NORSOK STANDARD M-001

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Materials selection

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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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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 Industry Association (OLF) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

Introduction

This NORSOK standard gives recommendations, requirements and guidelines for materials use in oil and gas production. This revision 4 includes requirements from NORSOK M-CR-505 "Corrosion monitoring design", which is withdrawn. The evaluation of internal corrosivity in hydrocarbon systems is rewritten and considers corrosion inhibitor availability instead of efficiency, and the maximum hardness and yield strength requirements of materials to be cathodically protected have been lowered.

This NORSOK standard is intended to comply with the requirements of the ”Pressure Equipment Directive” (PED) and the Norwegian implementation regulation ”Forskrift for trykkpåkjent utstyr” issued 9 June 1999. The requirements given for materials by PED, Annex I ”Essential Safety Requirements”, section 4.1, are fulfilled provided the principles of materials selection of this NORSOK standard are followed and documented.

The documentation requirement in PED, Annex I ”Essential Safety Requirements”, section 4.3, of the materials used in main pressure retaining parts of equipment in PED categories II, III and IV, shall take the form of a certificate of specific product control. This is fulfilled by the certification requirement given by the material data sheets compiled in NORSOK M-630.

The PED requires that the manufacturer provides documentation of elements relating to compliance with the material specifications of the PED in one of the following forms:

- by using materials which comply with a harmonised European standard;
- by using materials covered by a European approval of materials;
- by a PMA..

A particular appraisal has to be made to confirm compliance to PED for each particular installation.

1 Scope

This NORSOK standard provides general principles, engineering guidance and requirements for materials selection and corrosion protection for hydrocarbon production and processing facilities and supporting systems for fixed offshore installations. This NORSOK standard also applies for onshore terminals, except for structural and civil works.

This NORSOK standard gives guidance and requirements for

- corrosion and materials selection evaluations,
- specific materials selection where appropriate,
- corrosion protection,
- 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 which, 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 Spec 15 HR, High Pressure Fiberglass Line Pipe.
API Spec 15 LR, Low Pressure Fiberglass Line Pipe.
API Spec 17J, Unbonded Flexible Pipe.
ASME B 31.3, Process Piping.
ASTM A153, Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware.
ASTM A 193, Specification for Alloy - Steel and Stainless Steel Bolting Materials for High - Temperature Service.
ASTM A 194, Specification for Carbon and Alloy Steel Nuts for Bolts for High - Pressure and High-Temperature Service.
ASTM A 320, Specification for Alloy Steel Bolting Materials for Low - Temperature Service.
ASTM D 2992, Practice for Obtaining Hydrostatic or Pressure Design Basis for Fibreglass Pipe and Fittings.
BS 4994, Specification for design and construction of vessels and tanks in reinforced plastics.
BS MA 18, Salt Water Piping in Ships.
DIN 16965-2, Wound glass fibre reinforced polyester resin (UP-GF) pipes, Type B pipes, dimensions.
DIN 16966-1, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joint assemblies; Fittings; general quality requirements and testing.
DIN 16966-2, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joints; Elbows; Dimensions.
DIN 16966-4, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joints; Tees, Nozzles; Dimensions.
DIN 16966-5, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joints; Reducers; Dimensions.
DIN 16966-6, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joint assemblies; Collars, flanges, joint rings; Dimensions.
DIN 16966-7, Pipe joints and their elements of glass fibre reinforced polyester resins – Part 7: Bushings, flanges, flanged and butt joints; general quality requirements and test methods.
DIN 16966-8, Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joints; Laminated joints; Dimensions.
DNV RP B201, Metallic Materials in Drilling, Production and Process Systems.
DNV OS C501, Composite components.
DNV OS F101, Submarine Pipeline Systems.
DNV RP F201, Dynamic risers.
PED, Pressure Equipment Directive, 97/23/EC.
EN 10204, Metallic products – Types of inspection documents.

ISO 898,	Mechanical properties of fasteners.
ISO 3506-1,	Mechanical properties of corrosion resistant stainless steel fasteners – Part 1: Bolts, screws and studs.
ISO 3506-2,	Mechanical properties of corrosion resistant stainless steel fasteners – Part 2: Nuts.
ISO 13623,	Petroleum and natural gas industries. Pipeline transportations systems.
ISO 13628-2,	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 2: Unbonded flexible pipe systems for subsea and marine applications.
ISO 13628-5,	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5: Subsea control umbilicals.
ISO/DIS 13628-7,	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 7: Work over/completion riser systems.
ISO 14692-1,	Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – Part 1: Vocabulary, symbols, applications and materials.
ISO 14692-2,	Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – Part 2: Qualification and manufacture.
ISO 14692-3,	Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – Part 3: System design.
ISO 14692-4,	Petroleum and natural gas industries - Glass reinforced plastics (GRP) piping – Part 4: Fabrication, installation and operation.
ISO 15156-1,	Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials.
ISO 15156-2,	Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.
ISO 15156-3,	Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion resistant alloys) and other alloys.
NS 3420,	Beskrivelsestekster for bygg og anlegg (Specification texts for building and construction).
NS 3472,	Prosjektering av stålkonstruksjoner. Beregnings og konstruksjonsregler.
NS 3473,	Concrete Structures. Design Rules.
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.
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-601,	Welding and inspection of piping.
NORSOK M-622,	Fabrication and installation of GRP piping systems (draft standard).
NORSOK M-630,	Material data sheets for piping.
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.
ISO/DIS 13628-11,	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 11: Flexible pipe systems for subsae and marine applications.
MTI Manual No. 3,	Guideline Information on Newer Wrought Iron and Nickel-base Corrosion Resistant Alloys, Phase 1, Corrosion Test Methods. (Appendix B, Method MTI-2).
NORSOK M-506,	CO_2 Corrosion rate calculation model.

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1
C-glass
special fibre type that is used for its chemical stability in corrosive environments

3.1.2
can
verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.3
CAPEX
capital expenditure

3.1.4
corrosion resistant alloy
alloy which in a given environment shows negligible weight loss corrosion and no significant localised corrosion nor cracking problems

NOTE In this NORSOK standard it includes all metallic materials except carbon and low alloy steels and 3,5 % Ni.

3.1.5
E-glass
general purpose fibre that is most used in reinforced plastics

3.1.6
ECR-glass
modified E-glass fibre type with improved corrosion resistance against acids

3.1.7
free machining steel
steel to which elements such as sulphur, selenium or lead, have been added intentionally to improve machinability

3.1.8
glass fibre reinforced plastic
GRP
composite material made of thermosetting resin and reinforced with glass fibres as defined in ISO 14692-1

3.1.9
maximum operating temperature
maximum temperature predicted including deviations from normal operations, like start-up/shutdown, process flexibility, control requirements and process upsets

3.1.10
may
verbal form used to indicate a course of action permissible within the limits of the standard

3.1.11
operating temperature
temperature in the equipment when the plant operates at steady state condition, subject to normal variation in operating parameters

3.1.12
OPEX
operational expenditure

3.1.13
oxygen equivalent
mg/m^3 oxygen + 0,3 mg/m^3 free chlorine

3.1.14
pH stabilisation
increase in bulk pH to reduce corrosion in condensing water systems

3.1.15
pitting resistance equivalent
PRE
PRE = % Chromium + 3,3 x % Molybdenum + 16 x % Nitrogen

3.1.16
shall
verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.17
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 action is preferred but not necessarily required

3.1.18
descriptors used for metallic materials
Definitions of descriptors used for metallic materials in this NORSOK standard are given below.

Observe that non-inclusion in the table below does not imply that a material may not be used.

Generic type	**UNS**	**Typical alloy composition**			
		% Cr	**% Ni**	**% Mo**	**others**
Carbon and low alloy steels					
235[a]					
235LT					
360LT					
3,5 % Ni			3,5		
Martensitic stainless steels					
13Cr		13			
13Cr 4Ni		13	4		
SM13Cr		12	6	2	C < 0,015 %
S13Cr		12	6	2	
17 - 4 PH	S17400	17	4		Cu=4
Austenitic stainless steels					
310	S31000	25	20		
316	S31600	17	12	2,5	C ≤ 0,035
6Mo (PRE ≥ 40)	S31254 N08926 N08367	20 20 21	18 25 24	6 6 6	N = 0,2 N min. 0,15 N = 0,2
904	N08904	21	25	4,5	Cu = 1,5
Superaustenite (PRE ≥ 40)	S34565S31 266 S32654	24	17	4 to 5	Mn = 6 N = 0,40 to 0,60
Duplex stainless steels					
22Cr	S32205 S31803	22	5,5	3	N
25Cr (PRE ≥ 40)	S32550 S32750 S32760	25 25 25	5,5 7 7	3,5 3,5 3,5	N N N
Nickel base alloys					
Alloy C22	N26022	21	rem.	14	W = 3
Alloy C276	N10276	16	rem.	16	W = 4
Alloy 625	N06625	22	rem.	9	Nb = 4
Alloy 718	N07718	19	53	3	Nb = 5
Alloy 800H/Alloy 800HT	N08810/	21	33	-	Al + Ti

Generic type	UNS	Typical alloy composition			
		% Cr	% Ni	% Mo	others
	N08811				
Alloy 825	N08825	21	42	3	Ti
Co-base alloys					
Elgiloy	R30003	20	16	7	Co = 40
MP-35-N	R30035	20	35	10	Ti, Co rem.
Copper base alloys					
Cu-Ni 90-10	C70600	-	10	-	Fe, Cu rem.
Cu-Ni 70-30	C71500	-	31	-	Fe, Cu rem.
NiAl bronze	C95800	-	4,5	-	9Al, Fe, Mn, Cu rem.
Gun metal	C90500	-	-	-	10Sn, Zn, Cu rem.
Titanium					
Ti grade 2	R50400	-	-	-	C max. 0,10 Fe max. 0,30 H max. 0,015 N max. 0,03 O max. 0,25 Ti rem.

[a] This material does not comply with PED-requirements concerning documentation of impact toughness if specified according to NORSOK M-630.

3.2 Abbreviations

AFFF aqueous film forming foams
AWS American Welding Society
CRA corrosion resistant alloy
CSCC chloride induced stress corrosion cracking
CTOD crack tip opening displacement
EAM European approval of materials
EC European Commission
GRP glass fibre reinforced plastic
HAZ heat affected zone
HB Brinell hardness
HRC Rockwell hardness
HV Vickers hardness
HVAC heating-ventilation-air conditioning
MDS material data sheets
MTI Materials Technology Institute of the Chemical Process Industries
PED Pressure Equipment Directive
PMA Particular material appraisal.
PRE pitting resistance equivalent
SSC sulphide stress cracking
SMYS specified minimum yield strength
UNS unified numbering system

4 General principles for materials selection and corrosion protection

4.1 Philosophy

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

4.2 Materials selection requirements

Materials 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 for maintenance and repair.

For the final materials 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;
- the number of different materials shall be minimised considering stock, costs, interchangeability and availability of relevant spare parts.

Deviations from materials selections specified in this NORSOK standard may be implemented if an overall cost, safety and reliability evaluation shows the alternative to be more beneficial.

4.3 Corrosivity evaluation and corrosion protection

4.3.1 Internal corrosion allowance

A corrosion allowance of 3 mm is generally recommended for carbon steel piping, unless higher corrosion allowances are required. However, each system should be evaluated and the selected corrosion allowance be supported by corrosion evaluations. All piping classes in carbon steel grades in NORSOK L-001 have a corrosion allowance of 3 mm for standardization reasons.

For submarine pipeline systems a maximum corrosion allowance of 10 mm is recommended as a general upper limit for use of carbon steel. Carbon steel can be used in pipelines where calculated inhibited annual corrosion rate is less than 10 mm divided by design life. Otherwise corrosion resistant alloys, solid or clad or alternatively flexible pipe, should be used. For pipelines with dry gas or non-corrosive fluids, no corrosion allowance is required. Corrosion during installation and testing prior to start-up shall be considered.

4.3.2 Corrosivity evaluations in hydrocarbon systems

Evaluation of corrosivity shall as a minimum include

- CO_2-content,
- H_2S-content,
- oxygen content and content of other oxidising agents,
- operating temperature and pressure,
- organic acids, pH,
- halide, metal ion and metal concentration,
- velocity, flow regime and sand production,
- biological activity,
- condensing conditions.

A gas is considered dry when the water dew point at the actual pressure is at least 10 °C lower than the actual operation temperature for the system. Materials for stagnant gas containment needs particular attention.

NORSOK M-506 is a recommended practice for the evaluation of CO_2 corrosion.

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 percentage availability (A %) is defined as:

A % = 100 x (inhibitor available time)/(lifetime) (1)

Corrosion allowance (CA) = (the inhibited corrosion allowance) + (the uninhibited corrosion allowance) (2)

CA = (CRinhib x A %/100 x lifetime) + (CRuninhib x {1 – A %/100} x lifetime) (3)

where

CRinhib = inhibited corrosion rate.
CRuninhib = uninhibited corrosion rate (from NORSOK M-506 or other model).

At the design stage an assumption may be made that inhibition can decrease the corrosion rate to 0,1 mm/year. The inhibited corrosion rate shall, however, be documented by corrosion tests at the actual conditions or by relevant field or other test data. It should be noted that to achieve the target residual corrosion rate, high dosages of inhibitor may be required.

The inhibitor availablity 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 90 % shall be used. Maximum inhibitor availability shall not exceed 95 %. A 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. NORSOK M-506 does not apply for this case, and a corrosion rate of 0,1 mm/year shall be used for design purposes, unless field or test data are available.

Corrosion inhibitors may have low efficiency and are not recommended to reduce corrosion of carbon or low alloy steels in production wells, subsea trees and subsea piping systems.

Use of corrosion inhibitors in process systems is not recommended, but can be used provided the inhibitor in each process stream satisfies the inhibitor supplier's minimum recommended concentration for each stream and flow rate. Due to complex geometries and normally high flow rates, there is an increased risk for high inhibited corrosion rates locally in process systems compared to pipelines, which will influence the need for inspection and maintenance.

In pipeline systems carrying hydrocarbons with condensed water, the corrosivity may be reduced by application of inhibitors in combination with pH adjustment as an alternative to inhibitors alone. The combined effect of inhibitors and pH adjustment shall be qualified and documented by corrosion tests unless relevant documentation exists.

Vessel materials for oil separation and gas treating systems shall be selected based on the same corrosivity criteria as for hydrocarbon piping systems. Vessels manufactured in solid CRAs, internally CRA clad or weld overlayed, will not need additional internal corrosion protection systems.

Galvanic corrosion between CRA equipment and the vessel wall in internally paint coated (lined) carbon steel vessels shall be addressed in case of coating damages. As a minimum CRA support brackets shall be painted. Other protection methods like cathodic protection may be considered.

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.

4.3.3 External corrosion protection

Materials 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 with the condensed liquid saturated with chloride salts.

This may 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 criteria for steel structure design in order to avoid premature corrosion and degradation of coating and/or structures, are given in ISO 12944-3.

Corrosion resistant alloys should not be coated, except under insulation, under pipe clamps, and when submerged in sea water. Stainless steels may be coated at elevated temperature to reduce the probability for chloride induced stress corrosion cracking. Submerged small bore stainless steel piping with cathodic protection need not be coated.

4.3.4 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 structural steel will not be repaired during the lifetime. Coating on risers will be repaired within 2 years after a damage exposing bare steel. Then the corrosion protection for permanently installed equipment shall consist of coating and corrosion allowance calculated as follows:

- corrosion allowance for carbon steel in the splash zone with thin film coating: minimum 5 mm. For design lives more than 17,5 years: Corrosion allowance = (design life – X years) x 0,4 mm/year, where X = 5 for thin film coating and X = 10 for thick film coating. Thick film coating is understood as an abrasion resistant coating with thickness of minimum 1000 micron and applied in minimum 2 coats or layers;
- corrosion allowance for carbon steel and SM13Cr risers: minimum 2 mm in combination with minimum 12 mm vulcanised chloroprene rubber. At elevated temperature the corrosion allowance shall be increased by 1 mm per 10 °C increase in operating temperature above 25 °C;
- stainless steel risers: minimum 12 mm vulcanised chloroprene rubber.

4.3.5 Use of coating

Coating system selections for piping, structures and equipment shall make due consideration to structural 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.

The following areas/conditions shall be subject to special evaluation:

- coatings for areas in the splash zone;
- use of thermally sprayed aluminium coating for elimination of maintenance coating;
- coatings for passive fire protection;
- coatings for bolts and nuts, flanges, machined surfaces of valves, etc.;
- coating and/or insulation when connecting aluminium, stainless steel, carbon steel and other materials where galvanic corrosion may occur.

4.3.6 Cathodic protection

Cathodic protection shall be used for all metallic materials submerged in sea water, except materials which are immune to sea water corrosion. Surface coating shall in addition be used for components with complex geometry and where found to give cost effective design.

The extent and type of coating shall be determined by the following factors:

- cost savings due to reduced anode weight;
- required coating to obtain rapid polarisation, including use of shop primers only;
- required coating quality to obtain low coating breakdown;
- accessibility for coating application;
- cost saving by not coating weld and other areas subject to frequent inspection.

The cathodic protection design shall be based on NORSOK M-503. Welded connections are recommended for subsea applications. The electrical continuity to the cathodic protection system shall be verified by actual measurements for all components and parts not having a welded connection to an anode.

Any component permanently exposed to sea water and for which efficient cathodic protection can not be ensured, shall be fabricated in materials immune to corrosion in sea water. Exceptions are components where corrosion can be tolerated. Materials selection should take into account probability for, and consequence of, component failure.

The following materials are regarded as immune to corrosion when submerged in sea water:

- titanium alloys;
- GRP.

Alloy 625 and stainless steels with PRE ≥ 40 are borderline cases and should not be used for mechanical connections without cathodic protection when their material temperature exceeds ambient North Sea sea water temperatures. Threaded connections are particularly susceptible to crevice corrosion.

4.3.7 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.

4.3.8 Insulation, atmospheric exposure

Insulation shall be avoided to the extent possible, and only be used if required for safety or processing reasons. In wet saliferous atmosphere piping and equipment which have to be insulated shall be coated in accordance with NORSOK M-501.

The requirement for coating under insulation also includes CRAs. Titanium alloys need not be coated even if insulated.

The design of 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.

4.3.9 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. rubber. The metal in the distance spool should be the most noble of the dissimilar metals.
- 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 used to establish the magnitude of the corrosion allowances. Particular systems may have higher corrosion 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 shall 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.

For connections between aluminium and steel the following shall apply:

- bolts, nuts and washers shall be stainless steel type 316;
- the direct contact between aluminium and carbon steel shall be prevented by application of an insulation system, e.g. an organic gasket or equivalent. Alternatively the two materials may be separated by a 1 mm stainless steel barrier;
- if the environment can be defined as dry and non-corrosive, no special precautions are required, except that the contacting surface of the carbon steel shall be coated;
- if stainless steel bolts or screws are threaded into aluminium, a suitable thread sealant shall be applied to the threads to prevent ingress of water and corrosion of the threads.

Direct connection between aluminium and copper alloys shall be avoided.

4.3.10 Carbon steel welds

For pipe systems with corrosive service the welds shall be compatible with the base material in order to avoid local corrosion of the weldment and the heat affected zone.

Welds in submarine flowline and pipeline systems for corrosive hydrocarbons shall be qualified by corrosion testing under simulated operating conditions with and without corrosion inhibitors as a part of weld procedure qualifications, unless relevant documentation exist.

Welding consumables for water injection systems shall have a chemical composition according to NORSOK M-601 or have a composition which is documented not to give preferential corrosion in weld/heat affected zone.

4.4 Weld overlay

Weld overlay on carbon steel shall be used in accordance with Table 3. In corrosive hydrocarbon systems weld overlay giving minimum 3 mm thickness as-finished, may replace homogeneous corrosion resistant materials.

When Alloy 625 is used as overlay metal, the maximum iron content at the finished surface shall be 10 weight per cent.

Where weld overlay is used to prevent crevice corrosion in sea water systems, alloys with documented crevice corrosion resistance in the as weld overlayed condition shall be used. The maximum temperature shall be documented.

The use of MTI test procedure (see MTI Manual No. 3) is recommended for documentation of crevice corrosion resistance, using a tightening torque of 2 Nm.

The extent of weld overlay for hardfacing shall be as specified in relevant data sheets and shall be performed in accordance with requirements in NORSOK L-001. In corrosive service the hardfacing material as applied on the substrate shall have documented corrosion resistance.

4.5 Chemical treatment

Corrosion inhibitors, scale inhibitors, oxygen scavenger or other chemicals can be used to reduce corrosion in process, fresh water and sea water systems etc. when emission and/disposal of chemicals are accepted. The efficiency in the specified service shall be proven and documented as well as the compatibility with other chemicals to be used.

Chemicals can affect each other. Qualification testing should include all types of chemicals planned injected simultaneously. This is particularly important for surface active chemicals.

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

4.6 Corrosion monitoring

Internal corrosion monitoring shall be used in carbon steel systems with varying and/or uncertain corrosion rates. Permanent corrosion monitoring shall always be used when the corrosion control is based on chemical injection. This applies particularly for multiphase pipelines. The design of corrosion monitoring systems shall take note of probability of failure/damage and the consequences. Monitoring methods and systems where they can be used are given in Table 1. Other methods that can be used to assess corrosivity are water and other fluid analyses, and wall thickness measurements and inspection methods.

Table 1 - Internal corrosion monitoring

Method [a]	Applicable systems	Comments
Weight loss coupon [b]	All systems	Coupon should be of the same/similar material as the wall. May include weld.
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 Sub-sea production systems	
Hydrogen probes	Hydrocarbon systems	For sour service conditions.

[a] 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.
[b] Recommended maximum time between inspection/replacement: 3 months.

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

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.

5 Materials selection for specific applications/systems

5.1 Introduction

This clause gives requirements to material selection for specific areas and systems. The selections are based upon contemporary North Sea practice and available technology.

All bulk materials for piping systems and structural components shall comply with relevant NORSOK material data sheets. Materials selections are given below and limitations for material alternatives are given in Clause 6.

5.2 Drilling equipment

The materials used in drilling equipment shall be in compliance with relevant ISO standards or other internationally recognised standards.

5.3 Well completion

All well completion materials, including elastomers and polymeric materials, shall be compatible with produced/injected fluid. In addition, the materials shall as a minimum be compatible with the following well intervention fluids with additives for relevant exposure duration:

- completion and packer brine fluids;
- mud acids (HCl - hydrochloric acid, HF - hydrofluoric acid);
- stimulation fluids;
- scale inhibitors and chemicals used to dissolve scales;
- methanol;
- xylene.

Materials selection for well completion is given in Table 2.

Polymers shall satisfy the requirements given in 6.4.

Titanium alloys shall not be used in permanently installed well completion equipment when hydrofluoric acid or pure methanol (less than 5 % water) are planned to be used.

Flow couplings shall be used at transitions between CRA and low alloy tubing materials to allow for galvanic corrosion in injection wells. The sealing surface of couplings to be used should not be located in areas expected to be affected by corrosion. Alternatively, internal baked phenolic coating can be considered. For production wells, flow couplings may be evaluated for use upstream and downstream of components causing obstructions to fluid flow, such as for downhole safety valves.

For hydraulic control lines for downhole safety valves, stainless steel type 316 shall not be used above 60 ^{o}C. All materials shall have external thermoplastic sheathing resistant in the downhole environment. Clamps for cables and hydraulic control lines can be made in carbon or low alloy steel if the design allows for expected degree of corrosion.

Table 2 - Materials selection for wells

Well type	Tubing and liner	Completion equipment (Where different from tubing/liner)	NOTES
Production	13Cr is base case. See Table 6 for design limitations.		1
	Low alloy steel. (Option for systems with low corrosivity/short lifetime.)	13Cr	1, 2
	13 % Cr and 15 % Cr alloys modified with Mo/Ni (S13Cr), duplex and austenitic stainless steels and nickel alloys are options for high corrosivity		3
Aquifer water production	13Cr is base case		
Deaerated seawater injection	Low alloy steel	UNS N09925, Alloy 718 22Cr or 25Cr duplex	2, 4, 7
Raw seawater injection	Low alloy steel with GRP or other lining	Titanium. See also Table 6.	5, 8, 9
	Low alloy steel for short design life	Titanium. See also Table 6.	8, 9
	Titanium. See Table 6 for design limitations.		9
Produced water and aquifer water injection.	Low alloy steel	13Cr (limitations as for tubing for this service).	1, 2, 6
	Low alloy steel with GRP or other lining	13Cr (limitations as for tubing for this service).	1, 5
	13Cr. Provided oxygen < 10 mg/m^3, see also Table 6.		1
	22Cr duplex, Alloy 718, N09925. Provided oxygen < 20 mg/m^3.		
Gas injection	Materials selection shall be as for production wells and shall follow the guidelines in 4.3.2.		

Well type	Tubing and liner	Completion equipment (Where different from tubing/liner)	NOTES
Alternating injection and combination wells	Materials selection shall take into account that the corrosion resistance of different material alternatives will differ for various media.		

NOTES

1 For fluids with a partial pressure of H2S above 0,1 bar_g or pH below 3,5, 13Cr shall have a maximum SMYS of 560 MPa (80 ksi). Limiting the strength is generally recommended to avoid hydrogen stress cracking caused by hydrogen formed by galvanic corrosion of the casing.
2 Low alloy steel with corrosion allowance for tubing. Use of same CRA as for completion equipment shall be evaluated for liners.
3 Cold worked grades of duplex stainless steel shall be limited to 862 MPa (125 ksi) SMYS and maximum 966 MPa (140 ksi) actual yield strength in longitudinal and tangential direction.
4 Detailed materials selection for completion equipment to be based upon design requirements and supplier experience.
5 For GRP lining, qualification is required unless field experience can be provided. If GRP solid pipe is evaluated as an alternative for downhole tubing, see 6.3.3.
6 Corrosion inhibitors can be used in oxygen free systems provided acceptable from reservoir considerations.
7 Low alloy steel can be used in components located in lower sections of the well if strict dimensional tolerances in service are not required.
8 For short design lives and low temperatures, stainless steels or Ni-based alloys may be considered for completion equipment.
9 Raw seawater contains oxygen and may or may not contain chlorine.

5.4 Structural materials

5.4.1 Steel

Materials selection shall be in accordance with NORSOK N-004. For Norwegian onshore use NS 3472 applies. Requirements to applicable steel grades are defined in NORSOK material data sheets, NORSOK M-120 and NORSOK M-101. Cast and forged structural steel shall be as specified in NORSOK M-122 and NORSOK M-123, respectively.

Bolting materials shall comply with 5.6.

5.4.2 Concrete

For offshore load bearing concrete structures, concrete materials' properties shall comply with NS 3420, Exposure Class Ma - Highly Aggressive Environment, and NS 3473 or equivalent standards. Maximum water to binder ratio shall be 0,45.

5.4.3 Aluminium

Aluminium alloys shall be selected among those given in NORSOK M-121. Fabrication shall be in accordance with NORSOK M-102.

5.4.4 Glass fibre reinforced plastic (GRP)

GRP materials shall be selected and designed according to DNV OS C501.

5.4.5 Passive fireproofing materials

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.

For outdoor applications, or where the passive fireproofing is subjected to wear, impact or other mechanical damages, an epoxy based coating system shall be used. For other applications, cement type materials with a diffusion open top-coat can be used for steel structures.

5.5 Process facilities

5.5.1 General

Carbon steel can be used in process systems where the calculated annual corrosion rate is less than corrosion allowance divided by design life. For inhibitors in process systems reference is made to 4.3.2

The piping materials shall be standardised on the following material types as far as practical:

- carbon steel Type 235, Type 235LT, Type 360LT;
- stainless steel Type 316;
- stainless steel Type 22Cr and 25Cr duplex;
- stainless steel Type 6Mo;
- Cu-Ni 90-10;
- titanium;
- GRP.

Other materials shall only be introduced after their performance and availability have been considered.

Cast stainless steel Type 6Mo shall not be used for components to be welded.

Materials selections for process and utility use are given in Table 3 with amendments as given below. A premise for the selections in the table is limitation of number of grades and types for each application.

5.5.2 Oil and gas processing

For evaluation of corrosivity in a vessel (i.e. separator or scrubber) and in the liquid carrying piping downstream the vessel, the CO_2 and H_2S partial pressure in the gas carrying piping downstream the vessel can be used.

To compensate for the fact that these gases are not at equilibrium with the liquid in each vessel, the corrosion rate found by the prediction model in 4.3.2 shall be increased by 25 % for separators and liquid carrying piping downstream the separators. No compensation is required for gas scrubbers and liquid carrying piping downstream scrubbers.

Pressure rating, maximum/minimum design temperature and size shall be taken into account when selecting materials.

All components which may contact oil well streams shall be resistant against well treating and well stimulating chemicals and other additives.

5.5.3 Sea water systems

Sea water corrosion resistant materials shall be used for sea water systems, taking into account that most sea water for process use is chlorinated. Hot dip galvanised carbon steel with corrosion allowance can be used in sea water systems provided it is documented to be cost efficient and replacement is planned for in design if necessary. The galvanising shall be performed on completed spools to avoid welds without galvanising. If galvanised piping is evaluated for use in fire water systems, special measures shall be made to avoid plugging of sprinkler/deluge nozzles.

Important factors for design and operation of stainless steel sea water systems are as follows:

- threaded connections are not acceptable;
- commissioning and start-up of the systems should avoid chlorination the first two weeks.

In chlorinated sea water systems, internal cathodic protection of 6Mo or 25Cr duplex stainless steels may be used for piping and components provided that the operational conditions do not include full or partial draining of the systems. Internal cathodic protection shall not be used to protect complete piping systems in stainless steel type 316, but based on an evaluation in each case piping components in 316 may be internally cathodically protected.

Graphite gaskets shall not be used in sea water piping systems.

For piping downstream heat exchangers it shall be taken into account that relatively high operating temperatures may occur when marine fouling is not present inside the heat exchanger, i.e. initially and after cleaning operations.

Table 3 - Materials for process and utility use

	Materials	NOTES
Oil and gas production and processing	Corrosivity evaluations shall be based on 4.3.2 and 5.5.2.	
Wellhead equipment/X-mas trees	13Cr4Ni, Low alloy steel with Alloy 625 weld overlay.	1
Piping and vessels	22Cr duplex, 25Cr duplex, 6Mo, 316, Superaustenite. Carbon steel with internal organic lining.	2
Thick wall vessels	Carbon steel with 316/309 overlay, Alloy 625, Alloy 825 or 904 clad or weld overlay. Carbon steel with internal organic lining.	2
Piping and vessels in low corrosivity systems	Carbon steel.	
Inlet side of compressors	Carbon steel. Carbon steel with CRA weld overlay or solid CRA if required, based upon corrosivity evaluations.	
Piping, vessels for produced water	316, 22Cr duplex, 25Cr duplex, 6Mo, Titanium or GRP.	
Seawater systems and raw seawater injection	See also 5.5.3.	
Wellhead equipment/X-mas trees	Carbon steel with weld overlay according to 4.4	
Vessels	Titanium, GRP, carbon steel with internal rubber lining or organic coating in combination with cathodic protection.	
Piping materials	6Mo, 25 Cr duplex, Titanium, Cu-Ni 90-10, GRP.	3, 4
Piping components	6Mo, 25Cr duplex, Titanium, Alloy 625, Alloy C276, Alloy C22, Cu-Ni 90-10, NiAl bronze.	3, 4, 5, 6
Valves in GRP systems	GRP, Carbon steel with polymeric lining, NiAl bronze.	
Normally drained systems	Copper base alloys, 6Mo, Titanium. Carbon steel for short lifetimes, e.g. 5 years to 10 years.	3
Pumps	25Cr duplex, 6Mo, Titanium,	4, 7
Deaerated seawater injection	See also 5.5.4.	
Wellhead equipment/X-mas trees	Low alloy steel with Alloy 625 weld overlay in sealing surfaces.	
Piping	Carbon steel, GRP.	
Deaeration tower	Carbon steel with internal organic coating, plus cathodic protection in bottom section.	
Pump and valve internals	Provided carbon steel housing: 13Cr4Ni, 316, 22Cr duplex, 25Cr duplex.	7
Produced water and aquifer water injection	316, 22Cr duplex, 6Mo, Titanium, GRP. Wellhead and X-mas trees as for deaerated seawater injection.	
Fresh and potable water	Hot dip galvanised carbon steel, GRP, Polypropylene, 316, Copper base alloys.	8
Drains and sewage		
Open drain	GRP, carbon steel.	
Closed drain without oxygen	316, carbon steel.	
Closed drain with oxygen	22Cr duplex, 25Cr duplex, 6Mo, Titanium, GRP.	
Sewage	GRP, polyethylene.	
Flare systems		
Relief system	316, 6Mo, low temperature carbon steel.	
Burner components	Alloy 800H, Alloy 800HT, Alloy 625. For temperatures below 650 °C: 310.	
Flare boom	Structural steel with thermally sprayed aluminium.	
Dry fuel gas and diesel	Carbon steel.	
Piping	Carbon steel.	
Tanks	Carbon steel, GRP.	9
Lubrication and seal oil	316, 22Cr duplex, 6Mo.	10
Hydraulic fluid	316, carbon steel upstream filters.	10
Instrument air	316, carbon steel upstream filters.	10
Inert gas/plant air piping	Carbon steel, 316.	

	Materials	NOTES
Instrumentation		
Tubing	316, Alloy C276, 6Mo, 25 Cr duplex, Titanium.	4,10, 11, 14
Junction boxes/cabinets	GRP, 316.	
Cable trays	316; Hot dip galvanised carbon steel in fully HVAC controlled areas.	
HVAC ducts and units		
Ventilation/air intake ducts	316, Hot dip galvanised steel.	12
Air handling units	316.	
Seawater coils	Titanium.	
Active fire fighting systems		
Dry CO_2 systems	Carbon steel.	
Freshwater/plant air/nitrogen	316.	4
Glycol	Carbon steel, 316.	
Methanol	Carbon steel, 316.	
AFFF	316, GRP.	
Heating/cooling media	Carbon steel. CRA in heat exchanger tubes.	
Miscellaneous chemical systems	GRP, 316, 6Mo, Titanium.	13
Bolting materials	See 5.6	

NOTES

1 Sealing surfaces of components in Type 13Cr4Ni shall be overlay welded with Alloy 625. For wells with low corrosivity and/or short lifetime, low alloy steel with Alloy 625 weld overlay in sealing surfaces only can be used. For weld overlay, see 4.4.
2 Pressure vessels operating with low and moderate pressures can be made of carbon steel with internal lining. Sacrificial anodes may be required. Regular inspection and coating repairs shall be accounted for.
3 Copper alloys shall not be used in combination with CRAs and titanium. Exception can be components in fire water systems, provided galvanic corrosion can be avoided by proper isolation. If electrical isolation (15 000 ohm in dry system) is ensured and verified after installation, mechanical connections between bronze/brass and noble alloys such as Type 6Mo and titanium alloys are acceptable.
4 See Clause 6 for design limitations.
5 Shall also be used for process wetted parts of instrument systems.
6 See 6.3 for design limitations. Weld overlay can be applied to prevent crevice corrosion, see 4.4.
7 Ceramic filled epoxy coatings can be used for shorter lifetimes, e.g. 5 years to 10 years.
8 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. GRP, polypropylene and coating used for potable water shall be accepted by the national health authorities.
9 Tanks in carbon steel shall have 3 mm corrosion allowance at the bottom section. In addition the bottom and roof shall be coated. Cathodic protection shall only be used if corrosion products from the sacrificial anodes do not cause damage to the turbines. No corrosion allowance is required for cathodically protected surfaces.
10 Type 316 is acceptable up to operating temperature 70 °C provided located indoor or in sheltered areas and not insulated.
11 For uninsulated stainless Type 316 instrument piping downstream a shut-off valve, normally no extra precautions are required, provided process medium temperature is below 85 °C and there is no flow in the instrument piping.
12 Hot dip galvanised steel can be used in living quarter and domestic areas.
13 The combination of chemical and material has to be considered in each case. Titanium or GRP shall be used for hypochlorite systems.
14 There could be a high risk for crevice corrosion under clamps when using type 316 tubing externally at offshore conditions and at onshore plants close to sea. Alternative tubing material should be evaluated.

5.5.4 Water injection

Water injection covers systems for injection of deaerated sea water, raw untreated sea water, produced water and combinations and mixing of different waters.

Corrosivity evaluations and materials selection for deaerated seawater injection systems shall be based on residual oxygen and chlorine levels. A typical residual oxygen concentration for un-chlorinated sea water is 20 mg/m^3 for normal operation, but may be higher during upset conditions and during chemical treatments. For chlorinated sea water the following oxygen equivalent levels (see 3.1.12 for definition of oxygen equivalent) is recommended:

- 50 mg/m^3 for 90 % of operation time;
- 200 mg/m^3 for 10 % of operation time, non continuous.

In addition bacteria control and flow velocities shall be considered.

Even if the specification for the deaeration equipment gives more strict requirements, the above shall be basis for the materials selection. If the specified oxygen equivalent or temperature is above 50 mg/m^3 or 30 °C respectively for normal operation, the basis for materials selection shall be subject to special evaluation.

For carbon steel submarine injection flowlines the corrosion allowance should be minimum 3 mm.

In injection water systems where alternating deaerated sea water, produced water, aquifer water, any kind of process water, and/or gas could flow through the systems, the materials selection shall take this into account. Such systems may contain many corrosive species, e.g. CO_2, H_2S from bacteria activity, oxygen from blanketing gases, elemental sulfur. All components which may contact injection water or back-flowing fluids, shall be resistant against well treating chemicals or well stimulating chemicals in case of back-flow situations. For carbon steel piping maximum flow velocity shall be 6 m/s. Carbon steel should only be considered if the system can be kept clean and corrosion inhibition and biocide treatment is applied.

Internal organic lining should be considered for water injection flowlines.

5.6 Bolting materials for pressure equipment and structural use

5.6.1 General

Carbon or low-alloyed bolting materials shall be used. Bolts with a diameter 10 mm shall be stainless steel according to ISO 3506-1, Type A4 (Type 316), for metal temperatures below 60 °C if the stressed parts are exposed to humid saliferous environmental conditions (for nuts, see ISO 3506-2).

If other bolting materials are required due to corrosion resistance or other reasons, the material shall be selected in accordance with the general requirements of this NORSOK standard. For sub-sea applications Alloy 625 shall be used when corrosion resistant bolts are required at ambient temperature, i.e. for conditions where the bolts are exposed to natural sea water and cathodic protection cannot be ensured. It shall be verified that the materials have acceptable mechanical properties at the design temperatures.

Bolts used for sub-sea application shall have a maximum hardness of 300 HB or 32 HRC. The hardness shall be positively verified by spot hardness testing for each delivery, batch and size of bolts used.

Bolts screwed into component bodies shall be of a material that is compatible with the body with respect to galling and ability to disassemble the component for maintenance, if relevant. Possibility for galvanic corrosion and consequences of different thermal coefficients if relevant, shall be considered when dissimilar metals are used in bolts and materials to be joined.

All bolts and nuts shall be supplied with certification according to EN 10204, Type 2.2, as minimum. Bolts classified as main pressure bearing (see PED Guideline 7/6 and 7/8) or for main structural components shall be delivered with certification to EN 10204, Type 3.1B.

Carbon steel and/or low alloy bolting material shall be hot dip galvanised to ASTM A153 or have similar corrosion protection. For submerged applications, where dissolution of a thick zinc layer may cause loss of bolt pretension, phosphating shall be used. For sub-sea installations the use of poly-tetra-fluoro-ethylene (PTFE) based coatings can be used provided electrical continuity is verified by measurements. Cadmium plating shall not be used.

5.6.2 Bolting materials for pressure equipment

The general bolting material for pressure equipment shall be carbon or low alloy steel selected in accordance with the ASTM Standards listed in Table 4.

Table 4 - Temperature range for bolting materials

Temperature range °C	Bolt [a]	Nut	Size range mm
-100/+ 400	A 320 Grade L7	A 194 Grade 4/S3 or grade 7/S3	≤ 65
	A 320 Grade L43	A 194 Grade 7/S3 or A194 grade 4/S3	< 100
-46/+ 400 [e]	A 193 Grade B7	A 194 Grade 2H	All
-29/+ 540 [e]	A 193 Grade B16 [a]	A 194 Grade 7	All
-196/+ 540	A 193 Grade B8M [b]	A 194 Grade 8M/8MA [c]	All

[a] This grade should not be used for permanent sub-sea equipment. Grade B16 is intended for high temperature service, outside the temperature range for Grade B7.
[b] Type 316 bolts and nuts shall not be used at maximum operating temperature above 60 °C if exposed to wet marine atmosphere.
[c] Use 8MA with class 1 bolts.
[d] Use of bolting for pressure equipment under PED shall be verified by a PMA.
[e] The lower temperature limits are subject to different interpretations of PED, and shall be clarified for each project with the selected Notified Body.

5.6.3 Bolting materials for structural applications

Bolting materials for structural applications shall generally be carbon or low alloy steels with the following limitations:

- the hardness and strength class shall not exceed ISO 898 class 10.9;
- for submerged bolts, the strength class shall not exceed ISO 898 class 8.8 and the maximum hardness required in 5.6.1. Bolts in accordance with ASTM A 320 Grade L7 are acceptable alternatives within given limitations;
- bolts with a diameter above 25 mm shall be impact tested to the same requirements as for the steels to be bolted.

5.7 Sub-sea production and flowline systems

5.7.1 General

Materials selections for sub-sea production and flowline systems are given in Table 5. For carbon steel flowlines the requirements given in 5.8 apply.

Metal to metal seals that may be exposed to sea water without cathodic protection should be made in corrosion resistant alloys such as UNS R30035, R30003, Alloy 625 and Alloy C276. Generally, metal to metal sealing materials shall be more corrosion resistant than surrounding surfaces.

All polymeric/elastomeric materials shall be qualified and the performance documented in all relevant exposure conditions in accordance with 6.4.

For levelling systems and other systems mainly used for installation, carbon steel shall be considered.

All bolting materials shall comply with 5.6.

Restrictions for maximum SMYS and actual yield strength shall apply for all components exposed to ambient seawater with cathodic protection, according to 6.1.

Table 5 - Materials selection for sub-sea production and flowline systems

Application	Materials	NOTES
Wellheads and X-mas trees		
Wellhead equipment/X-mas trees for production	13Cr4Ni, Low alloy steel with Alloy 625 overlay. Relevant ISO standards.	1
Wellhead equipment/X-mas trees for deaerated seawater	Low alloy steel with Alloy 625 weld overlay in sealing surfaces. Design shall allow for corrosion on not-overlayed parts. Relevant ISO standards.	1
Wellhead equipment/X-mas trees for aerated seawater	Carbon steel with weld overlay according to 4.4.	
Wellhead equipment/X-mas trees for produced water and aquifer water	As for production.	
Retrievable equipment internals	13Cr or CRAs with higher PRE	
Non-retrievable equipment internals, incl. X-mas trees	Alloy 718 or CRAs with higher PRE	
Subsea manifold piping		
Piping systems for well fluids	6Mo, 22Cr duplex, 25Cr duplex.	
Piping for deaerated seawater	6Mo, 22Cr duplex, 25Cr duplex. Carbon steel can be used for shorter design life, i.e. less than 15 years.	
Piping for gas	Carbon steel, 22Cr duplex, 6Mo. Materials selection shall follow guidelines in 4.3.2.	
Piping for produced water and aquifer water	22Cr duplex, 25Cr duplex, 6Mo.	
Piping for raw seawater	25Cr duplex, Titanium.	
Hydraulic fluids/glycol/methanol	316.	2
Chemical injection and annulus bleed systems	316.	
Retrievable valve internals	13Cr, 17 - 4 PH, Alloy 718.	
Non-retrievable valve internals	Alloy 718.	
Subsea rigid flowlines		3
Oil and gas	Carbon steel, 13Cr, SM13Cr , 22Cr duplex or CRA clad carbon steel. Materials selection shall follow guidelines in 4.3.2.	4
Deaerated seawater injection	Carbon steel, internal organic lining may be used.	5
Produced water and aquifer water injection	Carbon steel, Carbon steel with internal organic lining, 22Cr and 25Cr duplex, 6Mo.	6
Raw seawater injection	Titanium, 6Mo, 25Cr duplex, Carbon steel with internal organic lining.	5
Hydrate inhibitor lines	Carbon steel, 316, 22Cr duplex.	7
Sub-sea production control systems		
Umbilicals, metallic	25Cr duplex, encapsulated. Titanium.	8,9,10
Umbilicals, polymer hoses	Polyamide 11, Thermoplastic elastomer, High strength carbon or high strength polymer fibres.	11

Application	Materials	NOTES

NOTES

1 For weld overlay, see 4.4. Sealing surfaces of components Type 13Cr4Ni shall be overlay welded with Alloy 625.
2 Carbon steel and stainless steel with lower PRE than Type 316 can be used provided documented by field experience and/or tests.
3 Flexible pipe should be considered as alternative to rigid pipe. Carbon steel clad with CRA can be used as alternative to solid CRA. Guidance on selection of CRAs for injection is given in Table 2.
4 Cost effectiveness of using duplex stainless steels with a lower alloying content than for Type 22Cr should be considered.
5 Organic linings shall be resistant under the operating conditions. Weld connections shall be CRA. The maximum flow velocity for carbon steel shall be 6 m/s.
6 Carbon steel can be used for produced water provided regular cleaning pigging, biocide treatment and corrosion inhibition.
7 Carbon steel can be used if acceptable from cleanliness point of view.
8 See Table 6 for limitation for titanium in methanol service.
9 Type 22Cr duplex can be used if cathodic protection can be ensured. For 25 Cr duplex without cathodic protection, external polymeric sheathing is required.
10 Carbon steel with external protection (cathodic protection in combination with coatings - organic or thermally sprayed aluminium) can be used if acceptable from cleanliness requirements point of view.
11 Documented functionality in relevant fluids with extrapolation of service life is required, see 5.7.3. Not to be used for methanol service.

5.7.2 Flexible flowlines and risers

Generally the requirements of ISO 13628-2 and API Spec 17J shall be satisfied. Due consideration shall be made to evaluate the possibility of failure due to corrosion and/or corrosion-fatigue of the steel reinforcement caused by the internal and/or the external environment. If "sour" conditions apply, the effect of H_2S on steel reinforcement and inner liner shall be considered. Gas diffusing through the polymeric sheets shall be considered. If welding is performed on reinforcement wires, the resulting reduction in strength shall be taken into consideration in the design.

NOTE API Spec 17J will be replaced by ISO 13628-11 which is under development.

Measures to avoid internal galvanic corrosion by proper materials selection and/or electrical isolation shall be ensured at all interfaces to neighbouring systems such as at subsea production manifold piping and flowlines.

The material for the inner metallic layer of non bonded pipe can be stainless steel Type 316 provided pitting corrosion and local erosion penetrating the liner do not deteriorate the functional performance and reliability of the flexible pipes. The choice of inner material shall take into account the possibility of being exposed to sea water during installation and commissioning.

The following shall be documented:

- material properties verifying consistency between the design requirements and the fabricated quality including ability to withstand defined and specific variations in temperature, pressure and the number of cycles;
- documentation demonstrating that polymeric materials will be resistant to the internal and external environment and maintain adequate mechanical and physical properties throughout the design life of the system shall be in accordance with 6.4;
- welding and properties of welded components including armour wires.

5.7.3 Sub-sea production control systems

For polymeric based hoses, materials selection shall be based upon a detailed evaluation of all fluids to be handled. The annulus bleed system will be exposed to a mixture of fluids, such as production fluid, methanol, completion fluid and pressure compensating fluid. A hose qualification programme shall be carried out including testing of candidate materials in stressed condition, representative for actual working pressure, unless relevant documentation exists. The results from qualification testing shall provide basis for service life extrapolation according to methods such as Arrhenius plots.

Sub-sea control umbilicals shall normally be designed according to and shall comply with materials requirements in ISO 13628-5. The electric cable insulation material shall be qualified for all relevant fluids. The materials selected for the electrical termination should be of similar type in order to ensure good bonding between different layers. The materials selection for metals and polymers in electrical cables in the outer protection (distribution harness) and in connectors in distribution systems shall have qualified compatibility with respect to dielectric fluid/pressure compensation fluid and sea water. The functionality in sea water of the individual barriers relative to the service life, shall be documented.

The different parts of the components in hydraulic and chemical distribution systems shall have documented compatibility with relevant process fluids, dielectric fluid and sea water.

5.7.4 Drilling and workover risers

The required accumulated exposed design life shall be defined at an early stage.

All welded parts shall be post weld heat treated. Materials requirements are given in ISO/DIS 13628-7. Composite drilling risers shall be designed according to DNV RP F201.

Resistance to "sour" conditions shall be taken into account for parts of the drilling and workover risers which may be exposed to reservoir fluids during drilling and testing. Compliance with "sour" service requirements as given in 4.3.2. shall be met, unless less stringent requirements are justified.

For drilling risers a total erosion/corrosion allowance of minimum 6 mm shall be included for accumulated design lives exceeding 10 years.

For workover risers manufactured from C-steel, reduction in wall thickness due to corrosion shall be evaluated. Effects of corrosion shall be accounted for by a minimum of 1 mm unless it can be demonstrated through routine maintenance that a corrosion allowance can be eliminated.

5.8 Pipeline systems

Pipeline systems shall be in accordance with ISO 13623 and DNV OS F101. Materials requirements shall comply with DNV OS F101.

The materials selection for pipeline systems for processed oil and gas shall be C-Mn steel. For unprocessed or partially processed oil and gas a corrosivity evaluation according to 4.3.2 shall be done and materials and corrosion control selected accordingly.

Pipeline systems containing gas shall be designed for a minimum design temperature that takes into account possible blow down situations.

5.9 Chains and mooring lines for floating units

In steel chain mooring line systems a corrosion rate of 0,4 mm/year for splash zone and 0,1 mm/year for fully submerged conditions shall be used as basis for corrosion allowance and lifetime estimates. An evaluation of possible corrosion due to bacterial activity on the seabed shall be carried out.

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.

Polymeric fibre rope mooring lines may be an option. Polymeric fibre rope can not be exposed to sea bed and where sand can penetrate in between the fibres. Chains and/or steel wire ropes shall be used for such conditions.

6 Design limitations for candidate materials

6.1 General

Design limitations for the application of different material types (e.g. maximum operating/minimum design temperature, maximum SMYS and actual yield strength, weldability, etc.) are defined in the following.

The following general requirements apply for all steel types (including bolts):

For carbon and low alloy steels, the yield to tensile strength ratio (actual values) shall not exceed 0,9.

- for materials intended for welding, SMYS shall not exceed 560 MPa. If this requirement can not be met, higher SMYS is acceptable provided documentation showing acceptable properties with respect to weldability and the in service properties of the base material, heat affected zone and weld metal on both sides is presented;

- for submerged parts that may be exposed to cathodic protection, the following shall apply:
  - for carbon and low alloy steels, SMYS shall not exceed 700 MPa (725 MPa for bolts). The actual yield strength shall not exceed 900 MPa. Alternatively, it may be verified that the actual hardness in base materials does not exceed 300 HB and welds 325 HV10;
  - for ferritic, martensitic and ferritic/austenitic stainless steels and non-ferrous materials, resistance against hydrogen embrittlement shall be controlled by specifying that the actual hardness of the material is less than 300 HV10 for base material and 320 HV10 for welds;
  - the hardness of austenitic stainless steels shall not exceed 35 HRC.
- metallic materials for pressure retaining components which are not covered by NORSOK standards and material data sheets or applicable codes, shall as a minimum be according to DNV RP B201.

In cases where the minimum design temperature is a limiting factor for a material, also temperature exposures during intermediate stages (such as manufacturing, storage, testing, commissioning, transport, installation) shall be considered when specifying the minimum design temperature and handling procedures.

Cracking due to hydrogen from cathodic protection can occur in ferittic, martensitic and duplex stainless steels with otherwise acceptable properties in case of very high local stresses. Attention should always be paid to local design to avoid large stress concentration factors for.

6.2 Materials for structural purposes

6.2.1 Steel

The impact toughness test requirements given to, and the application of, the specified structural materials are based on a minimum design temperature of -10 °C. If lower design temperatures are applicable, sufficient fracture toughness properties have to be verified. For the most critical design class, this shall include CTOD testing of base material, weld metal and HAZ at the minimum design temperature.

6.2.2 Concrete

Design limitations for application of structural concrete shall be according to NS 3473, including Exhibit B, and NS 3420 for use in Norway and Norwegian territorial waters.

6.2.3 Aluminium

Aluminium may be used within limitations given in NORSOK M-121, for all relevant ambient temperatures. Aluminium alloys shall not be used for elevated temperatures. In particular, AlMg-alloys with Mg-content above 3,0 % shall not be used when the design temperature is above 60 °C. Special consideration shall be given to loss of strength above approximately 100 °C.

Hardened aluminium alloys suffer from a reduction in strength in the heat affected zone after welding. The actual reduction factors to be used shall comply with applicable design codes but shall be evaluated and verified by welding and appropriate mechanical testing. The weld metal strength shall be included in this evaluation and minimum yield and tensile strength requirements shall also be defined. Necessary precautions shall be taken to ensure homogeneous material properties in extruded sections and in particular across extrusion welds.

6.2.4 Glass fibre reinforced plastic (GRP)

For GRP used in applications such as protection structures, panels, gratings and secondary applications, the design shall be based on DNV OS C501. Risk assessment and evaluation of fire performance shall be done when applicable.

6.3 Materials for pressure retaining purposes

6.3.1 General

Materials shall be used within the limits given in Table 6.

Piping systems according to NORSOK L-001 are based on ASME B31.3. Corresponding materials and fabrication requirements are given in ASTM standards and NORSOK M-630, NORSOK M-601 and NORSOK M-622 (when issued).

Materials shall resist general corrosion, localised corrosion in the form of pitting and crevice corrosion and environmental cracking in the form of CSCC and SSC. Limitation guidelines for CRAs in “sour” service are given in Table 7. It is emphasised that H_2S limits for CRA material categories are difficult to state on a general basis. Specific limits for the material type and grades to be used should be established by testing.

In carbon steel vessels that are clad or overlay welded with austenitic stainless steels or nickel alloys (minimum 3 mm thickness), the backing steel hardness shall be evaluated on an individual basis.

The lower temperature limits for carbon steel imposed by the design code and NORSOK standards requirements shall be adhered to. In special circumstances impact tested steel may be used below these limits. Such cases require individual attention. The maximum design temperature shall be according to the applicable design codes for all types of materials.

Free machining steel grades are not acceptable for pressure retaining purposes.

Table 6 - Metallic materials for pressure retaining purposes

Material	Minimum design temp. °C	Impact testing required	Other requirements	NOTES
Carbon and low alloy steel				
235 235 LT 360 LT 3,5 % nickel steel	- 15 - 46 - 46 -101	 Yes Yes Yes		1
Martensitic stainless steels				2,3
SM13Cr 13Cr 13Cr valve trim parts 13Cr4Ni 13Cr4Ni double tempered	- 35 - 10 - 29 - 46 -100	Yes Yes Yes		
Austenitic stainless steels				
316 6Mo Superaustenite	-196 -196 -101	Yes Yes	Max. operating temp. 60 °C. Higher temperatures acceptable if full HVAC control, oxygen free environment or used subsea with cathodic protection. 6 Mo seawater systems with crevices: Max. operating temp. 20 °C, max. free chlorine 1,5 ppm. Max. operating temperature 120 °C in saliferous environment, see 6.3.4. Max. operating temperature 120 °C in saliferous environment.	4 4, 11 11
Duplex stainless steels				5, 11
22Cr 25Cr	- 46 - 46	Yes Yes	Maximum operating temperature 100 °C if exposed to saliferous atmosphere. Maximum operating temperature 110 °C if exposed to saliferous atmosphere. Probability for cracking should be assessed in systems affected by acidising if sulphide containing scales	

Material	Minimum design temp. °C	Impact testing required	Other requirements	NOTES
			can be formed. Limitations for 25Cr in seawater systems as for 6Mo.	
Nickel base alloys	-200		Crevice corrosion limitation for Alloy 625 in sea water systems as for 6Mo.	
Titanium base alloys				6
Grade 2	-60		Sea water operating temperature limits if crevices are present: Unchlorinated 95 °C, Chlorinated 85 °C, Brine 80 °C.	
Other grades				7
Copper base alloys			Max. velocity, see BS MA 18. For intermittent service max. 10 m/s. Not for stagnant conditions.	8, 10
90-10, 70-30, NiAl bronze, gun metal			Fresh seawater and normally drained systems.	8
Admiralty brass, gun metal, tin bronze			Fresh water normally drained systems.	
Aluminium base alloys	-270			9

NOTES

1 Carbon steel Type 235 can be used in piping systems with minimum design temperature down to -15 °C for thickness less than 16 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 is required of weld metal at minimum design temperature.
5 No threaded connections acceptable in sea water systems.
6 Shall not be used for hydrofluoric acid or pure methanol (> 95 %) or exposure to mercury or mercury based chemicals. Titanium shall not be used for submerged applications involving exposure to sea water 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 to mercury or mercury based chemicals, ammonia and amine compounds.
9 Shall not be exposed to mercury or mercury containing chemicals
10 Chlorination may not be needed with a sea water system based on 90-10 Cu-Ni.
11 If used at higher temperatures, see 6.3.4 for protection against chloride induced stress corrosion cracking. No threaded connections acceptable in seawater systems.

Table 7 – Guidelines for H_2S limits for generic CRA classes [a b]

Material	Chloride concentration max. %	Min. allowed in-situ pH	Temperature, max. °C [c]	Partial pressure H_2S max. bar_a
Martensitic stainless steels				
13 Cr [d]	5	3,5	90	0,1
Austenitic stainless steels				
316	1 5 5	3,5 3,5 5	120 120 120	0,1 0,01 0,1
6Mo	5 5	3,5 5	150 150	1,0 2,0
Duplex stainless steels				
22Cr	3 1	3,5 3,5	150 150	0,02 0,1
25Cr	5 5	3,5 4,5	150 150	0,1 0,4
Nickel alloys				
625		3,5		5

Material	Chloride concentration max. %	Min. allowed in-situ pH	Temperature, max. °C [c]	Partial pressure H_2S max. bar_a
C276				>> 5
Titanium		3,5		>> 5

[a] The limits given assume complete oxygen free environments.
[b] If one of the listed parameters exceeds the given limit, the need for testing of the material according to ISO 15156-3 should be evaluated.
[c] The temperature limit may be increased based upon evaluation of specific field data and previous experience. Testing may be required.
[d] For SM13Cr testing has indicated that lower limits are required.

6.3.2 Bending and cold forming of pipes

Bending of pipes shall be in accordance with NORSOK L-001, data sheet NBE1. Additional materials limitations to cold forming are given below.

It shall be documented that the material after bending complies with the requirements to mechanical properties and corrosion resistance as per the relevant MDS.

The hardness of cold formed duplex stainless steels to be used sub-sea with cathodic protection shall be limited to 32 HRC.

6.3.3 Glass fibre reinforced plastic (GRP)

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

The use of GRP for piping systems is limited as follows:

- maximum internal design pressure is 40 bar_g;
- 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.

Recommended materials of construction for different fluids are listed in Table 8.

Table 8 - Recommended materials of construction of GRP systems

Service	Structural part	Inner liner
Service water Process water Cooling medium/water Sewage Non-hazardous drain Non-hazardous vent Fire water main Fire water deluge Produced water Ballast water	Bisphenol A epoxy resin [a] reinforced with E-glass.	Bisphenol A epoxy resin [a] reinforced with ECR-glass fibres and with C-glass fibre or synthetic fibre surface veil shall be used.
Potable water	Bisphenol A epoxy resin [a] reinforced with E-glass.	According to the national health or certifying authorities in the country of use.
Hydrochloric acid	Bisphenol A epoxy resin [a] reinforced with ECR-glass.	Bisphenol A epoxy resin [a] reinforced with ECR-glass.
Concentrated sodium hypochlorite and sulphuric acid	Chemical resistant laminate.	Thermoplastic liner [b]

Service	Structural part	Inner liner
[a] Aromatic or cycloaliphatic curing agents shall be used. An alternative is to use vinylester resin. In special cases other resins may be used. [b] Requirements related to thermoplastic liner material and lined pipes shall be according to DIN 16965-2 and DIN 16966 (all parts), pipe type B.		

GRP tanks and vessels shall be designed according to BS 4994 and with the following limitations:

- design pressure in bar_g times internal volume in litres shall not exceed 75 000 and a design temperature of maximum 75 °C;
- 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 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 sea water and open drain services.

In corrosive environment internally or externally, GRP material can be used as tubing, casing and linepipe. The GRP material used shall satisfy the requirements in API Spec 15 HR and API Spec 15 LR depending on pressure.

If 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 D 2992. GRP pipes can also be use as lining for downhole steel tubing with temperature and environmental limitations dependent on qualifications.

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

6.3.4 Chloride induced stress corrosion cracking (CSCC)

Chloride induced stress corrosion cracking depends on stress level and environmental conditions such as pH and salt concentration. The maximum operating temperatures for different unprotected stainless steels are given in Table 6.

The 22Cr, 25Cr and 6Mo materials may be used above these temperatures provided corrosion protection according to NORSOK M-501. The temperature limits may be exceeded in dry, fully HVAC controlled environments, see NORSOK R-004.

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 used in well completion components, X-mas trees, valves in manifolds and permanent subsea parts of the production control system shall be thoroughly documented. For these components documentation for relevant materials from all suppliers used shall be provided, see NORSOK M-710.

7 Qualification of materials and manufacturers

7.1 Material qualification

7.1.1 General

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

The materials listed in Clause 3 and 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:

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

7.1.2 Qualification by past 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 7.1.1 to 7.1.3, a qualification programme shall be initiated. The objective of the programme 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. Such qualification shall be evaluated when one of the following conditions are present:

a) The materials to be supplied include:
   1. 22Cr and 25Cr duplex stainless steels: all grades, product forms and dimensions;
   2. superaustenite and 6Mo stainless steels: all product forms and dimensions;
   3. nickel base alloys: castings;
   4. titanium and its alloys: castings.
b) The requested material dimensions and/or quality require special demands by being outside the range of standardised products or outside the normal production range of the potential manufacturer.
c) Non-metallic sealing materials for topside gas systems subjected to rapid de-pressurisation, well completion and critical permanent subsea equipment.

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, superaustenite and Type 25Cr duplex;
- welding of titanium;
- welding of aluminium;
- welding/joining of bimetallic (clad) pipes;
- cold forming.