INTERNATIONAL STANDARD

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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 au craquage

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 15156-1 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

This second edition cancels and replaces the first edition (ISO 15156-1:2001), of which it constitutes a minor revision, specifically by the following:

— inclusion of changes to Table 1 in line with the version shown in ISO 15156-2 and ISO 15156-3;

— inclusion of changes to Clause 5 to make clearer the roles of those involved in the selection and supply and use of materials;

— replacement of the term “pre-qualified material”.

ISO 15156 consists of the following parts, under the general title *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*

— *Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons*

— *Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

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 three parts of ISO 15156 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 part of ISO 15156 involves a consolidation of all changes agreed and published in the Technical Corrigendum 1, ISO 15156-1:2001/Cor.1:2005 and by the Technical Circular 1, ISO 15156-1:2001/Cir.1:2007(E), published by the ISO 15156 maintenance agency secretariat at DIN, Berlin.

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 maintenance website www.iso.org/iso15156maintenance.

When found necessary by oil and gas production industry experts, future interim changes to this part of ISO 15156 will be processed in the same way and will lead to interim updates to this part of ISO 15156 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 part of ISO 15156.

The ISO 15156 maintenance agency at DIN was set up after approval by the ISO Technical Management Board given in document 34/2007. This document describes the make up of the agency, which includes experts from NACE, EFC and ISO/TC 67/WG 7, and the process for approval of amendments. It is available from the ISO 15156 maintenance website and from the ISO/TC 67 Secretariat. The website also provides access to related documents that provide more detail of ISO 15156 maintenance activities.

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 ISO 15156 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 part of ISO 15156 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 part of ISO 15156 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 part of ISO 15156 is applicable, including permitted exclusions.

This part of ISO 15156 applies to the qualification and selection of materials for equipment designed and constructed using conventional elastic design criteria.

This part of ISO 15156 is not necessarily applicable to equipment used in refining or downstream processes and equipment.

Table 1 — List of equipment

ISO 15156-1 is applicable to materials used for the following equipment	Permitted 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 15156-2:2009, A.2.3.2.3 for more information.

[b] See ISO 15156-2:2009, A.2.3.2.1 for more information.

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

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

2 Normative references

The following referenced documents are indispensable for the application 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 15156-2:2009, *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 15156-3:2009, *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.

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
braze, verb
join 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 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, verb
deform metal plastically 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

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

3.8
ferritic steel
steel whose microstructure at room temperature consists predominantly of ferrite

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

3.10
heat-affected zone
HAZ
that portion of the base metal that is not melted during brazing, cutting, or welding, but whose microstructure 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 Heating for the sole purpose of hot working is not considered heat treatment.

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 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 (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 HSC describes cracking in metals that are not sensitive to SSC but which can be embrittled by hydrogen when galvanically coupled, as the cathode, to another metal that is corroding actively as an anode. The term “galvanically induced HSC” has been used for this mechanism of cracking.

3.14
low-alloy steel
steel with a total alloying element content of less than about 5 % mass fraction, but more than specified for carbon steel

3.15
microstructure
structure of a metal as revealed by microscopic examination of a suitably prepared specimen

3.16
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 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.

3.17
residual stress
stress present in a component free of external forces or thermal gradients

3.18
soft-zone cracking
SZC
form of SSC that can occur when a steel contains a local “soft zone” of low-yield-strength material

NOTE 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.

3.19
sour service
exposure to oilfield environments that contain sufficient H_2S to cause cracking of materials by the mechanisms addressed by this part of ISO 15156

3.20
stepwise cracking
SWC
cracking that connects hydrogen-induced cracks on adjacent planes in a steel

NOTE 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.

3.21
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 Chlorides and/or oxidants and elevated temperature can increase the susceptibility of metals to this mechanism of attack.

3.22
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 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) of welds in pressure vessels. SOHIC is a relatively uncommon phenomenon usually associated with low-strength ferritic pipe and pressure-vessel steels.

3.23
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 SSC is a form of hydrogen stress cracking (HSC) 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.

3.24
weld, verb
join 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

3.25
yield strength
stress at which a material exhibits a specified deviation from the proportionality of stress to strain

NOTE 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 %).

4 Abbreviated terms

BOP Blowout preventer

CRA Corrosion-resistant alloy

HAZ Heat-affected zone

HIC Hydrogen-induced cracking

HSC Hydrogen stress cracking

SCC Stress-corrosion cracking

SOHIC Stress-oriented hydrogen-induced cracking

SWC Step-wise cracking

SSC Sulfide stress cracking

SZC Soft-zone cracking

5 General principles

Users of ISO 15156 (all parts) shall first assess the conditions to which the materials they wish to select can be exposed. These conditions shall be evaluated, defined and documented in accordance with this part of ISO 15156.

The equipment user shall determine whether or not the service conditions are such that ISO 15156 (all parts) applies.

Materials selection shall be made following the requirements and recommendations of ISO 15156-2 or ISO 15156-3, as appropriate.

The use of ISO 15156-2 or ISO 15156-3 can require an exchange of information (for example concerning required or suitable service conditions) between the equipment user and the equipment or materials supplier. If necessary, the equipment user should advise other parties of the service conditions.

NOTE It can be necessary for the equipment supplier to exchange information with the equipment manufacturer, the materials supplier, and/or the materials manufacturer.

Qualification, with respect to a particular mode of failure, for use in defined service conditions also qualifies a material for use under other service conditions that are equal to or less severe in all respects than the conditions for which qualification was carried out.

It is the equipment user's responsibility to ensure that any material specified for use in their equipment is satisfactory in the service environment.

It is the equipment or materials supplier's responsibility to meet the metallurgical and manufacturing requirements, and, when necessary, any additional testing requirements, of ISO 15156 (all parts) for the material selected in the condition in which it enters into service.

It is the equipment or materials supplier's responsibility to comply with the requirements for the marking/documentation of materials in accordance with ISO 15156-2:2009, Clause 9, or ISO 15156-3:2009, 7.2, as appropriate.

This part of ISO 15156 applies to the qualification and selection of materials for equipment designed and constructed using conventional elastic design criteria. For designs utilizing plastic criteria (e.g. strain-based and limit-states designs), use of this part of ISO 15156 might not be appropriate and the equipment/material supplier, in conjunction with the equipment user, shall assess the need for other requirements.

6 Evaluation and definition of service conditions to enable material selection

6.1 Before selecting or qualifying materials using Parts 2 and 3 of ISO 15156, the user of the equipment shall define, evaluate and document the service conditions to which materials can be exposed for each application. The defined conditions shall include both intended exposures and unintended exposures that can result from the failure of primary containment or protection methods. Particular attention shall be paid to the quantification of those factors known to affect the susceptibility of materials to cracking caused by H_2S.

Factors, other than material properties, known to affect the susceptibility of metallic materials to cracking in H_2S service include H_2S partial pressure, *in situ* pH, the concentration of dissolved chloride or other halide, the presence of elemental sulfur or other oxidant, temperature, galvanic effects, mechanical stress and time of exposure to contact with a liquid water phase.

6.2 The documented service conditions shall be used for one or more of the following purposes:

a) to provide the basis for selection of SSC/SCC-resistant materials from existing lists and tables; see Clause 7;

b) to provide the basis for qualification and selection based upon documented field experience; see 8.2;

c) to define the laboratory test requirements to qualify a material for H_2S service with respect to one or more of SSC, SCC, HIC, SOHIC, SZC and/or galvanically induced HSC; see 8.3;

d) to provide the basis for the reassessment of the suitability of existing alloys of construction, using Clause 7 , 8.2 and/or 8.3, in the event of changes to the actual or intended service conditions.

7 Selection of materials, resistant to SSC/SCC in the presence of sulfides, from existing lists and tables

SSC-resistant carbon and low-alloy steels may be selected from the materials identified in ISO 15156-2:2009, Annex A.

SSC, SCC-resistant CRAs and other alloys may be selected from the materials identified in ISO 15156-3:2009, Annex A.

Generally, no additional laboratory testing of materials selected in these ways is required. The materials listed have given acceptable performance under the stated metallurgical, environmental and mechanical conditions based on field experience and/or laboratory testing. The equipment user should, nevertheless, give consideration to specific testing of materials for applications where they consider the potential consequences of failure make this justifiable (see **WARNING**).

NOTE The experience reflected in the requirements of NACE MR 0175:2003 is included in the lists and tables of materials of ISO 15156-2:2009, Annex A, and ISO 15156-3:2009, Annex A.

8 Qualification of materials for H_2S service

8.1 Material description and documentation

The material being qualified shall be described and documented, such that those of its properties likely to affect performance in H_2S-containing media are defined. The tolerances or ranges of properties that can occur within the material shall be described and documented.

Metallurgical properties known to affect performance in H_2S-containing environments include chemical composition, method of manufacture, product form, strength, hardness, amount of cold work, heat-treatment condition and microstructure.

8.2 Qualification based upon field experience

A material may be qualified by documented field experience. The material description shall meet the requirements of 8.1. The description of the service conditions in which the experience has been gained shall meet the relevant requirements of 6.1. The duration of the documented field experience shall be at least two years, and should preferably involve a full examination of the equipment following field use. The severity of intended service conditions shall not exceed that of the field experience for which documented records are available.

8.3 Qualification based upon laboratory testing

8.3.1 General

Laboratory testing can only approximate field service.

Laboratory testing in accordance with the ISO 15156 (all parts) may be used for the following:

— to qualify metallic materials for their resistance to SSC and/or SCC under service conditions up to the limits that apply to materials of similar types listed in ISO 15156-2 and ISO 15156-3;

— to qualify metallic materials for their resistance to SSC and/or SCC under service conditions with other limits;

EXAMPLE Qualification up to a higher-than-normally-acceptable level of H_2S, to a lower-than-normally-required test stress or to revised temperature limit(s) or to a lower pH.

— to qualify carbon and low-alloy steels with respect to their resistance to HIC, SOHIC or SZC;

— to qualify corrosion-resistant or other alloys with respect to their resistance to galvanically induced HSC;

— to provide qualification data for a material not currently listed in ISO 15156-2:2009, Annex A and ISO 15156-3:2009, Annex A in such a form that it may be considered for inclusion at a later date.

8.3.2 Sampling of materials for laboratory testing

The method of sampling the material for laboratory testing shall be reviewed and accepted by the equipment user.

The test samples shall be representative of the commercial product.

For multiple batches of a material produced to a single specification, an assessment shall be made of the properties that influence cracking behaviour in H_2S-containing environments; see 8.1. The distributions of these properties shall be considered when selecting samples for testing according to the requirements of ISO 15156-2 and ISO 15156-3. The materials in the metallurgical condition that has the greatest susceptibility to cracking in H_2S service shall be used for the selection of the test samples.

Materials source, method of preparation and surface condition of samples for testing shall be documented.

8.3.3 Selection of laboratory test methods

For carbon and low-alloy steels, test methods for SSC, HIC, SOHIC and/or SZC shall be selected from ISO 15156-2 as required.

For CRAs and other alloys, test methods for SSC, SCC and galvanically induced HSC shall be selected from ISO 15156-3 as required.