INTERNATIONAL STANDARD

ISO 21457

First edition
2010-09-01

Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems

Industries du pétrole, de la pétrochimie et du gaz naturel — Choix des matériaux et contrôle de la corrosion pour les systèmes de production de pétrole et de gaz

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Reference number
ISO 21457:2010(E)

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Published in Switzerland

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Foreword

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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 21457 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

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Introduction

The provision of well-established and robust material selection guidelines offers a means of satisfying long-term materials performance that meet the minimum requirements for a broad range of end users in the petroleum, petrochemical and natural gas industries. An additional benefit can be to enable product suppliers to develop, manufacture and provide off-the-shelf equipment that meets these requirements.

Oil and gas production projects benefit from a structured evaluation of materials used for the different fluids being handled. Therefore, the main objective of this International Standard is to provide general requirements with guidelines for the selection of materials for systems and components, with due consideration to the transported fluids and the external environment.

It is the end user's responsibility to provide a project document with respect to implementation of the requirements and guidelines of this International Standard, and to specify the design conditions for material selection. In addition to the end user, the organization responsible for the facility or for the equipment design, or for both, is regarded as responsible for materials selection.

This International Standard is developed to provide responsible parties with a structured process to carry out materials selection in a consistent manner as a part of the engineering work, based upon a design basis for a particular installation. This International Standard is intended for use by oil companies and engineering contractors.

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Users of this International Standard are advised that further or differing requirements might be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is advisable that the vendor identify any variations from this International Standard and provide details.

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Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems

1 Scope

This International Standard identifies the corrosion mechanisms and parameters for evaluation when performing selection of materials for pipelines, piping and equipment related to transport and processing of hydrocarbon production, including utility and injection systems. This includes all equipment from and including the well head, to and including pipelines for stabilized products. This International Standard is not applicable to downhole components.

Guidance is given for the following:

- corrosion evaluations;
- materials selection for specific applications, or systems, or both;
- performance limitations for specific materials;
- corrosion control.

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This International Standard refers to materials that are generally available, with properties that are known and documented. It also allows other materials to be evaluated and qualified for use.

This International Standard does not provide detailed material requirements or guidelines for manufacturing and testing of equipment. Such information can be found in particular product and manufacturing standards.

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 15156-1[1)], *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*

ISO 15156-2[1)], *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[1)], *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*

1) ISO 15156 (all parts) has been adopted by NACE as NACE MR0175/ISO 15156.

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3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
aquifer water
water from an underground layer of water-bearing permeable rock or unconsolidated materials

3.1.2
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.

[ISO 15156-1:2009, definition 3.3]

3.1.3
corrosion-resistant alloy
alloy intended to be resistant to general and localized corrosion by oilfield environments that are corrosive to carbon steels

NOTE This definition is in accordance with ISO 15156-1 and is intended to include materials such as stainless steel with minimum 11,5 % (mass fraction) Cr, and nickel, cobalt and titanium base alloys. Other ISO standards can have other definitions.

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3.1.4
end user
owner or organization that is responsible for operation of an installation/facility

3.1.5
free-machining steel
steel composition to which elements such as sulfur, selenium or lead have been intentionally added to improve machinability

3.1.6
fugacity
non-ideal partial pressure that a component in a mixture exerts in the vapour phase when in equilibrium with the liquid mixture

NOTE The fugacity factor depends on the temperature and the total pressure.

3.1.7
glass-fibre-reinforced plastic
composite material made of thermosetting resin and reinforced with glass fibres

3.1.8
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

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NOTE Cracking results from the pressurization of trap sites by hydrogen. No externally applied stress is needed 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.

[ISO 15156-1:2009, definition 3.12]

3.1.9
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.

[ISO 15156-1:2009, definition 3.13]

3.1.10
liquid metal embrittlement
form of cracking caused by certain liquid metals coming into contact with specific alloys

3.1.11
low alloy steel
steels containing a total alloying element content of less than 5 % mass fraction, but more than that specified for carbon steel

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EXAMPLE AISI 4130; AISI 8630; ASTM A182 Grade F22[20].

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3.1.12
manufacturer
firm, company or corporation responsible for making a product in accordance with the requirements of the order, or with the properties specified in the referenced product specification, or both

3.1.13
marine atmosphere
atmosphere over and near the sea

NOTE A marine atmosphere will extend a certain distance inland, depending on topography and prevailing wind direction. It is heavily polluted with sea-salt aerosols (mainly chlorides).

[ISO 12944-2:1998, definition 3.7.4]

3.1.14
maximum operating temperature
maximum temperature to which a component is subjected, including during deviations from normal operations, such as start-up/shutdown

3.1.15
onshore
inland area with a non-chloride-containing atmosphere

3.1.16
operating temperature
temperature to which a component is subjected during normal operation

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3.1.17
pH stabilization
increasing the bulk pH by addition of a suitable chemical to reduce CO_2 corrosion in hydrocarbon systems with condensing water

3.1.18
pitting resistance equivalent number
PREN
F_{PREN}
number, developed to reflect and predict the pitting resistance of a stainless steel, based upon the proportions of Cr, Mo, W and N in the chemical composition of the alloy

NOTE 1 For the purposes of this International Standard, F_{PREN} is calculated from Equation (1):

$$F_{PREN} = w_{Cr} + 3{,}3(w_{Mo} + 0{,}5w_{W}) + 16w_{N} \quad (1)$$

where

w_{Cr} is the percent (mass fraction) of chromium in the alloy;

w_{Mo} is the percent (mass fraction) of molybdenum in the alloy;

w_{W} is the percent (mass fraction) of tungsten in the alloy;

w_{N} is the percent (mass fraction) of nitrogen in the alloy.

NOTE 2 Adapted from ISO 15156-3:2009, definition 3.10, and ISO 15156-3:2009, 6.3.

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3.1.19
type 13Cr
martensitic stainless steel alloys with nominal 13 % Cr mass fraction alloying

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EXAMPLE UNS S41000; UNS S41500.

3.1.20
type 316
austenitic stainless steel alloys of type UNS S31600/S31603

3.1.21
type 6Mo
austenitic stainless steel alloys with PREN $\geqslant$ 40 and a nominal Mo alloying content of 6 % mass fraction, and nickel alloys with Mo content in the range 6 % to 8 % mass fraction

EXAMPLE UNS S31254; UNS N08367; UNS N08926.

3.1.22
type 22Cr duplex
ferritic/austenitic stainless steel alloys with 30 $\leqslant$ PREN $\leqslant$ 40 and Mo $\leqslant$ 2,0 % mass fraction

EXAMPLE UNS S31803; UNS S32205.

3.1.23
type 25Cr duplex
ferritic/austenitic stainless steel alloys with 40 $\leqslant$ PREN $\leqslant$ 45

EXAMPLE UNS S32750; UNS S32760.

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3.1.24
stress corrosion cracking
SCC
cracking of metal involving anodic processes of localized corrosion and tensile stress (residual and/or applied)

NOTE 1 Parameters that influence the susceptibility to SCC are temperature, pH, chlorides, dissolved oxygen, H_2S and CO_2.

NOTE 2 The above definition differs from that of the same term given in ISO 15156-1:2009, definition 3.21, since it includes external environments.

3.1.25
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 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.

[ISO 15156-1:2009, definition 3.23]

3.2 Abbreviated terms

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AFFF aqueous film-forming foams

API American Petroleum Institute

ASCC alkaline stress corrosion cracking

ASME American Society of Mechanical Engineers

CP cathodic protection

CRA corrosion-resistant alloy

CUI corrosion under insulation

GRP glass-fibre-reinforced plastic

HAZ heat-affected zone

HB Brinell hardness

HDG hot-dip galvanized

HIC hydrogen-induced cracking

HRC Rockwell hardness C scale

HSC hydrogen stress cracking

HVAC heating-ventilation-air conditioning

MEG monoethylene glycol

MIC microbiologically induced corrosion

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PE polyethylene

PP polypropylene

PREN pitting resistance equivalent number

PTFE polytetrafluoroethylene

PVC polyvinyl chloride

SCC stress corrosion cracking

SMYS specified minimum yield strength

SS stainless steel

SSC sulfide stress cracking

SWC step-wise cracking

TEG triethylene glycol

UNS unified numbering system (for alloys)

4 Design information for materials selection

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This International Standard provides guidelines for material selection for oil and gas production facilities. To enable the contractor to perform the material selections for the facility, the end user should as a minimum provide the information specified in Table 1 at the time of enquiry and contract.

Table 1 — Design information for materials selection

Information to be provided	Subclause
Project design basis, ref. Annex A	6.1
Corrosion-prediction model	6.2.1 and 6.2.2.2
Future changes in reservoir H_2S- content	6.2.2.4
Methodology or model for pH calculation of produced water	6.2.3.2
Formation water analysis	6.2.3.2
Content of mercury in production fluids or gas	6.2.3.8
The oxygen content in de-aerated seawater for injection	6.3
Erosion-prediction model	6.5
Temperature limitations for use of stainless steels in marine atmosphere	6.6.2, Table 3
Compliance with DNV-RP-F112[21] for duplex stainless steel exposed to cathodic protection	6.6.4
Limitations in mechanical properties and use of materials	6.9
Temperature limitations for non-metallic materials	7.4.2, Table 9
Environmental requirements regarding use of corrosion inhibitors	8.1
Model for inhibitor evacuation, corrosion inhibition test methods and acceptance criteria	8.1
Use of external coatings to increase maximum temperature for stainless steel (SS)	8.3
Applicable standard for cathodic protection (CP) design to be defined	8.5.1
Strength and hardness limitation of fasteners in marine atmosphere	8.9

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5 Materials selection report

Corrosion evaluations and materials selection should be documented in a report for further use by the project and operations.

The following elements should be included:

— short description of the project and expected facilities, e.g. field layout, remoteness of location, manned versus unmanned facilities, etc.;

— materials-related design input data for the operating conditions during the design life of the facility, e.g. temperatures, pressures, fluid composition, sand production, etc. (see Annex A);

— corrosion evaluations and materials selection;

— requirements for corrosion inhibitor efficiency and availability;

— requirements for corrosion control, e.g. CP and coatings;

— requirements for corrosion monitoring;

— identification of uncertainties from a materials perspective, new application for materials, use of new grades;

— need for material qualification testing.

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6 General guidelines for corrosion evaluations and materials selection

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6.1 General

The materials selection process shall take into account all statutory and regulatory requirements. The project design criteria, such as design lifetime, inspection and maintenance philosophy, safety and environmental profiles, operational reliability and specific project requirements, should be considered.

In general, robust materials selection should be made to ensure operational reliability throughout the design life. For offshore installations and particularly subsea, access for the purposes of maintenance and repair can be limited and costly, and should be carefully considered in the design.

Materials selection should normally be based on an evaluation of corrosion and erosion as described in the following subclauses. All internal and external media should be considered for the entire design life. This should also include the stages of transportation, storage, installation, testing and preservation. Degradation mechanisms not specifically covered in this International Standard, such as fatigue, corrosion-fatigue, wear and galling, should be considered for relevant components and design conditions.

Mechanical properties and usage limitations for different material grades should comply with applicable design code requirements and guidelines given in 6.9. The material weldability should also be considered to ensure an effective fabrication.

Cost and material availability have a significant influence on materials selection, and evaluations should be made to support the final selection.

NOTE If life-cycle cost evaluations are considered appropriate, then ISO 15663-2 describes one methodology.

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