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AMENDMENT 1
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Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 1: General requirements and recommendations

AMENDMENT 1: Revised Clause 6

Industries du pétrole et du gaz naturel — Conception et exploitation des systèmes de production immergés —

Partie 1: Exigences générales et recommandations

AMENDEMENT 1: Révision de l'Article 6

Reference number
ISO 13628-1:2005/Amd.1:2010(E)

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.

Amendment 1 to ISO 13628-1:2005 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*. The changes are made mainly to Clause 6, which has been amended with a revised set of provisions that includes the general material design requirements and recommendations applicable to the complete subsea production system.

Introduction

This amendment is based on ISO 13628-1:2005, Clause 6; EEMUA Publication 194:2004; several NORSOK standards and many oil company and supplier material specifications.

This revised Clause 6 does not include detailed material requirements and recommendations, e.g. for manufacturing and testing. Such information is included in the product-specific parts of this part of ISO 13628. It is intended that there not be any duplication of this part of ISO 13628 with the other parts of ISO 13628, whereas there can be overlap of material requirements between product-specific parts. In case of conflict between this part of ISO 13628 and product specific parts, it is intended that the latter take precedence.

Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 1: General requirements and recommendations

AMENDMENT 1: Revised Clause 6

Page iii, Contents:

Replace the list of subclauses for Clause 6 with the following.

Page 1, Clause 2:

Add the following normative references:

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings. Informative supplement to part 1: Representative photographic examples of the change of appearance imparted to steel when blast-cleaned with different abrasives*

ISO 8503 (all parts), *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates*

ISO 9588, *Metallic and other inorganic coatings — Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 12944 (all parts), *Paints and varnishes — Corrosion protection of steel structures by protective paint systems*

ISO 15156 (all parts)[1)], *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

1) ISO 15156 (all parts) was adopted by NACE as NACE MR0175/ISO 15156[41].

ISO 23936-1, *Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production — Part 1: Thermoplastics*

Page 3, 3.1:

Add the following terms and definitions after 3.1.12.

3.1.13
carbon steel
alloy of carbon and iron containing up to 2 % mass fraction carbon, 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, 3.3]

3.1.14
corrosion-resistant alloys
CRAs
alloys that are intended to be resistant to general and localized corrosion in 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 steels with minimum 11,5 % mass fraction Cr, and nickel, cobalt and titanium base alloys. Other ISO documents can have other definitions.

3.1.15
low-alloy steel
steels containing a total alloying element content of less than 5 % mass fraction, but more than that for carbon steel

EXAMPLES AISI 4130, AISI 8630, ASTM A182 Grade F22[12] are examples of low alloy steels.

3.1.16
pitting resistance equivalent number
PREN
number developed to reflect and predict the pitting resistance of a stainless steel, based on the proportions of Cr, Mo, W and N in the chemical composition of the alloy

NOTE This number is based on observed resistance to pitting of CRAs in the presence of chlorides and oxygen, e.g. seawater, and is not directly indicative of the resistance to produced oil and gas environments.

$$F_{\mathrm{PREW}} = w_{\mathrm{Cr}} + 3{,}3(w_{\mathrm{Mo}} + 0{,}5w_{\mathrm{W}}) + 16w_{\mathrm{N}}$$

where

w_{Cr} is the mass fraction of chromium in the alloy, expressed as a percentage of the total composition;

w_{Mo} is the mass fraction of molybdenum in the alloy, expressed as a percentage of the total composition;

w_{W} is the mass fraction of tungsten in the alloy, expressed as a percentage of the total composition;

w_{N} is the mass fraction of nitrogen in the alloy, expressed as a percentage of the total composition.

3.1.17
sour service
service in an H_2S-containing (sour) fluid

NOTE In this part of ISO 13628, “sour service” refers to conditions where the H_2S content is such that restrictions as specified by ISO 15156 (all parts) apply.

3.1.18
sweet service
service in an H_2S-free (sweet) fluid

3.1.19
type 316
austenitic stainless steel alloys of type UNS S31600/S31603

3.1.20
type 6Mo
austenitic stainless steel alloys with PREN $\geqslant$ 40 and Mo alloying $\geqslant$ 6,0 % mass fraction, and nickel alloys with Mo content in the range 6 % mass fraction to 8 % mass fraction

EXAMPLES UNS S31254, N08367 and N08926 alloys.

3.1.21
type 22Cr duplex
ferritic/austenitic stainless steel alloys with 30 $\leqslant$ PREN $\leqslant$ 40 and Mo $\leqslant$ 2,0 % mass fraction

EXAMPLES UNS S31803 and S32205 steels.

3.1.22
type 25Cr duplex
ferritic/austenitic stainless steel alloys with 40 $\leqslant$ PREN $\leqslant$ 45

EXAMPLES UNS S32750 and S32760 steels.

Page 3, 3.2:

Add the following abbreviated terms.

CRA corrosion-resistant alloy

HB Brinell hardness

HIC hydrogen induced cracking

HRC Rockwell hardness C scale

MIC microbiologically influenced corrosion

SWC stepwise cracking

Page 42:

Replace Clause 6 with the following.

6 Materials selection and corrosion protection

6.1 General principles

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

Robust materials selection should be made to ensure operation reliability throughout the design life as the access for the purposes of maintenance and repair is limited and costly.

Materials selection should be based on an evaluation of corrosion and erosion as described within this clause. All internal and external media should be considered for the entire design life. Degradation mechanisms not specially covered in this part of ISO 13628 (e.g. fatigue, corrosion-fatigue, wear and galling), should be considered for relevant components and conditions.

Mechanical properties and usage limitations for different material grades shall comply with applicable design code requirements and guidelines given in 6.5. The material weldability should also be considered to avoid fabrication defects.

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 the methodology described in ISO 15663-2[43] can be helpful.

The end user shall specify how to implement the requirements and guidelines of Clause 6, and specify the design conditions. The scope of work in relevant contracts defines the responsible party for materials selection for the facility and/or equipment. Alternatives to the requirements in Clause 6 may be utilized when agreed between the user/purchaser and the supplier/manufacturer to suit specific field requirements. The intention is to facilitate and complement the material selection process rather than to replace individual engineering judgment and, where requirements are non-mandatory, to provide positive guidance for the selection of an optimal solution.

Similarly, the normative references in this part of ISO 13628 may be replaced by other recognized equivalent standards when agreed between the user/purchaser and the supplier/manufacturer.

Some common oilfield alloys are described in Table 1. This is, however, not meant to be an all-inclusive list and other alloys may be used.

6.2 Corrosivity evaluation

6.2.1 Design premise

The corrosivity evaluation shall consider all media exposed to the system components including the stages of transportation, storage, installation, testing and preservation. This typically includes

— seawater,

— produced fluids,

— drilling and completion fluids,

— hydraulic control fluid,

— chemicals such as inhibitors, well stimulation fluids, etc.

It is recommended that a compatibility matrix be developed showing to which media all components are exposed.

6.2.2 Internal corrosion

6.2.2.1 Hydrocarbon systems

A corrosion evaluation should be carried out to determine the general corrosivity of the internal fluids for the materials under consideration.

The corrosion evaluation should be based on a corrosion prediction model, or on relevant test or field corrosion data agreed with the end user. General and localized corrosion of carbon steel takes place over time, and the anticipated corrosion rate should be calculated for the operating conditions.

For wet hydrocarbon systems made of carbon and low-alloy steel or CRA, the corrosion mechanisms indicated in Table 1 should be evaluated. Details on mechanisms and parameters for consideration are given in ISO 21457[38].

Table 1 — Materials prone to corrosion mechanisms in hydrocarbon systems

Corrosion mechanism	Carbon and low-alloy steel	CRA
CO_2 and H_2S corrosion	Yes	Yes[a]
MIC	Yes	Yes
SSC/SCC caused by H_2S	Yes	Yes
HIC/SWC	Yes	No

[a] The presence of H_2S in combination with CO_2 can also lead to a localized attack of CRAs. The critical parameters are temperature, chloride content, pH and partial pressure of H_2S. There are no generally accepted limits and the limits vary with type of CRA.

In cases where the potential exists for significant sand production, a sand-erosion evaluation should be carried out. The evaluation should include sand-prediction studies in the reservoir to provide information regarding reservoir sanding potential, as well as an evaluation of possible erosion damage. Erosion-prediction models can be used to evaluate the likelihood of erosion damage; the model used should be specified by, or agreed with, the end user. Even where the predicted erosion rate is low, the potential for synergistic erosion-corrosion should be considered.

Chemicals for scale inhibition, scale removal and well stimulation may be corrosive and shall be considered in the corrosion evaluation.

6.2.2.2 Injection systems

Injection systems involve injection of water or gas into the sub-surface for disposal or stimulation purposes.

Water-injection systems include injection of de-aerated seawater, untreated seawater, chlorinated seawater, produced water, aquifer water and combinations and mixing of different waters.

NOTE Aquifer water comes from an underground layer of water-bearing, permeable rock from which ground water can be extracted. This water can be used for injection into oil-bearing reservoirs.

The most relevant corrosion mechanisms for injection of gas, produced water and aquifer water are as for the hydrocarbon carrying systems covered in 6.2.2.1 and the corrosion evaluation should be made accordingly. Details on mechanisms and parameters to consider are given in ISO 21457[38].

All components that can contact injection water should be resistant to well-treatment chemicals or well-stimulation chemicals if back-flow situations can occur.

6.2.3 External corrosion

External corrosion evaluations shall consider all of the following:

— atmospheric corrosion during transport;

— storage and construction;

— seawater corrosion during and after installation;

— availability of cathodic protection.

It has been shown that some materials, such as martensitic and duplex stainless steel and other high-strength alloys, are susceptible to hydrogen stress cracking if they are subjected simultaneously to stresses and cathodic protection. For guidelines in design and limitations in mechanical properties, see 6.5.

6.3 Corrosion control

6.3.1 Galvanic corrosion mitigation

Wherever dissimilar metals are coupled together, a corrosivity evaluation shall be made. Cathodic protection prevents galvanic corrosion externally when the different materials are in electrical contact with each other.

When the corrosivity assessment indicates that galvanic corrosion can be a problem for dissimilar metals in a hydrocarbon service, consideration should be given to applying mitigation measures. Examples of mitigation techniques are given in ISO 21457[38].

NOTE Additional recommendations with respect to preferential weld corrosion prevention can be found in EEMUA 194:2004, 3.5.8[40].

6.3.2 Weld overlay

Weld overlay materials on carbon steel should be applied when specified in Table 3. In corrosive hydrocarbon systems, weld overlay with a minimum as-finished thickness of 3,0 mm may replace a homogeneous CRA.

When alloy 625 is used as overlay metal, the maximum iron content at the finished surface should be 10 % of the mass.

In corrosive service, any hard-facing material applied to the substrate should have its corrosion-resistance properties documented to show its suitability for the intended service.

6.3.3 Chemical treatment

Corrosion inhibitors, oxygen scavenger or other chemicals can be used to reduce corrosion in production, injection-water and seawater systems. The efficiency in the specified service, as well as the compatibility with other chemicals being used, should be proven and documented.

Qualification testing should include all types of chemicals being injected simultaneously. This is particularly important for surface-active chemicals.

Biocides can be used in process systems, injection water systems, etc., to prevent bacterial growth and possible microbiologically induced corrosion problems.

Corrosion inhibitors can have a low efficiency to control corrosion of carbon or low-alloy steels in production wells, subsea trees and subsea piping systems. Effectiveness downstream of the X-mas tree should be evaluated on a case-by-case basis as it depends on the flow regime, piping configuration and injection point availability.

Welds in carbon steel systems for corrosive hydrocarbons should be included in the corrosion-inhibitor qualification testing.

6.3.4 Cathodic protection

Subsea installations shall be protected against corrosion using paint or other coating systems combined with cathodic protection. Cathodic protection prevents all kinds of metal-loss corrosion, including crevice corrosion, from taking place. Structures and all retrievable components should have self-supporting cathodic protection systems designed for the specified design life.

Cathodic protection shall be used for all metallic materials that are susceptible to seawater corrosion. An exception is made for components where it is impractical to obtain reliable electrical contact with the anode system. Such components shall be either made of seawater-resistant materials, or made from carbon steel with a sufficient corrosion allowance for the required lifetime.

NOTE Examples of materials that are regarded as resistant to corrosion when submerged in seawater and therefore do not require cathodic protection and coating, are as follows:

— titanium alloys;

  NOTE Some Ti alloys are susceptible to hydride formation when subjected to cathodic protection.

— stainless steels and Ni alloys with PREN ⩾ 40 (service temperature less than 20 °C);

— fibre-reinforced polymers.

The cathodic-protection design shall be based on an internationally recognized specification such as DNV-RP-B401[31] or NACE RP 0176[34]. Welded connections between anodes and parts being protected are recommended. The electrical continuity to the cathodic protection system shall be measured for all components and parts that do not have a welded connection to an anode. The maximum acceptable resistance required to ensure electrical continuity is 0,1 Ω. Particular attention shall be given to ensure that bolts are electrically continuous with the cathodically protected structure, e.g. by removal of the paint from the bolts and the surfaces underneath bolt heads/nuts/washers.

In order to ensure effective cathodic protection, surface coating of components and structures with complex geometry is required. Coating of tubing with outer diameter less than 25 mm (1,0 in) is not required.

6.3.5 Use of paint systems

Paint-system selection shall make due consideration to design, operating conditions and conditions during transport, storage, commissioning and installation. Sufficient temporary corrosion protection for the fabrication phase shall be provided.

As a minimum, the requirements in accordance with ISO 12944 (all parts) shall apply for all work. The paint products and systems shall be selected for seawater immersion in accordance with ISO 12944-5 and/or Table 2.

The paint systems shall be used in combination with cathodic protection. The paint break-down factor shall be in compliance with the CP design.

The paint systems in Table 2 are aimed at ambient operating temperatures and maximum 50 °C (122 °F). For higher operating temperatures, specific evaluation and performance documentation is needed. For temperatures between 50 °C and 100 °C (122 °F to 212 °F), two coats of immersion-grade epoxy phenolic each 125 μm, may be considered acceptable.

NOTE Immersion-grade epoxy phenolic systems tend to be rather brittle and are less suitable for items that are subject to significant elastic or plastic deformation.

Using an additional number of coats with a lower film thickness is acceptable provided that each coat is applied and cured in accordance with the paint manufacturer's recommendation.

Table 2 — Paint systems

<table>
<tr><th>Application</th><th>Surface preparation</th><th>Paint system</th></tr>
<tr><td>Submerged carbon steel</td><td>Cleanliness: ISO 8501-1 Sa 2½
Roughness: ISO 8503 (all parts)
Grade Medium G (50 µm to 85 µm, R_{y5})</td><td rowspan="2">Two-component epoxy system
Minimum number of coats: two
Minimum dry-film thickness of complete paint system: 350 µm</td></tr>
<tr><td>Submerged CRA</td><td>Sweep blasting with non-metallic and chloride-free grit to obtain an anchor profile of approximately 25 µm to 45 µm</td></tr>
</table>

6.4 Materials selection

6.4.1 Subsea systems

Table 3 presents materials that are typically selected for different systems. Deviations from materials selection specified in this part of ISO 13628 may be implemented if an overall cost, safety and reliability evaluation shows that the alternative is more beneficial.

All metallic materials shall be supplied according to a recognized international manufacturing standard.

Cathodic protection is assumed for all external seawater-exposed surfaces.

6.4.2 Fasteners

Material for fasteners shall be selected in accordance with the requirements of the applicable design code for the connection.

Fasteners in contact with the cathodic protection system shall be made of low-alloy steel. The specified minimum yield strength of the material shall not exceed 725 MPa. If cathodic protection cannot be assured, fasteners shall be made of seawater-resistant material. For further limitations in material property limitations, see 6.5.

Fasteners may be used in the black (uncoated) condition or coated with one of the following coatings for intermediate protection:

— heat-cured fluoro-polymer such as PTFE (provided electrical continuity to CP system is verified);

— electrolytic zinc plating;

— chemically converted coatings such a phosphates.

All plating materials shall be selected with due regard to national and international health, safety and environmental issues concerning manufacture and use.

Fasteners in low alloyed steel, with an actual tensile strength greater than 1 000 MPa or a hardness greater than 31 HRC and exposed to acid cleaning and/or electrolytic plating shall be baked in accordance with ISO 9588.

Table 3 — Materials selection for subsea systems

Application		Materials
Wellheads and X-mas trees	Wellhead equipment/X-mas trees for production	Carbon or low-alloy steel with alloy 625 overlay covering seal areas and other fluid-wetted areas Type 13Cr steel with/without Alloy 625 overlay at sealing surfaces depending on the fluid corrosivity
	Wellhead equipment/X-mas trees for de-aerated seawater	Carbon or low alloy steel internally clad with alloy 625 on all sealing surfaces or on all wetted surfaces
	Wellhead equipment/X-mas trees for aerated seawater	Carbon or low alloy steel internally clad with alloy 625 on all wetted surfaces
	Wellhead equipment/X-mas trees for produced water and aquifer water	Carbon or low alloy steel internally clad with alloy 625 on all wetted surfaces
Manifold piping	Piping systems for hydrocarbons Piping for produced water and aquifer water	Carbon steel (protected by corrosion inhibition): Carbon steel clad with CRA Type 22Cr duplex Type 25Cr duplex Type 6Mo
	Piping for de-aerated seawater	Carbon steel: type 22Cr duplex
	Piping for raw seawater	CRA with PREN $\geqslant$ 40 GPR and titanium alloys
	Controls/instrument tubing and fittings	Type 316 or CRA with a higher PREN value[a]
	Hydraulic fluids/glycol/methanol Chemical injection and annulus bleed systems	Type 316 or CRA with a higher PREN value
	Retrievable valve internals	Type 13Cr steel CRA with a PREN value higher than that of the body
	Non-retrievable valve internals	Alloy 718 CRA with a PREN value higher than that of the body
Production control systems	Umbilicals, metallic	Type 25Cr duplex Zinc-encapsulated carbon steel Zinc-encapsulated UNS S32001[b,c,d]
	Umbilicals, polymer hoses	Polyamide 11 Thermoplastic elastomer High-strength carbon or high-strength polymer fibres[e]

[a] Type 316 instrument lines are suitable for subsea applications provided that they are protected by cathodic protection. The use of type 316 is not recommended for instrument lines that are exposed to atmospheric conditions in tropical climates.

[b] Carbon steel and stainless steel with a PREN lower than that of type 316 can be used, provided that their suitability is documented by field experience and/or tests.

[c] Duplex stainless steels with PREN < 40 can be used if cathodic protection can be ensured.

[d] Carbon steel with external protection (cathodic protection in combination with coatings, such as organic or thermally sprayed aluminium) can be used if acceptable from the cleanliness requirements point of view.

[e] Documented functionality in relevant fluids with extrapolation of service life is required. This shall not be used for methanol service.

6.4.3 Sealing materials

All possible environmental conditions (including commissioning) should be considered when deciding on the optimum choice for ring gaskets. The seal ring shall, as a minimum, be resistant to the actual process environment.

For non-metallic seals, the possibility of crevice corrosion at the metal−to−non-metallic seal interface should be considered.

For raw seawater service, careful consideration should be given to assure adequate crevice- and galvanic-corrosion resistance of materials at the expected operating conditions.

Material for the seal ring in API ring-type joints are normally selected to be of a lower hardness than the flange material to assist seating and prevent permanent damage to the flange-ring groove.

Seal rings designed to operate within the elastic area, such as rings for hub connectors and compact flanges, should be made from a material with appropriate ductility and toughness properties. Selection of the seal ring material should also address any environmental limits imposed by other standards, such as ISO 15156 (all parts), if applicable.

6.4.4 Polymeric materials

The selection of polymeric materials, including elastomeric materials, shall be based on an evaluation of the functional requirements for the specific application. The materials shall be qualified according to procedures described in applicable material/design codes. Dependent upon application, properties for documentation and inclusion in the evaluation are

— thermal stability and ageing resistance at specified service temperature and environment,

— physical and mechanical properties,

— thermal expansion,

— swelling and shrinking by gas and by liquid absorption,

— gas and liquid diffusion,

— decompression resistance in high pressure oil/gas systems,

— chemical resistance,

— control of manufacturing process.

Necessary documentation of all properties relevant for the design, type of application and design life shall be provided. The documentation shall include results from relevant tests and confirmed successful experience in similar design, operational and environmental situations. Compatibility tests, acceptance criteria and methods for defining service life shall be established for all fluids being handled. Permeation rate and absorption of service fluids and gases and liquids present shall be given for all polymeric materials.

Polymeric sealing materials used in well completion components, subsea trees, valves in manifolds and permanent subsea parts of the production control system shall be documented. For these components, qualification of relevant materials shall be provided in accordance with ISO 23936-1.

6.5 Mechanical properties and material usage limitations

Mechanical properties (e.g. yield/tensile strength, hardness and impact toughness, and weldability), shall be considered in the selection of materials.

Exposure temperatures during intermediate stages, such as manufacturing, storage, testing, commissioning, transport and installation, should be considered when specifying the minimum design temperature.

The following guidelines for design and limitations in mechanical properties should apply, in general, for the selection of materials.

— The SMYS of steels intended for welding should not exceed 560 MPa. A higher SMYS is acceptable provided that documentation showing acceptable properties with respect to weldability and the properties of the base material, heat-affected zone and weld metal supports the selection. Exposure to all fluids specified in 6.2.1 shall be considered.

— Usage limitations for materials in H_2S-containing environments shall be in accordance with ISO 15156 (all parts).

— Free-machining steel grades shall not be used.

— Austenitic SS castings with PREN $\geqslant$ 40 should not be used for butt weld components due to risk of micro-cracking in HAZ in weldments.

— The hardness of weld and HAZ of any steel grade should not exceed 350 HV10 for non-sour service conditions.

— Titanium shall not be used for hydrofluoric acid or anhydrous methanol (A water content > 5 % volume fraction should be used).

For any component including fasteners that can be exposed to cathodic protection, the following additional limitations shall apply.

— The actual yield strength of any steel grade shall not exceed 950 MPa.

— The hardness of any steel grade shall not exceed 35 HRC or 328 HB.

NOTE For conversion of hardness numbers, ISO 18265[42] is used.

— For components made in duplex stainless steel, compliance with DNV-RP-F112[39] should be specified.

— The hardness of components in nickel-based alloys should not exceed hardness values stated in ISO 15156-3.

— Titanium shall not be used for submerged applications involving exposure to seawater with cathodic protection.

NOTE Practical design solutions including application of a suitable electrical isolation of the integrated titanium component can be agreed with end user.

Bibliography

Page 232, Bibliography:

Add date to Reference [10] ISO 15156-1: ISO 15156-1:2009.

Add the following references at the end.

[38] ISO 21457, *Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems*

[39] DNV-RP-F112, *Design of Duplex Stainless Steel Subsea Equipment Exposed to Cathodic Protection*

[40] EEMUA 194:2004, *Guidelines for materials selection and corrosion control for subsea oil and gas production equipment* (2nd edition)[2)]

[41] NACE MR0175/ISO 15156, *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

[42] ISO 18265, *Metallic materials — Conversion of hardness values*

[43] ISO 15663-2, *Petroleum and natural gas industries — Life-cycle costing — Part 2: Guidance on application of methodology and calculation methods*

2) The Engineering Equipment and Materials Users Association.

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