

Materials selection

This NORSOK standard is developed with broad petroleum industry participation by interested parties in the Norwegian petroleum industry and is owned by the Norwegian petroleum industry represented by The Norwegian Oil and Gas Association and the Federation of Norwegian Industries. Please note that whilst every effort has been made to ensure the accuracy of this NORSOK standard, neither the Norwegian Oil and Gas Association nor the Federation of Norwegian Industries or any of their members will assume liability for any use thereof. Standards Norway is responsible for the administration and publication of this NORSOK standard.

Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

Copyrights reserved

Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum



Documents
Document Sharing Hub

Foreword	3
Introduction	3
1 Scope	4
2 Normative and informative references	4
2.1 Normative references	4
2.2 Informative references	5
3 Terms, definitions and abbreviations	6
3.1 Additional terms and definitions	6
3.2 Abbreviations	7
4 General principles for material selection and corrosion protection	8
4.1 Philosophy	8
4.2 Material selection requirements	8
4.3 Corrosivity evaluation and corrosion protection	9
4.4 External corrosion protection	10
4.5 Splash zone protection	10
4.6 Use of coating	11
4.7 Cathodic protection	11
4.8 Corrosion protection of closed compartments	11
4.9 Insulation, atmospheric exposure	11
4.10 Galvanic corrosion prevention	12
4.11 Preferential weld corrosion	12
4.12 Weld overlay and hardfacing	12
4.13 Chemical treatment	13
4.14 Corrosion management	13
5 Material selection for specific applications/systems	14
5.1 Introduction	14
5.2 Well completion	14
5.3 Subsea and surface wellhead and christmas tree equipment	14
5.4 Structural materials	15
5.5 Oil and gas production, process and produced water systems	15
5.6 Injection systems	16
5.7 Utility systems	16
5.8 Subsea pipelines and flowline systems	19
5.9 Subsea production and injection systems	19
5.10 Mooring systems for floating units	19
5.11 Fastener materials for pressure equipment and structural use	19
6 Design limitations for candidate materials	22
6.1 General	22
6.2 Materials for structural purposes	22
6.3 Materials for pressure retaining purposes	22
6.4 Polymeric materials	25
7 Qualification of materials and manufacturers	25
7.1 Material qualification	25
7.2 Manufacturer qualification	26
7.3 Familiarisation programmes for fabrication contractors	26
Appendix A Design basis for hydrocarbon systems	27

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.

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

EN 1090-3	<i>Execution of steel structures and aluminium structures – Part 3: Technical requirements for the execution of aluminium structures</i>
EN 10204	<i>Metallic products – Types of inspection documents</i>
EN 1999-1-1	<i>Eurocode 9: Design of aluminium structures – Part 1-1: General structural rules</i>
EN 13121-3	<i>GRP tanks and vessels for use above ground. Design and workmanship</i>
ISO 898	<i>Mechanical properties of fasteners made of carbon steel and alloy steel – All parts</i>
ISO 3506	<i>Mechanical properties of corrosion resistant stainless steel fasteners – All parts</i>
ISO 9588	<i>Metallic and other inorganic coatings – Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement</i>
ISO 10423	<i>Petroleum and natural gas industries – Drilling and production equipment – Wellhead and christmas tree equipment</i>
ISO 10474	<i>Steel and steel products – Inspection documents</i>
ISO 10684	<i>Fasteners – Hot dip galvanized coatings</i>
ISO 13628	<i>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</i>
ISO 14692	<i>Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – All parts.</i>
ISO 15156	<i>Petroleum and natural gas industries – Materials for use in H₂S-containing environments in oil and gas production – All parts.</i>
ISO 19902	<i>Petroleum and natural gas industries – Fixed steel offshore structures</i>
ISO 19906	<i>Petroleum and natural gas industries – Arctic offshore structures</i>
ISO 21457	<i>Petroleum, petrochemical and natural gas industries – Materials selection and corrosion control for oil and gas production systems</i>
ISO 21809	<i>Petroleum and natural gas industries – External coatings for buried or submerged pipelines used in pipeline transportation systems – All parts</i>
NORSOK A-001N	<i>Utvikling av NORSOK-standarder</i>
NORSOK L-001	<i>Piping and valves</i>
NORSOK N-004	<i>Design of steel structures</i>
NORSOK M-101	<i>Structural steel fabrication</i>
NORSOK M-102	<i>Structural aluminium fabrication (under development)</i>
NORSOK M-120	<i>Material data sheets for structural steel</i>
NORSOK M-121	<i>Aluminium structural materials</i>
NORSOK M-122	<i>Cast structural steel</i>
NORSOK M-123	<i>Forged structural steel</i>
NORSOK M-501	<i>Surface preparation and protective coating</i>
NORSOK M-503	<i>Cathodic protection</i>
NORSOK M-506	<i>CO₂ Corrosion rate calculation model</i>
NORSOK M-601	<i>Welding and inspection of piping</i>
NORSOK M-622	<i>Fabrication and installation of GRP piping systems</i>
NORSOK M-630	<i>Material data sheets for piping</i>
NORSOK M-650	<i>Qualification of manufacturers of special materials</i>
NORSOK M-710	<i>Qualification of non-metallic sealing materials and manufacturers</i>
NORSOK R-004	<i>Piping and Equipment Insulation</i>

2.2 Informative references

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

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 $\leq$ 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, $PRE_N \geq 28$.

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

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

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 H₂S 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 $Mo \geq 2.0$ % 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

EDS	element data sheet
FRP	fibre reinforced plastic
GRP	glass fibre reinforced plastic
H ₂ S	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.

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 CO₂ corrosion of carbon and low alloy steels. The application limits for H₂S 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.

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

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

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:
 $CA = (DL - X \text{ years}) \times 0,4 \text{ mm/year}$, 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.