NORSOK STANDARD

M-001

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Materials selection

Provided by Standard Online AS for Mariano+Iannuzzi+/+GE+Oil+and+Gas 2014-10-20

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by the Norwegian Oil and Gas Association and the Federation of Norwegian Industries.

NORSOK standards are administered and published by Standards Norway.

Introduction

This NORSOK standard provides guidance and requirements for material selection and corrosion protection for hydrocarbon production and processing facilities and supporting systems for fixed offshore installations including subsea production systems.

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1 Scope

This NORSOK standard provides guidance and requirements for material selection and corrosion protection for hydrocarbon production and processing facilities and supporting systems for fixed offshore installations including subsea production systems. This NORSOK standard also applies for onshore terminals, except for structural and civil works. The basis for material selection and corrosion protection in this document is minimum 20 years design life.

This NORSOK standard gives guidance and requirements for:

- corrosion and material selection evaluations;
- specific material selection where appropriate;
- corrosion protection and corrosion control;
- design limitations for specific materials;
- qualification requirements for new materials or new applications.

2 Normative and informative references

The following standards include provisions and guidelines that through reference in this text constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

2.1 Normative references

API Std 6A718 *Nickel-Base Alloy 718 (UNS N07718) for Oil and Gas Drilling and Production Equipment*
API Spec 15 HR *Specification for High Pressure Fiberglass Line Pipe*
API Spec 15 LR *Low Pressure Fiberglass Line Pipe and Fittings*
API RP 6HT *Heat Treatment and Testing of Carbon and Low Alloy Steel Large Cross Section and Critical Section Components*
ASME B 31.3 *Process Piping*
ASTM A153 *Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware*
ASTM A193 *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*
ASTM A194 *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*
ASTM A320 *Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service*
ASTM A335 *Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*
ASTM A409 *Standard Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service*
ASTM A453 *Standard Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels*
ASTM A1014 *Standard Specification for Precipitation-Hardening Bolting (UNS N07718) for High Temperature Service*
ASTM D2992 *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings*
ASTM F467 *Standard Specification for Nonferrous Nuts for General Use*
ASTM F468 *Standard Specification for Nonferrous Bolts, Hex Cap Screws, Socket Head Cap Screws, and Studs for General Use*
DNV-OS-C501 *Composite components*
DNV-OS-E302 *Offshore Mooring Chain*
DNV-OS-E303 *Offshore Mooring Fibre Ropes*
DNV-OS-E304 *Offshore Mooring Steel Wire Ropes*
DNV-OS-F101 *Submarine Pipeline Systems*
DNV-RP-F102 *Pipeline Field Joint Coating and Field Repair of Linepipe Coating*
DNV-RP-F106 *Factory Applied External Pipeline Coatings for Corrosion Control*
DNV-RP-F112 *Design of Duplex Stainless Steel Subsea Equipment Exposed to Cathodic Protection*
DNV-RP-F202 *Composite Risers*

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EN 1090-3	*Execution of steel structures and aluminium structures – Part 3: Technical requirements for the execution of aluminium structures*
EN 10204	*Metallic products – Types of inspection documents*
EN 1999-1-1	*Eurocode 9: Design of aluminium structures – Part 1-1: General structural rules*
EN 13121-3	*GRP tanks and vessels for use above ground. Design and workmanship*
ISO 898	*Mechanical properties of fasteners made of carbon steel and alloy steel – All parts*
ISO 3506	*Mechanical properties of corrosion resistant stainless steel fasteners – All parts*
ISO 9588	*Metallic and other inorganic coatings – Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*
ISO 10423	*Petroleum and natural gas industries – Drilling and production equipment – Wellhead and christmas tree equipment*
ISO 10474	*Steel and steel products – Inspection documents*
ISO 10684	*Fasteners – Hot dip galvanized coatings*
ISO 13628	*Petroleum and natural gas industries – Design and operation of subsea production systems –* *Part 1: General requirements and recommendations* *Part 4: Subsea wellhead and tree equipment* *Part 7: Completion/workover riser systems* *Part 11: Flexible pipe systems for subsea and marine applications*
ISO 14692	*Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – All parts.*
ISO 15156	*Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – All parts.*
ISO 19902	*Petroleum and natural gas industries – Fixed steel offshore structures*
ISO 19906	*Petroleum and natural gas industries – Arctic offshore structures*
ISO 21457	*Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems*
ISO 21809	*Petroleum and natural gas industries – External coatings for buried or submerged pipelines used in pipeline transportation systems – All parts*
NORSOK A-001N	*Utvikling av NORSOK-standarder*
NORSOK L-001	*Piping and valves*
NORSOK N-004	*Design of steel structures*
NORSOK M-101	*Structural steel fabrication*
NORSOK M-102	*Structural aluminium fabrication (under development)*
NORSOK M-120	*Material data sheets for structural steel*
NORSOK M-121	*Aluminium structural materials*
NORSOK M-122	*Cast structural steel*
NORSOK M-123	*Forged structural steel*
NORSOK M-501	*Surface preparation and protective coating*
NORSOK M-503	*Cathodic protection*
NORSOK M-506	*CO_2 Corrosion rate calculation model*
NORSOK M-601	*Welding and inspection of piping*
NORSOK M-622	*Fabrication and installation of GRP piping systems*
NORSOK M-630	*Material data sheets for piping*
NORSOK M-650	*Qualification of manufacturers of special materials*
NORSOK M-710	*Qualification of non-metallic sealing materials and manufacturers*
NORSOK R-004	*Piping and Equipment Insulation*

2.2 Informative references

DNV-RP-O501	*Erosive wear in piping systems*
ISO 12944-3	*Paints and Varnishes – Corrosion protection of steel structures by protective paint systems – Part 3: Design considerations*

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3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the terms, definitions and abbreviations listed in ISO 21457 shall apply with exceptions as listed below.

3.1 Additional terms and definitions

3.1.1

bolt
externally partially threaded fastener with a head

3.1.2

can
verbal form used for statements of possibility and capability, whether material, physical or causal.

3.1.3

carbon steel type 235
carbon steel with SMYS ≤ 275 MPa and not impact tested

3.1.4

coating
A layer of a substance spread over a surface for protection or decoration; a covering layer

3.1.5

fastener
a metallic screw, nut, bolt, or stud having external or internal threads, with a nominal diameter of 6 mm or larger

3.1.6

fixed offshore installations
offshore installations for oil and gas processing, including facilities on jackets, gravity based and floating structures which are not planned to be moved ashore for maintenance during the design life

3.1.7

lean duplex SS
ferritic/austenitic stainless steel alloys with less alloying elements than type 22Cr duplex SS, PRE_N ≥ 28.

EXAMPLE: UNS S32003

3.1.8

lining
a coating or layer of sheet material adhered to or in intimate contact with the interior surface of a container. Used to protect the container against corrosion by its contents and/or to protect the contents of the container from contamination by the container material

3.1.9

may
verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.10

Notified Body
an organisation that has been accredited by a Member State to assess whether a product meets certain preordained standards.

3.1.11

PRE_N pitting resistance equivalent with nitrogen

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$$PRE_N = wt\%Cr + 3.3 \times wt\%Mo + 16 \times wt\%N$$

3.1.12

shall

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted

3.1.13

should

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred, but not necessarily required

3.1.14

small bore piping/tubing

defined as piping/ tubing 2 inch and below

3.1.15

splash zone

the zone of the platform that is alternately in and out of the water because of the influence of tides, winds and seas. The actual extension depends on astronomical tide range plus the wave height and should be defined in Design Basis. Including subsidence may be applicable.

3.1.16

sour service

exposure to oilfield environments that contain sufficient H_2S to cause cracking of materials by the mechanisms addressed by ISO 15156

3.1.17

thick film coating

thick film coating is understood as an abrasion resistant coating with thickness of minimum 1000 µm and applied in minimum 2 coats or layers

3.1.18

thin film coating

a thin film coating is understood as coating with < 50 µm thickness

3.1.19

type 22Cr duplex SS

ferritic/austenitic stainless steel alloys with $30 \leq PRE_N < 40$ and Mo ≥ 2.0 % mass fraction

EXAMPLE: UNS S31803; UNS S32205

3.2 Abbreviations

The following list abbreviations used in this standard:

AFFF	Aqueous Film Forming Foams
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
CA	corrosion allowance
CAPEX	capital expenditure
CO_2	carbon dioxide
CP	cathodic protection
CRA	corrosion resistant alloy
CRI	cuttings re-injection
CR_{in}	inhibited corrosion rate
CSCC	chloride induced stress corrosion cracking
DL	design life

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EDS	element data sheet
FRP	fibre reinforced plastic
GRP	glass fibre reinforced plastic
H_2S	hydrogen sulphide
HB	Brinell hardness
HDG	hot dip galvanized
HISC	hydrogen induced stress cracking
HRC	Rockwell hardness C scale
HVAC	heating, ventilation, and air conditioning
LDSS	lean duplex SS
MDS	material data sheet
MIC	microbiologically induced corrosion
NDT	non-destructive testing
OPEX	operational expenditure
PED	European Pressure Equipment Directive
PEX	cross-linked polyethylene
PRE_N	pitting resistance equivalent w/ nitrogen
PTFE	polytetrafluoroethylene
SM13Cr	Super 13 Chrome martensitic stainless steels
SMYS	specified minimum yield strength
SS	stainless steel
TSA	thermal spray aluminium
UNS	Unified Numbering System (for alloys)
WHRU	waste heat recovery unit

4 General principles for material selection and corrosion protection

4.1 Philosophy

The material selection process shall reflect the overall philosophy regarding design lifetime, cost profile (CAPEX/OPEX), inspection and maintenance philosophy, safety and environmental profile, failure risk evaluations and other specific project requirements.

End user requirements to philosophy may be defined in standards and/or design basis.

4.2 Material selection requirements

Material selection shall be optimised and provide acceptable safety and reliability. As a minimum, the following shall be considered:

- corrosivity, taking into account specified operating conditions including start up and shut-down conditions;
- design life and system availability requirements;
- failure probabilities, failure modes and failure consequences for human health, environment, safety and material assets;
- resistance to brittle fracture;
- inspection and corrosion monitoring;
- access and philosophy for maintenance and repair;
- minimum and maximum operating temperature;
- minimum and maximum design temperature;
- weldability (girth welds and overlay welds);
- hardenability (carbon and low alloy steels).

For the final material selection, the following additional factors shall be included in the evaluation:

- Priority shall be given to materials with good market availability and documented fabrication and service performance.
- Number of different materials shall be minimised considering stock, costs, interchangeability and availability of relevant spare parts.
- Environmental impact and authority permissions, e.g., on discharge of chemicals like corrosion inhibitors shall be considered.

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Materials listed in the tables under each section are the recommended options for material selection. All requirements, i.e. temperature limitations, in this document shall be fulfilled. Use of materials with equal or better performance shall be agreed with end user.

A material selection report shall be prepared in accordance with ISO 21457 Clause 5. The table in Appendix A shall be filled in by the end user as part of the contract agreement prior to start of work on the material selection report.

4.3 Corrosivity evaluation and corrosion protection

4.3.1 Internal corrosion allowance

ISO 21457, subclause 8.2 applies in full.

4.3.2 Corrosion mechanisms and parameters

ISO 21457, subclauses 6.2.2 and 6.2.3 apply with additions as shown below:

- The corrosion mechanisms in ISO 21457, Table 2 shall be evaluated.
- Based on operational experience CRAs will mitigate anaerobic MIC.

4.3.3 Corrosivity evaluations in hydrocarbon systems

ISO 21457, subclause 6.2.3 applies with additions as shown below:

- NORSOK M-506 is a recommended practice for the evaluation of CO_2 corrosion of carbon and low alloy steels. The application limits for H_2S and organic acids are given in the standard. The prediction model to be used for conditions beyond these limits shall be agreed with the end user.
- Calculated corrosion rates should be verified by end user in order to incorporate field experience.
- A corrosion evaluation with inhibition should be based on the inhibitor availability, considered as the time the inhibitor is present in the system at a concentration at or above the minimum dosage.
- The corrosion allowance is determined by the equation shown below. The corrosion rates without corrosion control shall be determined by NORSOK M-506.

$$CA = \sum_{i=1}^{n} [\frac{A}{100} \cdot CR_{in} + \left(\frac{100 - A}{100}\right) \cdot CR_u]_i$$

CA = corrosion allowance [mm]
A = availability of corrosion control [%]
N = number periods with constant conditions
CR_{in} = corrosion rate with corrosion control [mm/year]
CR_u = Corrosion Rate without corrosion control [mm/year]

Possibility for "sour" service conditions during the lifetime shall be evaluated. Sour service definition, metallic materials' requirements and qualification shall be according to ISO 15156 (all parts).

Drying or use of corrosion inhibitors shall not relax the requirement to use "sour" service resistant materials if the conditions otherwise are categorised as "sour" by the above documents.

If sand production and/or particles from well cleaning and squeeze operations are expected, an erosion evaluation shall be carried out. The evaluation should be based on DNV-RP-O501 or a model agreed with end user.

For pipelines an inhibited corrosion rate, CR_{in}, in the order of 0,1 to 0,2 mm/year shall be used. The inhibited corrosion rate shall, however, be documented by corrosion tests at the actual conditions, by relevant field or other test data. If corrosion inhibitors are used for (topside) process systems, ref. subclause 5.1, an increased value for the inhibited corrosion rate of 0,5 mm/year shall be used for design purposes.

The inhibitor availability to be used in a design calculation depends on the planned corrosion management programme, including corrosion monitoring and corrosion inhibition. Unless defined otherwise, an inhibitor availability of 0,90 (90 %) shall be used. Maximum inhibitor availability shall not

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exceed 0,95 (95 %). 0,95 inhibitor availability requires that a qualified inhibitor is injected from day one and that a corrosion management system is in place to actively monitor corrosion and inhibitor injection.

The inhibited corrosion rate includes the effect of glycol and/or methanol injection. Lower inhibited corrosion rates with glycol and/or methanol can be used when documented by tests or other relevant documentation. The effect of any inhibitor depends on reservoir conditions which may change during production time.

pH stabilisation can be used in condensed water systems to reduce the corrosion rate. pH stabilisation is only applicable in combination with glycol in sweet systems. Partial pH stabilisation combined with a film forming corrosion inhibitor can be used as an alternative for condensed water systems. The combined effect of inhibitors and pH adjustment shall be qualified and documented by corrosion tests unless relevant documentation exists. Use of NORSOK M-506 may not be relevant for such conditions. The corrosion rate to be used in the design calculations shall be agreed with the end user.

NOTE Deposits may prevent the corrosion inhibitor to reach the steel surface and the inhibitor efficiency may be reduced. Adsorption of the corrosion inhibitor onto sand or other surface active components may further deplete inhibitor from the solution inside the sand layer. Cleanliness of the system should therefore be taken into account when designing a system with corrosion inhibitor

4.4 External corrosion protection

Material selection and surface protection shall be such that general corrosion is cost effectively prevented and chloride stress corrosion cracking, pitting and crevice corrosion are prevented. Offshore the external atmospheric environment shall be considered wet and aggressive with the condensed liquid saturated with chloride salts. This should also apply for on-shore facilities located in a coastal environment.

Carbon steel shall always have external surface protection when exposed to external atmospheric environment. Guidelines and design criteria to avoid premature corrosion and degradation of coating and/or steel structures are given in ISO 12944-3.

4.5 Splash zone protection

Splash zone protection depends on the maintenance philosophy and the environmental conditions at the site.

For North Sea use, the following maintenance philosophy applies:

- Coating on risers will be repaired within 2 years after a damage exposing bare steel. Repair of coating on risers shall be based on project specific risk analysis and maximum 2 years.
- Coating on structural steel will not be repaired during the lifetime, and the selected coating shall be designed to perform for the entire DL.

The corrosion protection for permanently installed equipment shall consist of coating and corrosion allowance.

The corrosion allowance for structural steel shall be calculated as follows:

- CA in the splash zone for structural steel shall be minimum 5 mm for a coating as per NORSOK M-501 System 1 and 3 mm for a thick film coating
  For design life (DL) more than 17,5 years:
  CA = (DL – X years) x 0,4 mm/year, where X = 5 for a coating as per NORSOK M-501 System 1 and X=10 for a thick film coating. A thick film coating shall be in accordance with NORSOK M-501 System 7A with a thickness of minimum 1000 µm.

The corrosion allowance for risers shall be calculated as follows:

- CA for carbon steel and SM13Cr in the splash zone coated with 12 mm (nominal) vulcanised chloroprene rubber shall be minimum 2 mm.
- At elevated temperature the CA for carbon steel shall be increased by 1 mm per 10 °C increase in operating temperature above 25 °C;
- No CA is required for risers made of solid type 22Cr duplex and type 25Cr duplex SS with 12 mm (nominal) vulcanised chloroprene rubber.

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NORSOK M-501 System 2A shall not be used for splash zone protection of risers, but may be used for structural steel with minimum 3 mm CA.

4.6 Use of coating

Coating system selections for piping, structures and equipment shall make due consideration to design, operating conditions and conditions during storage and installation.

The coating systems selection and requirements to application shall be as specified in NORSOK M-501.

- Stainless steels do not have to be coated, except:
    - under insulation;
    - under pipe clamps;
    - when submerged in seawater.
- Stainless steel with $PRE_N \geq 40$ does not have to be coated under pipe clamps.
- Stainless steels type 316 used in hydrocarbon service shall always be fully coated unless when used in full HVAC controlled environments.

NOTE 1 HVAC controlled environments can be

- inside heated compartment/ rooms, or
- inside enclosures with IP protection (IP56), or
- inside HVAC/mechanically ventilated areas.

- Submerged small bore piping/tubing with cathodic protection do not require coating.

NOTE 2 Coating mainly required for reduction of CP current.

NORSOK M-501 System 2A may be used to prevent external SCC for temperatures above the critical limit as defined in subclause 6.3.4.

Line pipe and field joint coating for pipelines and risers shall comply with ISO 21809, DNV-RP-F102 or DNV-RP-F106.

The requirement for coating under insulation also includes stainless steels. Nickel based alloys, such as alloy 625, alloy C22, alloy C276 and titanium alloys do not need to be coated, even if insulated.

4.7 Cathodic protection

The cathodic protection design shall be in accordance with NORSOK M-503.

Surface coating shall in addition be used for all submerged components unless as listed in subclause 4.6.

CRAs resistant to seawater corrosion at operating temperature do not require cathodic protection. Temperature limits for chlorinated seawater as given in Table 10 applies also for natural seawater.

For materials susceptible to HISC special precautions shall be considered, see subclause 6.1.

4.8 Corrosion protection of closed compartments

For completely closed seawater filled compartments in carbon steel (e.g. in jacket legs, J-tubes and caissons) no internal corrosion protection is needed.

For compartments with volume to area ratios exceeding 1 m^3/m^2 and a possible, but restricted sea water exchange (e.g. subsea installations), treatment with oxygen scavenger can be used as an alternative to cathodic protection. For compartments with volume to area ratios less than 1 m^3/m^2, internal protection may not be necessary. In structural compartments with low water circulation where H_2S can be formed, zinc anodes should be used.

Closed structural compartments which are not filled with water need no internal corrosion protection if the compartments are completely sealed off by welding, or there is a proven gas tight gasket in any manhole or inspection covers.

4.9 Insulation, atmospheric exposure

Insulation for structures, vessels, equipment, piping systems etc. shall be according to NORSOK R-004 and ensure drainage at low points and access in areas where maintenance and inspection are required. Heat tracing shall to the extent possible be avoided in conjunction with stainless steel materials.

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Passive fireproofing materials for protection of structural steel or for area segregation should be of spray applied types. A corrosion protection coating system shall be applied to the steel. Further requirements are given in NORSOK M-501.

The use of cement type fire protection of aluminium structures should be avoided.

For coating under insulation, see subclause 4.6.

4.10 Galvanic corrosion prevention

Wherever dissimilar metals are coupled together in piping systems, a corrosivity evaluation shall be made. If galvanic corrosion is likely to occur, there are the following methods to mitigate it:

- Apply electrical insulation of dissimilar metals. Possible electrical connection via pipe supports, deck and earthing cables shall be considered.
- Install a distance spool between the dissimilar metals so that they will be separated by at least 10 pipe diameters from each other. The distance spool may be either of a solid electrically non-conducting material (e.g. GRP) or of a metal that is coated internally with an electrically non-conducting material, e.g. vulcanized rubber. The metal in the distance spool should be the most noble of the dissimilar metals unless vulcanized rubber lining is selected.
- Apply a non-conducting coating on the most noble of the dissimilar metals. The coating shall extend at least 10 pipe diameters into the most noble pipe material.
- Apply corrosion allowance on the less noble metal, e.g. in hydrocarbon systems.
- Install internal sacrificial anodes through access fittings near the interface, e.g. resistor controlled cathodic protection.

At galvanic connections between dissimilar materials without insulation or distance spool, it can be assumed that the local corrosion rate near the interface is approximately 3 times higher than the average corrosion rate, decreasing exponentially away from the interface within a length of 5 pipe diameters. This should be rates depending on area ratio and material combinations.

For connections between copper alloys and stainless steel/nickel alloys/titanium, the use of easily replaceable spools with added wall thickness should be evaluated.

In hydrocarbon systems, insulation spools shall be avoided and transitions shall normally be made in dry, inhibited or other areas with low corrosivity.

Direct contact between aluminium and carbon steel shall be prevented in marine environments. Aluminium and steel (carbon steel and stainless steel) surfaces shall in general be segregated with pads made of non-metallic materials such as rubber. For combinations carrying high loads type 316 SS shims can be used in between carbon steel and aluminium. Fasteners shall be made of type 316 SS grade 70 or 80 with type 316 SS plate washers used under both bolt head and nut. The plate washer shall not be thinner than 4 mm.

Direct connection between aluminium and copper alloys shall be avoided.

The use of isolation systems, e.g. an organic gasket or equivalent is not recommended.

Copper alloys will suffer from galvanic corrosion in combination with stainless steels and titanium in seawater systems.

4.11 Preferential weld corrosion

Care shall be taken when choosing welding consumables to make sure that the corrosion resistance of the entire weld metal, HAZ and base metal are compatible with the environment. In addition, corrosion testing may be necessary to demonstrate adequate corrosion resistance.

4.12 Weld overlay and hardfacing

ISO 21457, subclause 8.10 applies with the following additional requirements:

- Weld overlay on carbon steel shall be performed in accordance with NORSOK M-630, EDS NHF7.
- For equipment designed to other design codes than ASME B31.3, e.g. pressure vessels, pumps, X-mas tree, and pipeline components, the requirements for weld overlay given by the relevant design code shall as a minimum apply.

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- Hardfacing on piping, valves, and piping components shall be applied by spraying according to NORSOK EDS NHF2 or welding according to NORSOK EDS NHF1.
- For other equipment; e.g., pumps, pipeline components criteria in NORSOK EDS NHF1 and NHF2 should also be applied.
- Relaxation of hardness requirements according to ISO 15156 on substrate material after weld overlay on pressure vessels with min. 3 mm CRA 10 kPa H_2S (100 mbar) is subject to agreement with end user.

4.13 Chemical treatment

ISO 21457, subclause 8.1 applies in full.

For assessment of corrosion inhibitor the requirements in subclause 4.3.3 shall apply.

4.14 Corrosion management

4.14.1 General

A corrosion management program shall be prepared and implemented before start-up of production. Selection of CRAs will limit the need for inspection and monitoring. A corrosion management program for carbon steels used in corrosive service should as a minimum consist of the following parts:

- definitions of roles, responsibilities and reporting routines within the organisation;
- corrosion risk evaluation;
- planning and execution (methods, location and frequency) for corrosion monitoring, process parameter monitoring and water analyses;
- planning and execution of addition of corrosion control chemicals;
- develop procedures for evaluation of corrosion monitoring data and for verification that the corrosion rates and conditions are within acceptable levels (pre-defined targets);
- definition of consequences and actions if targets are not met.

4.14.2 Corrosion monitoring

Permanent corrosion monitoring shall always be used when the corrosion control is based on chemical treatment. The design of corrosion monitoring systems shall take into account the probability and consequences of failure. Typical monitoring methods and their application are given in Table 1.

Other methods that can be used to assess the corrosivity are fluid analyses and wall thickness measurements and various inspection methods.

It is recommended to use at least two methods. One method should always be weight loss coupon(s). To avoid flow interference, the distance between the probes should be at least 0.5 m.

Table 1 – Internal corrosion monitoring

Method	Applicable systems	Comments	Notes
Weight loss coupon	All systems	Coupon should be of the same/similar material as the wall. May include weld.	1
Linear polarisation resistance	Systems with an aqueous/electrically conducting phase	Requires normally approx. 30% aqueous phase with min. 0.1% salinity.	
Galvanic probes	Aqueous	Water injection systems.	
Electrical resistance	All systems	Downstream inhibitor injection points when monitoring pipelines.	
Erosion/sand monitoring probes	Process flowline systems Subsea production systems		
Hydrogen probes	Hydrocarbon systems	For sour service conditions.	
Notes 1. Recommended maximum time between inspection/replacement: 3 months.			

Probes for corrosion monitoring shall be located where there is a high probability of corrosion to occur, e.g. bottom of line in stratified flow, top of line in condensing systems in the corrosive phase. Where pigging and inspection tools will be used, the probes shall be mounted flush with the wall.

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Permanently installed corrosion monitoring systems subsea should be considered for systems applying chemicals to control internal corrosion. Permanently installed monitoring probes shall be installed at the dry termination(s) of pipelines.

Permanently installed monitoring systems for cathodically protected components should be considered when the components are not accessible for potential measurements. Monitoring can include both reference electrode(s) for potential measurement and monitored anodes for current determination.

Further guidance on corrosion monitoring is found in ISO 21457, Annex B.

5 Material selection for specific applications/systems

5.1 Introduction

Material selection is given below and limitations for material alternatives are given in Clause 6.

The recommended material selection is based on experience from the Norwegian Continental Shelf. Parameters such as local regulations, high cost for offshore work, tax regime and long design lives have led to focus on life cycle cost. The use of carbon steels has therefore been limited to subsea flowlines and piping and pipelines for dry gas and stabilised crude oil. Field developments in other locations may have other requirements that may give other solutions.

Corrosion inhibitors may have low efficiency in geometries such as bends, reducers and other flow restrictions. Carbon steels with corrosion inhibitors are therefore not recommended for wells, well heads, trees, manifolds or process systems handling unprocessed or partly processed fluids.

5.2 Well completion

Different fluids are used in the wells. Examples of such fluids are:

- completion and packer brine fluids;
- stimulation fluids;
- scale dissolvers;
- scale inhibitors;
- hydrate preventer

All fluids shall be qualified to ensure compatibility with relevant materials in the well completion. This includes both metallic and polymer materials.

5.3 Subsea and surface wellhead and christmas tree equipment

Material selection shall be in accordance with ISO 10423 and ISO 13628-1 and -4 with additional requirements as given below.

The following materials selection requirements apply for both subsea and surface wellheads and christmas trees:

- All production fluid or injection fluid wetted areas and sealing areas of carbon and low alloy steel shall be overlay welded with alloy 625.
- For low corrosivity fluids, overlay welding of fluid wetted areas may be omitted if agreed with the end user.
- EE material class shall be applied for non-production fluid wetted surfaces, in accordance with ISO 10423 for tree components. EE material class is also acceptable for surfaces that are only fluid wetted for short periods, such as the annulus lines.
- DD material class or better in accordance with ISO 10423 shall be applied for wellhead components
- Alloy 718 is sensitive to oxygen and should be used with care for water injection or cutting reinjection service.
- 13Cr4Ni (F6NM) shall not be used unless cladded with alloy 625.

The following quality requirements apply for both subsea and surface wellheads and christmas trees including wellhead extensions and conductor housing extensions:

- Product specification level (PSL) Level 3 and Level 3G shall be applied.
- Heat treatment process shall comply with API RP 6HT.

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- Components made of alloy 718 shall comply with API 6A718.
- Selection of low alloy steels shall be based upon verified hardenability through the critical cross section of the forged components.
- Testing for certifications of carbon and low alloy steels for pressure containing and primary load bearing components shall use sacrificial forgings or prolongations. Separate test coupons are not acceptable.
- Hardfacing of gate and seat shall be by thermal spraying of tungsten carbide. It is an option to follow the requirements in NORSOK M-630, EDS NHF2.

5.4 Structural materials

5.4.1 Steel

Materials selection shall be in accordance with NORSOK N-004 or alternatively ISO 19902. Requirements for applicable steel grades are defined in NORSOK material data sheets, NORSOK M-120.

Cast and forged structural steel shall be specified in accordance with NORSOK M-122 and NORSOK M-123, respectively.

Weldable cast and forged structural steel for Steel Quality Level I and II shall be specified in accordance with NORSOK M-122 and NORSOK M-123, respectively.

Materials for structures in arctic areas shall be made to ISO 19906.

Stainless steels such as type 316 SS or lean duplex SS for structural purpose do not require coating and may be used in secondary structural elements such as pipe supports, cable trays and wind-walls.

5.4.2 Aluminium base alloys

Aluminium base alloys shall be selected among those given in NORSOK M-121.

Fabrication of aluminium structures shall be according to NORSOK M-102 (under development) and EN 1090-3. The design shall be based on EN 1999-1-1 Part 1-1 to 1-4.

5.4.3 Fibre reinforced plastic

Components to be made from FRP/GRP materials shall be designed according to DNV-OS-C501.

All FRP/GRP products for topside applications shall have documented fire performance as specified by the Petroleum Safety Authority Norway (PSA) – Facility Regulation. Fire performance properties are not relevant for subsea applications.

5.5 Oil and gas production, process and produced water systems

Materials selection for the process system shall be evaluated based on type of service, weight and maintenance. Pressure rating, maximum/minimum design temperature and size shall be taken into account when selecting materials.

For produced water systems, ingress of oxygen should be considered.

Dry gas systems, stabilized crude etc. are considered to have low corrosivity.

Materials selection for production, process and produced water systems shall be as given in table 2.

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Table 2 – Materials for production, process and produced water systems

Systems/equipment	Materials
Wellhead equipment/X-mas trees	Low alloy steel with alloy 625 weld overlay on wetted surfaces.
Piping, valves, pumps and inline instruments	Type 22Cr duplex SS, type 25Cr duplex SS, type 6Mo SS.
Pressure vessels	Type 22Cr duplex SS, type 25Cr duplex SS, carbon steel with alloy 625, alloy 825 or alloy 904 clad or weld overlay
Vessel internals	316 SS, type 22Cr duplex SS, type 25Cr duplex SS
Piping and vessels in low corrosivity systems	CRA, carbon steel.
Flare systems	
Relief system	Type 6Mo SS, type 25Cr duplex SS for temperatures above – 46°C
Burner components	Alloy 800H, alloy 800HT, alloy 625, 310 SS or temperatures below 650°C.

5.6 Injection systems

5.6.1 Water injection

Internal organic lining should be considered for water injection flowlines.

Materials selection for seawater and injection systems shall be as given in Table 3.

Table 3 – Materials for water injection systems

Systems/equipment	Materials	Notes
Aerated seawater		1
Wellhead equipment/X-mas trees	Carbon steel with alloy 625 weld overlay on wetted surfaces	
Piping ,valves and inline instruments	Type 25Cr duplex SS, GRP, titanium.	2, 3 4
Pumps	Type 25Cr duplex SS	2
De-aerated seawater injection		
Wellhead equipment/X-mas trees	Low alloy steel with alloy 625 weld on wetted surfaces	
Piping ,valves and inline instruments	FRP/GRP, type 22Cr duplex SS, type 25Cr duplex SS.	3, 4
De-aeration tower	Carbon steel with internal organic coating/lining, with cathodic protection in bottom section.	
Pumps	Type 22Cr duplex SS, type 25Cr duplex SS	
Produced water and aquifer water injection		5

Notes
1. Temperature limits are given in Table 10.
2. See Clause 6 for design limitations.
3. FRP/GRP only for low pressure piping
4. For inline instruments alloy 625, alloy C276, alloy C22.may be used
5. Material selection as for de-aerated seawater

5.6.2 Gas injection

Materials for gas injection systems shall be the same as for the gas processing system, see Table 2. Pipelines for dry gas may be made from carbon steel. If the gas is not dehydrated, the system should be considered as a production system (wet gas).

5.7 Utility systems

5.7.1 Seawater systems

ISO 21457, subclause 7.4.3 applies with the following additional requirements:

- Seawater corrosion resistant materials shall be used for seawater systems.
- Materials selection shall take into account that most seawater for process use is chlorinated
- Internal cathodic protection of type 6Mo SS or type 25Cr duplex SS may be used for piping and components in chlorinated seawater systems provided that the operational conditions do not include full or partial draining of the systems.
- Threaded connections shall not be used.
- Graphite gaskets with type 316 SS reinforcement shall not be used.

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Materials selection for seawater systems as given in Table 4 of this standard shall apply. Temperature limitations for the different materials shall be as given in Table 10.

Table 4 – Materials for seawater systems

Systems/equipment	Materials	Notes
Vessels	Titanium, FRP/GRP, type 25Cr duplex SS	
Piping valves and inline instruments	Type 25Cr duplex SS, FRP/GRP, type 6Mo SS, titanium, carbon steel with polymeric lining.	1
Valves in GRP systems	FRP/GRP, Carbon steel with polymeric lining, NiAl bronze, titanium, type 25Cr duplex SS.	
Normally drained systems	Type 25Cr duplex SS, titanium.	
Pumps	Type 25Cr duplex SS	

Notes

1. For inline instruments alloy 625, alloy C276 and alloy C22 may be used in addition to materials listed

5.7.2 Waste heat recovery units (WHRU)

Waste heat recovery units may be installed in exhaust ducting from gas turbines etc. The corrosivity of the exhaust gas depends on the type and cleanliness of the fuel. Small amounts of sulphur in form of hydrogen sulphide or organic sulphur compounds in the fuel could result in condensation of sulphurous and/or sulphuric acid that has to be considered when selecting materials.

Material selection for waste heat recovery units is given in Table 5.

Table 5 – Materials for WHRU

System	Equipment	Material	Comments	Notes
Waste heat recovery unit and general exhaust ducting in cold casing design	Shell	External ducting: Type 316 SS + TSA externally	Internal surface protection is not required	1, 2
	Piping	Material to be resistant against chloride stress corrosion cracking	Carbon steel type ASTM A335 P11 or alloy 625 and fins in ASTM A409 for carbon steel may be considered.	
	Internal casing	Type 321 SS UNS S32100,		2
	Heat exchanger tube	Carbon steel ASTM A335 P11		2

Notes

1. Cold casing design: max 200°C external temperature.
2. Material selection for WHRU and exhaust ducting is based on cold casing design and shall be submitted to end user for review and approval. Sulphuric acid corrosion shall be considered.

5.7.3 Flare system

Minimum design temperature shall be considered for materials selection.

Piping and vessels in the relief system shall be made of type 6Mo SS or type 316 SS. Type 316 SS shall be externally coated for all temperatures. For parts of the system with minimum design temperature above -46°C, type 22Cr duplex and type 25Cr duplex SS may be used.

Type 316 SS valves may be used in type 6Mo piping.

Alloy UNS N08810/8811 (800 H/HT) shall be used for temperatures above 400°C for the flare tip assembly

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5.7.4 Other utility systems

ISO 21457, subclause 7.4.4 applies with the following additional requirement:

- Material selection for utility systems shall be in accordance with Table 6.

Table 6 – Materials for utility use

Service	Equipment	Materials	Notes
Fresh and potable water	Piping and vessels	GRP, type 22Cr duplex SS, Type 316 SS, Copper base alloys.	1
Open drain	Piping and vessels	Type 25Cr duplex SS, GRP/FRP	
Closed drain	Piping and vessels	Type 22Cr duplex SS, type 25Cr duplex SS, GRP/FRP	
Sewage	Piping	Type 316 SS, type 22Cr duplex SS, GRP/FRP.	2
Jet fuel	Piping	Type 22Cr duplex SS	
Dry fuel gas and diesel	Piping	Type 22Cr duplex SS	
	Tanks and vessels	Type 316 SS, type 22Cr duplex SS, carbon steel	3
Instrument air	Piping and vessels	Type 316 SS, type 22Cr duplex SS.	4
Instrumentation	Tubing	HVAC controlled environment: type 316 SS Marine: Type 6Mo SS, type 25Cr duplex SS	5
	Cable trays	Type 316 SS, aluminium, carbon steel HDG	6
Fire-fighting systems	Dry CO_2 systems	Carbon steel, CRA	
	Deluge system	See table 4	
	AFFF piping	Type 316 SS, type 22Cr duplex SS, FRP/GRP	
Freshwater / plant air / nitrogen	Piping, vessels and tanks	Type 316 SS, type 22Cr duplex SS, PEX	10
Lubrication and seal oil	Piping, vessels and tanks	Type 316 SS, type 22Cr duplex SS	5, 10
Hydraulic fluid	Piping and tanks	Type 316 SS, type 22Cr duplex SS.	10
Glycol	Piping, vessels and tanks	Type 316, type 22Cr duplex SS	10
Methanol	Piping, vessels and tanks	Type 316, type 22Cr duplex SS	10
Heating/cooling media	Piping and vessels	Carbon steel, type 22Cr duplex SS, CRA in heat exchangers	7, 8, 11
HVAC	Ventilation/air intake ducts	Type 316 SS, LDSS, Al alloys, carbon steel HDG	6
	Air handling units	Type 316 SS, LDSS, Al alloys	
	Seawater coils	Titanium.	
Miscellaneous chemical injection systems	Piping and tanks	FRP/GRP, type 316 SS, type 22Cr duplex SS, titanium grade 2	9

Notes

1. Large diameter piping and tanks can be made in internally coated carbon steel. Tanks not intended for potable water, shall in addition be cathodically protected. The national health authorities shall accept GRP, polypropylene and coating used for potable water tanks.
2. type 22Cr duplex SS for outdoor application
3. Diesel tanks in carbon steel should have a 3 mm corrosion allowance in the bottom section. In addition, the bottom and roof should be coated. Cathodic protection should be used only if corrosion products from the sacrificial anodes do not cause damage to the down-stream equipment. The same applies for use of Zn primers. No corrosion allowance is required for cathodically protected surfaces. Consider coating the entire diesel tank if corrosion products can be detrimental when stored product is utilized.
4. Type 316 SS is acceptable up to operating temperature 70°C provided located indoor in fully HVAC controlled environment and un-insulated.
5. In marine atmosphere there may be a high risk for localized corrosion of type 316 SS, in particular crevice corrosion under clamps. The use of alternative tubing material should be evaluated.
6. Hot dip galvanised carbon steel in fully HVAC controlled areas only.
7. Fresh-water heating and cooling media are normally treated with a corrosion inhibitor and an oxygen scavenger. In a freezing environment, it is normally mixed with TEG.
8. Requirements on internal cleanliness shall be considered when choosing materials for systems containing filters, nozzles and compact heat exchangers.
9. The combination of chemical and material should be considered in each case. Titanium grade 2, GRP or chlorinated polyvinyl chloride should be used for hypochlorite systems.
10. Lean duplex SS (LDSS) may be applicable for tanks, not for piping and pressure vessels
11. Plates in plate heat exchangers shall be made in titanium grade 1, alternatively in alloy 276 or C22

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5.8 Subsea pipelines and flowline systems

Material selection shall be based on a corrosion evaluation to subclause 4.3.3.

ISO 21457, subclause 7.5 applies with the following additional requirements:

- Pipeline systems shall be in accordance with DNV-OS-F101.
- Flexible flowlines and risers shall be in accordance with requirements in ISO 13628-11.

5.9 Subsea production and injection systems

5.9.1 General

Materials selections for subsea production and injection systems shall be as per requirements in ISO 13628, Part 1. (ISO 13628-1:2005/Amd.1:2010)

Non-retrievable valve internals shall be selected to be corrosion resistant in the actual environment regardless of PRE_N value of the valve body.

Material selection for subsea production and injection systems shall be as given in Table 7.

Table 7 – Materials for subsea production and injection systems

Systems/equipment	Materials	Notes
Wellhead equipment/X-mas trees	See subclause 5.3	
Large bore piping	Type 22Cr duplex SS, type 25Cr duplex SS, type 6Mo SS, carbon steel with alloy 625 weld overlay	1, 2
Large bore valve body and bonnet	Type 25Cr duplex SS, type 22Cr duplex SS, carbon steel with alloy 625 overlay welding, alloy 625 solid	1
Large bore valve internals	Type 22Cr duplex SS, type 25Cr duplex SS, Ni alloys as alloy 625, 716, 718, 725, 825, 925	2
Small bore piping/tubing and valves	Type 316 SS, type 22Cr duplex SS, type 25Cr duplex SS, type 6Mo SS, alloy 625	

Notes
1. CRA with PRE_N>40 is required for raw seawater
2. Carbon steel may be used for dry gas and deaerated water injection. Seal areas to be alloy 625 clad

5.9.2 Drilling and workover risers

Materials requirements given in ISO 13628-1 and -7 shall apply in full with the following additional requirement:

- Composite drilling risers shall be designed according to DNV-RP-F202.

5.10 Mooring systems for floating units

Material requirements for mooring chains as specified in DNV-OS-E302 and DNV-OS-E304 shall apply.

Material requirements as specified in DNV-OS-E303 shall apply for fibre ropes.

Steel wire rope segments shall have a protection system consisting of an outer jacketing (typically polyethylene or polyurethane), galvanised wires and a filler material to prevent ingress of water. In addition, zinc sacrificial wires may be incorporated.

5.11 Fastener materials for pressure equipment and structural use

5.11.1 General

Fastener materials shall be selected in accordance with the general requirements of the applicable design code.

Fasteners integrated in component bodies shall be of material that is compatible with the body with respect to thermal expansion, galling and corrosion properties. The minimum specified strength and/or hardness of the nut shall not be less than for the bolt to avoid thread stripping.

Body/Bonnet bolts for valves shall follow the requirements of NORSOK M-630 EDS NBO2

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Baking <u>shall</u> be specified for electrolytic zinc plated or HDG carbon and low alloy steel fasteners with an actual tensile strength greater than 1000 MPa or hardness greater than 32 HRC. Baking shall be performed in accordance with ISO 9588 to class ER-9.

Cadmium plating shall not be used.

5.11.2 Marine atmosphere

For structural purposes the hardness and strength class shall not exceed ISO 898 (all parts) class 10.9.

Fasteners with a diameter ≤ 10 mm shall be stainless steel according to ISO 3506-1 and2, Type A4 (type 316 SS) for temperatures < 60°C. For metal temperatures ≥60°C, materials resistant to stress corrosion cracking at the actual temperature shall be selected if the stressed parts are exposed to humid marine environmental conditions.

Recommendations for fastener materials for pressure containing applications in marine atmospheric environments are given in Table 8. In marine atmosphere, fasteners in low alloy steel should be hot dip galvanized (HDG) in accordance with ISO 10684 or ASTM A153. Polymeric coating with or without PTFE is alone not sufficient to provide corrosion protection in marine environment.

Type 25Cr duplex SS bolting in accordance with NORSOK M-630 MDS D-59 and D60 should be considered in topside condensing environment, e.g. seawater systems.

Table 8 – Design temperature range for fastener materials in marine atmospheric applications

Temperature range °C	Bolt	Nut	Size range mm	Notes
-100/+ 400	A320 Grade L7	A194 Grade 7/S3/S4/S5 or Grade 4/S3/S4/S5	≤ 65	
	A320 Grade L7M	A194 Grade 7M/S3/S4/S5	≤ 65	1
	A320 Grade L43	A194 Grade 7/S3/S4/S5 or Grade 7/S3/S4/S5	≤ 100	
-46/+ 400	A193 Grade B7	A194 Grade 2H	≤ 100	2
	A193 Grade B7M	A194 Grade 2HM	≤ 100	1
-46/+ 200	Type 25Cr duplex SS	Type 25Cr duplex SS	All	3, 4
-29/+ 540	A193 Grade B16	A194 Grade 7	≤ 100	3
-196/+ 540	A193 Grade B8M	A194 Grade 8M/8MA	≤ 100	5, 6

Notes

1. Minimum hardness shall not be less than 200 HBW or 93 HRB, i.e. not less than the minimum hardness of the bolt.
2. Minimum hardness shall not be less than 248 HBW or 24 HRC, i.e. not less than the minimum hardness of the bolt for size over 40 mm or M36.
3. The lower temperature limits are subject to different interpretations of PED, and shall be clarified for each project with the selected Notified Body.
4. As per NORSOK M-630 MDS D59 and D60. Shall not be used at maximum operating temperature above 110°C if exposed to wet marine atmosphere.
5. Type 316 SS bolts and nuts shall not be used at maximum operating temperature above 60°C if exposed to wet marine atmosphere. Alloy 718 may be considered as an alternative.
6. Use 8MA with class 1 bolts.

Certification of low alloy steel fasteners shall comply to NORSOK M-630 MDS X07/X08.

5.11.3 Fasteners for subsea applications

Low alloy steel fasteners shall be used for structural purposes and the hardness and strength class shall not exceed ISO 898 (all parts) class 8.8 or in special cases may be selected from Table 9.

Low alloy steel, type 316 SS, grade 660 SS and alloy 718 fasteners require electrical contact with the cathodic protection system. This can be ensured by removal of any paint coating at contacting surface or use of serrated washers. If electrical continuity to the cathodic protection system cannot be guaranteed or the fastener is intentionally isolated, the fastener material shall be resistant to both seawater corrosion and HISC.

Nickel alloy grades 625, 59 and 686 shall be used when corrosion resistant bolts are required, i.e. for conditions where the bolts are exposed to natural sea water and cathodic protection cannot be ensured. Alloy 625 can be used at ambient temperatures and alloys 59 and 686 can be used at elevated temperatures.

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Low alloy steel fasteners may be used in uncoated condition or coated with an intermediate protection, e.g. PTFE, electrolytic zinc plating or chemically converted coatings such as phosphates. All uncoated low alloy fasteners shall have a scale-free finish.

Table 9 lists acceptable product standards and material grades for fasteners for pressure containing equipment permanently installed subsea.

Max hardness shall be in accordance with the fastener standard and limits given in subclause 6.1 of this standard.

Table 9 –Fasteners for pressure containing purposes for subsea applications

Stud/bolt/screw	Heavy hex nut	Notes
A320 Grade L7	A194 Grade7/S3/S4/S5	
A320 Grade L7M	A194 Grade 7M/S3/S4/S5	
A320 Grade L43	A194 Grade 7/S3/S4/S5	
A193 Grade B8M Class 1	A194 Grade 8MA	
A193 Grade B8M Class 2	A194 Grade 8M A453 Grade 660 Class D	1, 2
A453 Grade 660 Class D	A453 Grade 660 Class D	
A1014 Grade API 6A 718	F467 Grade API 6A 718	
F468 Grade Ni 625	F467 Grade Ni 625	3, 4
F468 Grade Ni 59 or Ni 686	F467 Grade Ni 59 or Ni 686	5

Notes
1. For fasteners with nominal thread diameter d > 24 mm (1 in) the mechanical properties shall be agreed upon.
2. Alternatively fasteners to ISO 3506 (all parts) may be used up to maximum strength grade 80. Nuts shall be heavy hex.
3. Fasteners to be used without CP at ambient temperatures.
4. Alloy 625 to be solution annealed.
5. Fasteners to be used without CP at elevated temperatures.

The manufacturing process steps and pertaining inspection and testing shall be established for each type of fastener and manufacturing route and identify all subcontractors involved.

Oversizing of nut threads and under sizing of bolt/stud threads is not permissible.

Threads may be cut or rolled. Unified National Threads shall be “R” (UNR controlled radius) series.

Nuts for pressure containing and critical load bearing equipment shall be heavy hex type.

For all headed fasteners, the mechanical tests specified by the relevant product standards shall be performed on the finished fastener.

Positive material identification examination shall be performed for all fasteners materials made of stainless steels or nickel alloys prior to the shipment of the fasteners.

For fasteners manufactured directly from bars, the bar material certificate shall be attached to the fastener manufacturer’s certificate.

All fasteners supplied in bulk shall be delivered with a specific test report or certification according to the specified product standard.

All fasteners shall be delivered with material certificates in accordance with EN 10204 Type 3.1 or ISO 10474 Type 3.1.

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6 Design limitations for candidate materials

6.1 General

ISO 21457, subclause 6.9 shall apply with the below additional requirements.

For submerged parts that may be exposed to cathodic protection, the following shall apply:

- SMYS of carbon and low alloy steels intended for welding shall not exceed 560 MPa. A higher SMYS may be specified, provided that documentation showing acceptable properties with respect to weldability and the properties of the base material, heat-affected zone and weld metal is presented.
- For martensitic carbon, low-alloy and CRA, the hardness of any components shall not exceed 328 HB or 35 HRC.
- Ferritic-austenitic (duplex) stainless steel shall be regarded as potentially susceptible to HISC, independent of SMYS or specified maximum hardness. Compliance with DNV-RP-F112 shall be specified.
- Certain titanium alloys may not be compatible with cathodic protection.

6.2 Materials for structural purposes

6.2.1 Steel

Reference is made to NORSOK M-101, NORSOK M-120 and ISO 19902.

ISO 19902 may be applied for establishing Charpy impact test temperatures when design temperatures are below -14°C. The design class approach as described in ISO 19902, Appendix D of the standard, shall be selected.

ISO 19902 may also be used for design temperatures above -14 °C.

Guidance when using ISO 19902:

- The steel toughness classes and material requirements for base materials shall be as defined in Clause 19 and Appendix D and F.
- Correlation between design classes and steel toughness classes shall be as defined in Annex D.
- The fabrication, welding and inspection shall be in accordance with ISO 19902 and NORSOK M-101.
- The toughness requirements for weldments, extent and type of NDT shall comply with Annex F of ISO 19902.

For arctic conditions reference is made to ISO 19906.

6.2.2 Aluminium base alloys

Reference is made to subclause 5.4.2.

6.2.3 Glass fibre reinforced plastic

The design of GRP used for structural purpose (e.g. as protection structures, panels, gratings and secondary applications) shall be based on DNV-OS-C501.

6.3 Materials for pressure retaining purposes

6.3.1 General

Materials shall be used within the limits given in Table 10 and ISO 21457, Tables 4 – 11.

Piping design is covered by NORSOK L-001. Corresponding materials and fabrication requirements are given in NORSOK M-601, NORSOK M-622 and NORSOK M-630.

Recommendations for metallic materials for pressure retaining purpose with temperature limitations are given in Table 10.

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Table 10 – Metallic materials for pressure retaining purposes

Material	Minimum design temp. °C	Impact testing required	Maximum operating temp. °C		Notes
			Marine environment	Seawater	
Carbon and low alloy steel					
235	- 15				1
235LT	- 46	Yes			
360LT	- 46	Yes			
3.5 % nickel steel	-101	Yes			
Martensitic stainless steels					
SM13Cr	- 35	Yes			2, 3
13Cr	- 10				
13Cr valve trim parts	- 29				
13Cr4Ni	- 46	Yes			
13Cr4Ni double tempered	-100	Yes			
Austenitic stainless steels					
Type 316 SS	-196	Yes	60		4
Type 6Mo SS	-196	Yes	120	20	4
Duplex stainless steels					
Type 22Cr duplex SS	- 46	Yes	100		
Type 25Cr duplex SS	- 46	Yes	110	20	
Nickel base alloys					
Alloy 625	-200			30	
Titanium base alloys					5, 6
Grade 2	-60			85	7
Copper base alloys					8, 10
CuNi 90-10, CuNi 70-30, NiAl bronze	-100				6, 9
Aluminium base alloys	-270				6

Notes

1. Carbon steel type 235 can be used in piping systems with minimum design temperature down to -15 °C for thickness less than 12,7 mm.
2. A corrosivity evaluation shall be carried out if temperature > 90 °C, or chloride concentration > 5 %.
3. Impact testing for well completion shall be carried out at -10 °C or the min. design temperature if this is lower. Use of 13Cr at temperatures below -10 °C requires special evaluation.
4. For temperatures lower than -101 °C impact testing at minimum design temperature is required of weld metal.
5. No threaded connections acceptable in sea water systems.
6. Shall not be used for hydrofluoric acid or pure methanol (> 95 %). Titanium shall not be used for submerged applications, involving exposure to seawater, with cathodic protection unless suitable performance in this service is documented for the relevant operating temperature range.
7. Service restrictions shall be documented for other titanium grades.
8. Shall not be exposed ammonia and amine compounds.
9. Shall not be exposed to mercury or mercury containing chemicals
10. If used at higher temperatures, see subclause 6.3.4 for protection against chloride induced stress corrosion cracking.

6.3.2 Bending and cold forming of pipes

Bending of pipes shall be in accordance with NORSOK M-630, EDS NBE1 for cold bending and NBE2 for hot induction bending.

Generally cold bending of type 22Cr and type 25Cr duplex SS is not recommended for subsea applications as it may lead to residual stresses and increase the risk for HISC. For small-bore piping/tubing cold bending may be performed provided the resulting hardness is kept below limits set by ISO 21457, subclause 6.9.2.

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6.3.3 Fibre reinforced plastic

Design of piping systems in FRP/GRP materials shall in general be according to NORSOK M-622, ISO 14692 (all parts) and ASME B 31.3. The need for fire and impact protection shall be evaluated whenever FRP/GRP is used.

The use of FRP/GRP for piping systems is limited as follows;

- maximum internal design pressure is 40 barg;
- design temperature range from -40 °C up to 95 °C for epoxy and up to 80 °C for vinylester (according to qualifications);
- the possible hazard for static electricity build-up shall be accounted for.
- FRP/GRP tanks and vessels shall be designed according to EN 13121-3 and with the following limitations:
    - the potential hazard for static electricity build-up shall be accounted for;
    - the use for systems containing hydrocarbons shall be based on risk assessment.

For systems where FRP/GRP can be applied, epoxy and vinylester resins shall be evaluated as alternatives for vessels and tanks. Polyester resin can be used in tanks for seawater and open drain services.

For corrosive environments, both internally and externally, FRP/GRP material can be used as tubing, casing and line pipe. The FRP/GRP material used shall satisfy the requirements in API 15 HR or API 15 LR, depending on pressure.

If FRP/GRP is considered used as rigid pipe for downhole produced water and seawater injection tubing, material properties shall be documented in accordance with relevant API standards and ASTM D2992. FRP/GRP pipes can also be used as lining for downhole steel tubing with temperature and environmental limitations dependent on qualifications.

For other than seawater and fresh water, the fluid compatibility shall be documented in accordance with subclause 6.4.

6.3.4 Chloride induced stress corrosion cracking

Table 11 presents typical maximum operating temperature limits that have been applied to avoid CSCC for some types of uncoated SS in marine atmospheric environments.

The materials may be used at higher operating temperatures at marine installations within areas with full heating-ventilation-air conditioning (HVAC) control, in oxygen free environment or subsea with cathodic protection.

The type 22Cr duplex SS, type 25Cr duplex SS and type 6Mo SS materials coated with NORSOK M-501 system 2A may be used above these temperatures.

Titanium alloys, certain nickel based alloys and copper based alloys are recognized to be resistant to CSCC in marine atmosphere.

Table 11 – Maximum operating temperature for uncoated SS in marine atmospheric environments

Material type	Grade	Maximum operating temperature °C
Austenitic SS	Type 316	60
	Type 6Mo	120
Duplex SS	Type 22Cr	100
	Type 25Cr	110

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6.4 Polymeric materials

The selection of polymeric materials, included elastomeric materials, shall be based on a thorough 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 to be documented and included 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 for all important properties relevant for the design, area/type of application and design life shall be provided. The documentation shall include results from relevant and independently verified tests, and/or confirmed successful experience in similar design, operational and environmental situations.

Polymeric sealing materials wetted by bore fluids, (primary and secondary seals) for permanent subsea use and topside valves in critical gas systems shall meet the requirements of NORSOK M-710. Polymeric sealing materials in ISO 10423 designed equipment shall also conform to the requirements given in ISO 10423.

7 Qualification of materials and manufacturers

7.1 Material qualification

7.1.1 General

The selection of material for applications that may affect the operational safety and reliability level shall be made among the listed qualified materials.

The materials listed in Clause 5 shall be regarded as qualified when used within the design limitations given in Clause 6. Other materials can be added to those listed if adequate documentation is available and the objective of limiting number of material types and grades is maintained.

Qualified materials shall fulfil the following requirements:

- is listed by the relevant design code for use within the stated design requirements;
- is standardised by recognised national and international standardisation bodies;
- is readily available in the market and stocked by relevant dealers;
- is readily weldable, if welding is relevant, and known by potential fabricators;
- has a past experience record for the applicable use, e.g. same type of component and dimensional range.

7.1.2 Qualification by experience

Where the same type of material is regularly supplied for the same application, the qualification shall be based on experience. This applies to most materials supplied and used within the limitation of the design codes. The exception to this can be manufacturing of special components outside the normal dimensional range.

7.1.3 Qualification by general test data

Where well-known materials are used in "new" applications or "new" materials are to be used, the qualification may be by reference to results from relevant laboratory or production tests.

7.1.4 Qualification by specific test programme

When a material is proposed for a new application and the selection cannot be based on the criteria in subclauses 7.1.1 to 7.1.3, a qualification programme shall be initiated. The objective of the programme

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shall be clearly defined before starting any testing. Such objectives may be qualitative or quantitative and aim at defining if the product is acceptable or not for the design life of the system.

The qualification programme shall consider both the effect of the manufacturing route as well as fabrication on the properties obtained. Where possible, reference materials with known performance (good, borderline, or unacceptable) shall be included for comparison.

7.2 Manufacturer qualification

Under certain conditions it may be necessary to apply additional requirements to the potential or selected manufacturers to ensure their capabilities to supply the required material.

The special materials covered in NORSOK M-650 shall only be purchased from manufacturers qualified according to NORSOK M-650.

7.3 Familiarisation programmes for fabrication contractors

Fabrication contractors having limited experience with the specified material or with the intended fabrication procedures and equipment shall perform familiarisation and qualification programmes prior to initiating critical or major work during procurement, manufacturing, fabrication and construction. The purpose shall be to prequalify and verify the achievement of specified requirements on a consistent basis.

Areas identified which may require such familiarisation and qualification programmes are listed below:

- joining and installation of GRP components;
- welding and fabrication of aluminium structures;
- aluminium thermal spraying;
- internal vessel coating;
- wax coating of valves and other components;
- welding of steels with SMYS > 460 MPa;
- welding of stainless steel type 6Mo SS and type 25Cr duplex SS;
- welding of titanium;
- welding of aluminium;
- welding/joining of bimetallic (clad) pipes;
- cold forming.

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Appendix A Design basis for hydrocarbon systems

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DATA FORM FOR DESIGN BASIS INFORMATION FOR HYDROCARBON PROCESSING FACILITIES

Field name	
Contract name	
Contract No.	
Design life	

RESERVOIR DATA

Reservoir pressure		Type of fluid	
Reservoir temperature		Completion fluid composition	
Bubble point pressure		Design value for CO_2 content (mole fraction, %)	
Reservoir fluid density		Design value for H_2S content (mole fraction, %)	
Sand and silt production		Mercury	
Wax		Elemental sulphur	
		Presence of free water	

FORMATION WATER CHEMISTRY

Bicarbonate, HCO_3^- or total alkalinity	

Total amount of chlorides		Organic acids	

Na^+	K^+	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}	$Fe^{2+/3+}$	Cl^-	SO_4^{2-}	

PRODUCTION WELLHEAD DESIGN CONDITIONS

Shut-in pressure		Operation pressure	
Min. temperature		Operation temperature	
Max. temperature			

INJECTION WELLHEAD DESIGN CONDITIONS

Type of injection fluid	

Max. O_2 content		Max. design pressure	
CO_2 content (in gas phase)		Normal injection pressure	
H_2S content (in gas phase)		Min. temperature	

FLOWLINE DESIGN CONDITIONS

Design temperature		H_2S content	
Inlet temperature		Condensed or formation water	
Outlet temperature		Flowline inner diameter	

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DATA FORM FOR DESIGN BASIS INFORMATION FOR HYDROCARBON PROCESSING FACILITIES			
Design pressure		Flow regime	
Inlet pressure		Oil production rate	
Outlet pressure		Gas production rate	
CO_2 content in gas phase		Water production rate	

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<tr><td rowspan="4">Erosion prediction model (4.3.3)</td><td rowspan="4" colspan="2"></td><td rowspan="4">Maximum operation temperature for use of uncoated SS in marine environments (6.3.4)</td><td>Type 316 SS</td><td></td></tr>
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