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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

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.

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.

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.

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.

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

— 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.

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).

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 %).

3.27
chemical activity
unit-less ratio of actual fugacity (of a gas species) divided by its fugacity at a conveniently defined reference state

Note 1 to entry: In this document, the term chemical activity is primarily used as a property of species in the liquid or aqueous phase, a "pseudo mole fraction", see also Notes in ISO 15156-2:2020, C.1.3.

3.28
fugacity
effective pressure of an ideal gas species, which has the same chemical potential (partial Gibbs free energy) as the real gas species

Note 1 to entry: In this document, the term fugacity is primarily used as a property of species in the gas phase, an "effective partial pressure", see also Notes in ISO 15156-2:2020, C.1.2.

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 the ISO 15156 series 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 document.

The equipment user shall determine whether or not the service conditions are such that the ISO 15156 series 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 the ISO 15156 series for the material selected in the condition in which it enters into service.

It is the equipment or materials supplier's responsibility to conform with the requirements for the marking/documentation of materials in accordance with ISO 15156-2:2020, Clause 9 or ISO 15156-3:2020, 7.2, as appropriate.

This document applies to the qualification and selection of materials for equipment designed and constructed using load controlled design methods. For designs utilizing strain-based design methods, use of this document might not be appropriate and other test methods, not addressed in the ISO 15156 series, might be required. The equipment/material supplier, in conjunction with the equipment user, shall define and agree on other testing requirements and acceptance criteria.

6 Evaluation and definition of service conditions to enable material selection

6.1 Before selecting or qualifying materials using ISO 15156-2 or ISO 15156-3, 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 (or H_2S concentration or chemical activity in the water phase), 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.

For systems with a gas phase, evaluations based on H_2S partial pressure imply an environmental severity that equals or exceeds that of the field service considered and are therefore acceptable. For gas-free liquid systems, an alternative approach to partial pressure is needed. ISO 15156-2:2020, Annex C, provides guidance in C.1 for systems with a gas phase to assess H_2S partial pressure and to reduce excess environmental severity by using H_2S fugacity, and in C.2 for evaluating gas-free liquid systems. This includes a recommendation to apply non-ideal thermodynamic rules for high pressure oil wells.

NOTE 1 The degree to which environmental severity, as characterized by H_2S partial pressure, exceeds that of the service environment considered, is determined by non-ideal thermodynamic effects. Generally, this degree increases with increasing pressure and decreases with increasing temperature.

NOTE 2 The environmental severity regions in ISO 15156-2, and the prequalified H_2S exposure limits in ISO 15156-3, are stated in terms of H_2S partial pressure. No guidance is given on equivalent regions or limits in terms of H_2S fugacity in the gas phase or H_2S chemical activity in the 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 15156-2:2020, Annex A.

SSC, SCC-resistant CRAs and other alloys may be selected from the materials identified in ISO 15156-3:2020, 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**).

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 series 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 15156-2:2020, Annex A and ISO 15156-3:2020, 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.

8.3.4 Conditions to be applied during testing

For qualification of carbon and low-alloy steels for general sour service applications or for more restricted application ranges, standardized test environments and mechanical test conditions shall be chosen from those described in ISO 15156-2.

For qualification of CRAs or other alloys for the restricted application ranges appropriate to each alloy type, the standardized test environments and mechanical test conditions shall be chosen from those described in ISO 15156-3.

For qualification of a material for use in application-specific service conditions, the equipment user shall take care to ensure that the test conditions and the test results obtained from them are appropriate for those specific service conditions. All the test conditions applied shall be at least as severe, with respect to the potential mode of failure, as those defined to occur in the field service (see 6.1). The pH applied shall represent the service in situ pH.

The justification of the selection of the test environment and mechanical test conditions with respect to a specific application shall be documented by the equipment user.

8.3.5 Acceptance criteria

Test acceptance criteria shall be as defined for each test method in ISO 15156-2 and ISO 15156-3.

9 Report of the method of selection or qualification

Materials selected or qualified in accordance with this document shall have the method of selection documented by reporting item a) from the following list, together with one other item [b), c), or d)]:

a) for all materials, evaluation of the service conditions (see 6.1);

b) for a material selected with respect to SSC and/or SCC resistance, from lists and tables (see Clause 7), documentation making reference to the relevant subclauses of ISO 15156-2 or ISO 15156-3.

c) for a material selected on the basis of field experience, documentation describing the following:

   1) mechanism(s) of cracking for which qualification and selection has been made;

   2) material used (see 8.1);

   3) field experience (see 8.2).

d) for a material selected on the basis of qualification by laboratory testing, a test report describing the following:

   1) mechanism(s) of cracking for which qualification and selection has been made;

   2) material selected for laboratory testing (see 8.1);

   3) selection, sampling, and preparation of test specimens (see 8.3.2);

   4) justification of the test environment and physical test conditions for qualification (see 8.3.3);

   5) test results that demonstrate conformance with ISO 15156-2 or ISO 15156-3 (see 8.3).

The equipment user shall be responsible for ensuring that the required documentation is prepared.

Bibliography

[1] NACE MR0175[1], *Sulfide stress cracking resistant metallic materials for oilfield equipment*

[2] NACE TM0177, *Laboratory testing of metals for resistance to sulfide stress cracking and stress corrosion cracking in H_2S environments*

[3] NACE TM0284, *Evaluation of pipeline and pressure vessel steels for resistance to hydrogen induced cracking*

[4] NACE MR0176, *Metallic materials for sucker-rod pumps for corrosive oilfield environments*

[5] EFC Publication 16[2], *Guidelines on materials requirements for carbon and low alloy steels for H_2S-containing environments in oil and gas production*

[6] EFC Publication 17, *Corrosion resistant alloys for oil and gas production: guidelines on general requirements and test methods for H_2S service*

[7] the ISO 15156 series maintenance website, http://www.iso.org/iso15156maintenance

1) www.nace.org

2) www.efcweb.org

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