des matériaux résistant à la fissuration

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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 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 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 15156-1:2015), which has been technically revised. The main changes compared to the previous edition are as follows:

— new definition on "galvanically induced hydrogen stress cracking" (see 3.14), "chemical activity" (see 3.27) and "fugacity" (see 3.28);

— inclusion of an expanded description of factors affecting the susceptibility of materials to cracking caused by H_2S. The expanded description includes specific guidance provided in ISO 15156-2:2020, Annex C for gas phase containing systems using H_2S fugacity (as an alternative to H_2S partial pressure) and application of non-ideal thermodynamic rules for gas-free liquid systems.

A list of all parts in the ISO 15156 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.

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Introduction

The consequences of sudden failures of metallic oil and gas field components, associated with their exposure to H_2S-containing production fluids, led to the preparation of the first edition of NACE MR0175, which was published in 1975 by the National Association of Corrosion Engineers, now known as NACE International.

The original and subsequent editions of NACE MR0175 established limits of H_2S partial pressure above which precautions against sulfide stress cracking (SSC) were always considered necessary. They also provided guidance for the selection and specification of SSC-resistant materials when the H_2S thresholds were exceeded. In more recent editions, NACE MR0175 has also provided application limits for some corrosion-resistant alloys, in terms of environmental composition and pH, temperature, and H_2S partial pressures.

In separate developments, the European Federation of Corrosion issued EFC Publication 16 in 1995 and EFC Publication 17 in 1996. These documents are generally complementary to those of NACE though they differed in scope and detail.

In 2003, the publication of the ISO 15156 series and NACE MR0175/ISO 15156 was completed for the first time. These technically identical documents utilized the above sources to provide requirements and recommendations for materials qualification and selection for application in environments containing wet H_2S in oil and gas production systems. They are complemented by NACE TM0177 and NACE TM0284 test methods.

The revision of this document, i.e. ISO 15156-1, involves a consolidation of all changes agreed and published in the Technical Circular 1, ISO 15156-1:2015/Cir.1:2017, published by the ISO 15156 series Maintenance Agency secretariat at DIN.

The changes were developed by, and approved by the ballot of, representative groups from within the oil and gas production industry. The great majority of these changes stem from issues raised by document users. A description of the process by which these changes were approved can be found at the ISO 15156 series maintenance website: www.iso.org/iso15156maintenance.

When found necessary by oil and gas production industry experts, future interim changes to this document will be processed in the same way and will lead to interim updates to this document in the form of Technical Corrigenda or Technical Circulars. Document users should be aware that such documents can exist and can impact the validity of the dated references in this document.

The ISO 15156 series Maintenance Agency at DIN was set up after approval by the ISO Technical Management Board given in document 34/2007. This document describes the makeup of the agency, which includes experts from NACE, EFC, and ISO/TC 67, and the process for approval of amendments. It is available from the ISO 15156 series maintenance website and from the ISO/TC 67 Secretariat. The website also provides access to related documents that provide more detail of the ISO 15156 series maintenance activities.

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Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production —

Part 1: General principles for selection of cracking-resistant materials

WARNING — Metallic materials selected using this document are resistant to cracking in defined H_2S-containing environments in oil and gas production but not necessarily immune to cracking under all service conditions. It is the equipment user's responsibility to select materials suitable for the intended service.

1 Scope

This document describes general principles and gives requirements and recommendations for the selection and qualification of metallic materials for service in equipment used in oil and gas production and in natural-gas sweetening plants in H_2S-containing environments, where the failure of such equipment can pose a risk to the health and safety of the public and personnel or to the environment. It can be applied to help to avoid costly corrosion damage to the equipment itself. It supplements, but does not replace, the materials requirements given in the appropriate design codes, standards, or regulations.

This document addresses all mechanisms of cracking that can be caused by H_2S, including sulfide stress cracking, stress corrosion cracking, hydrogen-induced cracking and stepwise cracking, stress-oriented hydrogen-induced cracking, soft zone cracking, and galvanically induced hydrogen stress cracking.

Table 1 provides a non-exhaustive list of equipment to which this document is applicable, including exclusions.

This document applies to the qualification and selection of materials for equipment designed and constructed using load controlled design methods. For design utilizing strain-based design methods, see Clause 5.

This document is not necessarily applicable to equipment used in refining or downstream processes and equipment.

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Table 1 — List of equipment

This document is applicable to materials used for the following equipment	Exclusions
Drilling, well construction, and well-servicing equipment	Equipment exposed only to drilling fluids of controlled composition[a]
	Drill bits
	Blowout preventer (BOP) shear blades[b]
	Drilling riser systems
	Work strings
	Wireline and wireline equipment[c]
	Surface and intermediate casing
Wells, including subsurface equipment, gas-lift equipment, wellheads, and christmas trees	Sucker rod pumps and sucker rods[d]
	Electric submersible pumps
	Other artificial lift equipment
	Slips
Flowlines, gathering lines, field facilities, and field processing plants	Crude-oil storage and handling facilities operating at a total absolute pressure below 0,45 MPa (65 psi)
Water-handling equipment	Water-handling facilities operating at a total absolute pressure below 0,45 MPa (65 psi)
	Water injection and water disposal equipment
Natural-gas treatment plants	—
Transportation pipelines for liquids, gases, and multiphase fluids	Lines handling gas prepared for general commercial and domestic use
For all equipment above	Components loaded only in compression

[a] See ISO 15156-2:2020, A.2.3.2.3 for more information.

[b] See ISO 15156-2:2020, A.2.3.2.1 for more information.

[c] Wireline lubricators and lubricator connecting devices are not excluded.

[d] For sucker rod pumps and sucker rods, reference can be made to NACE MR0176.

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 15156-2, *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons*

ISO 15156-3, *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

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

3.1
blowout preventer
BOP
mechanical device capable of containing pressure, used for control of well fluids and drilling fluids during drilling operations

3.2
brazing
joining metals by flowing a thin layer (of capillary thickness) of a lower-melting-point non-ferrous filler metal in the space between them

3.3
carbon steel
alloy of carbon and iron containing up to 2 % mass fraction carbon and up to 1,65 % mass fraction manganese and residual quantities of other elements, except those intentionally added in specific quantities for deoxidation (usually silicon and/or aluminium)

Note 1 to entry: Carbon steels used in the petroleum industry usually contain less than 0,8 % mass fraction carbon.

3.4
christmas tree
equipment at a wellhead for the control of fluid production or injection

3.5
cold work
plastic deformation of metal under conditions of temperature and strain rate that induce strain hardening, usually, but not necessarily, conducted at room temperature

3.6
corrosion-resistant alloy
CRA
alloy intended to be resistant to general and localized corrosion of oilfield environments that are corrosive to *carbon steels* (3.3)

3.7
ferrite
body-centred cubic crystalline phase of iron-based alloys

3.8
ferritic steel
steel whose *microstructure* (3.16) at room temperature consists predominantly of *ferrite* (3.7)

3.9
hardness
resistance of metal to plastic deformation, usually measured by indentation

3.10
heat-affected zone
HAZ
portion of the base metal that is not melted during brazing, cutting, or welding, but whose *microstructure* (3.16) and properties are altered by the heat of these processes

3.11
heat treatment
heating and cooling a solid metal or alloy in such a way as to obtain desired properties

Note 1 to entry: Heating for the sole purpose of hot working is not considered heat treatment.

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3.12
hydrogen-induced cracking
HIC
planar cracking that occurs in carbon and low alloy steels when atomic hydrogen diffuses into the steel and then combines to form molecular hydrogen at trap sites

Note 1 to entry: Cracking results from the pressurization of trap sites by hydrogen. No externally applied stress is required for the formation of hydrogen-induced cracks. Trap sites capable of causing HIC are commonly found in steels with high impurity levels that have a high density of planar inclusions and/or regions of anomalous *microstructure* (3.16) (e.g. banding) produced by segregation of impurity and alloying elements in the steel. This form of hydrogen-induced cracking is not related to welding.

3.13
hydrogen stress cracking
HSC
cracking that results from the presence of hydrogen in a metal and tensile stress (residual and/or applied)

Note 1 to entry: SSC and GHSC are forms of HSC.

3.14
galvanically induced hydrogen stress cracking
GHSC
cracking that results due to the presence of hydrogen in a metal induced in the cathode of a galvanic couple and tensile stress (residual and/or applied)

3.15
low-alloy steel
steel with a total alloying element content of less than about 5 % mass fraction, but more than specified for *carbon steel* (3.3)

3.16
microstructure
structure of a metal as revealed by microscopic examination of a suitably prepared specimen

3.17
partial pressure
pressure that would be exerted by a single component of a gas if present alone, at the same temperature, in the total volume occupied by the mixture

Note 1 to entry: For a mixture of ideal gases, the partial pressure of each component is equal to the total pressure multiplied by its mole fraction in the mixture, where its mole fraction is equal to the volume fraction of the component.

3.18
residual stress
stress present in a component free of external forces or thermal gradients

3.19
soft-zone cracking
SZC
form of SSC that can occur when a steel contains a local “soft zone” of low-yield-strength material

Note 1 to entry: Under service loads, soft zones can yield and accumulate plastic strain locally, increasing the SSC susceptibility to cracking of an otherwise SSC-resistant material. Such soft zones are typically associated with welds in *carbon steels* (3.3).

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3.20
sour service
exposure to oilfield environments that contain sufficient H_2S to cause cracking of materials by specific mechanisms

Note 1 to entry: These specific mechanisms are addressed in this document.

3.21
stepwise cracking
SWC
cracking that connects hydrogen-induced cracks on adjacent planes in a steel

Note 1 to entry: This term describes the crack appearance. The linking of hydrogen-induced cracks to produce stepwise cracking is dependent on the local strain between the cracks and the embrittlement of the surrounding steel by dissolved hydrogen. HIC/SWC is usually associated with low-strength plate steels used in the production of pipes and vessels.

3.22
stress corrosion cracking
SCC
cracking of metal involving anodic processes of localized corrosion and tensile stress (residual and/or applied) in the presence of water and H_2S

Note 1 to entry: Chlorides and/or oxidants and elevated temperature can increase the susceptibility of metals to this mechanism of attack.

3.23
stress-oriented hydrogen-induced cracking
SOHIC
staggered small cracks formed approximately perpendicular to the principal stress (residual or applied) resulting in a "ladder-like" crack array linking (sometimes small) pre-existing HIC cracks

Note 1 to entry: The mode of cracking can be categorized as SSC caused by a combination of external stress and the local strain around hydrogen-induced cracks. SOHIC is related to SSC and HIC/SWC. It has been observed in parent material of longitudinally welded pipe and in the *heat-affected zone (HAZ)* (3.10) of welds in pressure vessels. SOHIC is a relatively uncommon phenomenon usually associated with low-strength ferritic pipe and pressure vessel steels.

3.24
sulfide stress cracking
SSC
cracking of metal involving corrosion and tensile stress (residual and/or applied) in the presence of water and H_2S

Note 1 to entry: SSC is a form of *hydrogen stress cracking (HSC)* (3.13) and involves the embrittlement of the metal by atomic hydrogen that is produced by acid corrosion on the metal surface. Hydrogen uptake is promoted in the presence of sulfides. The atomic hydrogen can diffuse into the metal, reduce ductility, and increase susceptibility to cracking. High-strength metallic materials and hard weld zones are prone to SSC.

3.25
weld
joint between two or more pieces of metal by applying heat and/or pressure with or without filler metal, to produce a union through localized fusion of the substrates and solidification across the interfaces

3.26
yield strength
stress at which a material exhibits a specified deviation from the proportionality of stress to strain

Note 1 to entry: The deviation is expressed in terms of strain by either the offset method (usually at a strain of 0,2 %) or the total-extension-under-load method (usually at a strain of 0,5 %).

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