



Material selection In oil and gas industry

PREPARED

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SCOPE

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GENERAL PRINCIPLES FOR MATERIAL SELECTION AND CORROSION PROTECTION

Material selection

Material selection shall be optimized, considering investment and operational costs, such that Life

Cycle Costs (LCC) are minimized while providing acceptable safety and reliability.

The following key factors apply to materials selection:

- Primary consideration shall be given to materials with good market availability and documented fabrication and service performance.
 - The number of different material types shall be minimized considering costs, interchangeability and availability of relevant spare parts.
 - Design life.
 - Operating conditions.
 - Experience with materials and corrosion protection methods from conditions with similar corrosivity.
 - System availability requirements.
 - Philosophy applied for maintenance and degree of system redundancy.
 - Weight reduction.
 - Inspection and corrosion monitoring possibilities.
 - Effect of external and internal environment, including compatibility of different materials.
 - Evaluation of failure probabilities, failure modes, criticalities and consequences.
- Attention
- shall be paid to any adverse effects material selection may have on human health, environment, safety and material assets.
 - Environmental issues related to corrosion inhibition and other chemical treatments.

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- For main systems where materials/fabrication represent significant investments and/or
- operational costs, an LCC analysis shall be basis for material selection (Ref. Annex A).

Deviation from specified material selections

Where an overall evaluation of LCC, safety and reliability shows that it is more cost effective to deviate from the specific materials selections and corrosion protection principles given in this document and the NORSOK standards referenced herein the alternative solution should be implemented. Such deviations may include replacement of CRAs with carbon steel where CRAs are specified in this standard.

Suppliers standard materials shall be used for equipment, provided that:

- This is cost efficient.
- The supplier can document previous successful experience.
- The materials satisfy the general requirements given in this document with respect corrosion resistance and/or maintenance and replacement.

Corrosivity and corrosion protection

Evaluation of corrosivity shall as a minimum include:

- CO₂-content.
- H₂S-content.
- Oxygen content and content of other oxidizing agents.
- Operating temperature and pressure.
- Acidity, pH.
- Halogenide concentration.
- Velocity flow regime.
- A gas system is defined wet when the relative humidity exceeds 50 %.

Corrosion inhibitors shall not be used to reduce corrosion of carbon or low alloy steels in production wells, subsea trees and subsea piping systems.

Recommendation:

Use of corrosion inhibitors in topside process systems is not recommended, but can be used provided inhibitor in each process stream satisfies the inhibitor suppliers minimum recommended concentration.

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For pipelines, an inhibitor efficiency of 85 % shall be used for design, including effect of glycoland/or methanol injection. The inhibitor efficiency shall be qualified and documented by corrosion tests unless relevant field or test data are available.

In pipeline systems carrying hydrocarbons with condensed water, the corrosivity may be reduced by application of inhibitors in combination with pH stabilizers as an alternative to inhibitors alone.

The combined effect of inhibitors and pH stabilizers shall be qualified and documented by corrosion tests unless relevant documentation exists.

Vessel materials for topside oil separation and gas treating systems shall be selected based on the same corrosivity criteria as for topside hydrocarbon piping systems.

Vessels manufactured in solid CRAs, internally CRA clad or weld overlayed, will not need additional internal corrosion protection systems.

Risk for "sour" conditions during the lifetime shall be evaluated. Requirements to metallic materials in "sour" service shall comply with NACE MR0175 standard with amendments given in this standard.

Recommendation:

When new EFC standards are issued, such as EFC document EFC 086 WPI-93, it is recommended to replace NACE MR0175 by these. (The EFC standards are planned issued later as CEN and/or ISO standards).

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

External corrosion protection

The external atmospheric environment shall be considered wet with the condensed liquid saturated with chloride salts. 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.

Carbon steel shall always have surface protection to the external environment.

Additional corrosion allowance or other means of protection are required for installations in the splash zone.

Recommendations:

Corrosion resistant alloys should not be coated, except under insulation or pipe clamps or when submerged in seawater. Submerged small bore stainless steel piping should not be coated.

Corrosion allowance sizing for carbon steel in the splash zone should follow the below guidelines:

- Structures with thin film coating: Min. 5 mm.

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- For design lives > 17,5 years.
- Corrosion allowance = (Design life - 5 years) x 0,4 mm/year.
 - Risers: Min. 2 mm in combination with min. 12 mm vulcanized chloroprene rubber. At elevated temperature the corrosion allowance should be increased by 1 mm pr. 10 degrees C increase in temperature above 20 °C.

Coating system selections for pipelines, structures and topside equipment shall take due consideration to structural design, operating conditions and conditions during storage and installation.

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. For such applications
- wax coatings should be considered.

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

Recommendation:

- 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 polarization, including use of shop primers only.
- Required coating quality to obtain low coating breakdown.
- Accessibility for coating application.
- Cost saving by not coating weld areas.

Welded connections are recommended for subsea applications. Flanged and screwed connections shall be avoided where possible. 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 components permanently exposed to ambient seawater and for which efficient cathodic protection can not be ensured, shall be fabricated in seawater resistant materials. Exceptions are components where corrosion can be tolerated. Material selection should take into account probability for, and consequence of, component failure.

Recommendation:

The following materials are regarded as corrosion resistant when submerged in seawater at ambient temperature:

- Alloy 625 and other nickel alloys with equal or higher PRE value.

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- Titanium alloys (For limitation wrt. cathodic protection, ref. table 5).
- GRP.
- Other materials, provided adequately documented.

NOTE: Stainless steels Type 6Mo and Type 25Cr duplex are borderline cases and not considered as fully seawater resistant in this respect. These materials should not be used for threaded connections without cathodic protection.

Corrosion protection of closed compartments

For completely closed seawater filled compartments in carbon steel, e.g. in jacket legs, J-tubes and caissons, etc. no internal corrosion protection is needed. For compartments with volume to area ratios exceeding 1 m³/m², treatment with oxygen scavenger can be used as an alternative to cathodic protection.

Insulation, topside applications

Thermal insulation for topside applications shall be avoided to the extent possible, and only be used if required for safety or processing reasons. Piping and equipment which have to be insulated shall be coated in accordance with NORSOK Standard M-CR-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 and piping systems shall ensure drainage, 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.

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, the dissimilar materials shall either be electrically isolated with an isolating spool or the more noble material shall be internally coated close to the coupling. Length of coated/isolated section shall be minimum 10 pipe diameters. Necessary corrosion allowance shall be provided in transition areas. Alternatively, galvanic corrosion can be catered for by corrosion allowance, only.

Recommendation:

At galvanic connections between dissimilar materials without isolation, 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 magnitude of

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, isolating spools shall be avoided and transitions shall normally be made in dry, inhibited or other areas with low corrosivity.

Chemical treatment

Corrosion inhibitors, scale inhibitors, oxygen scavenger or other chemicals can be used to reduce corrosion in process, fresh water and seawater systems etc. The efficiency in the specified service shall be proven and documented as well as the compatibility with other chemicals to be used.

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

Corrosion monitoring

Design of corrosion monitoring systems shall be based upon criticality evaluations taking appropriate note of probability of failure/damage and the consequences. Such systems shall at least be evaluated for carbon steel pipelines and flowlines, carbon steel hydrocarbon piping and cathodic protection systems.

The material selection task is accomplished through the following steps:

- Fluid corrosivity evaluation based on fluid characteristics and operating conditions
- Definition of chemical injection philosophy
- Definition of most suitable materials for each component
- Identification of proper corrosion control methods
- Additional requirements for sour service, low temperature and welding
- Requirements for selection and qualification of corrosion inhibitors (laboratory and field-testing)
- Requirements for external corrosion protection with coatings and cathodic protection systems
- Requirements for internal corrosion monitoring
- Requirements for internal and external corrosion inspections.
- Material Selection is carried out in conformity with International

MATERIAL SELECTION FOR SPECIFIC APPLICATIONS/SYSTEMS

MATERIAL SELECTION PROCESS

As discussed in the previous section, there are many factors that affect the decision-making process in material selection problems. Several quantitative and qualitative methods have been applied in the industry to solve such problems, but there is no one particular method that is applicable to all problems or that covers all the considerations together. This is analogous to the fact that no single material or alloy is applicable to all service conditions.

To start with, the boundary conditions have to be established in the form of engineering design parameters. Defining boundary conditions includes defining the chemical and physical attributes of the intended service. This means that we need to know the detailed chemical composition of the fluids we are working with. We need to know the pressures, temperatures, flow rates, and other physical parameters that are important in defining the material to be selected. This process also involves developing a detailed corrosion model taking into consideration the corrosion management mechanism that has been proposed for the project. Once we have fully defined the physical and chemical boundary conditions, we then match these boundary conditions with the engineering properties of various metals and their alloys. Generally, we may, 'beforehand' define a slightly smaller set of materials to start working with. Out of this set of materials, we can now identify the smaller subset of the materials that satisfy the requirements as stated by the boundary conditions.

This is our first list of candidate materials. The first list of candidate materials may consist of two or more materials, in which case we have to perform further quantitative analysis to determine the best choice for the given application.

At this stage, there could be situations wherein cost may not be the only criterion. In fact, it could be the case that cost is just 'one' among a list of other criteria for judging the candidate materials.

In this case, a reasonable approach would be to 'score' the candidate materials against each of these criteria. This process is very simple. We first create the list of criteria against which we wish to judge the candidate materials. The criteria could include cost, availability, ease of fabrication, reliability, and so forth. For each criterion, we assign a weightage based on its level of importance.

Once this is done, we then turn to our list of candidate materials and score each material against each criterion. We then calculate the weighted score for each of the candidate materials and rank the materials in descending order of their weighted scores. The material with the highest score is the most fitting choice for the given

application. In such cases, other techniques such as decision trees can also be used to arrive at a solution.

Sometimes, cost may be the only criterion in material selection. This is particularly true when it is known that the candidate materials are fairly evenly poised on all other criteria. This calls for a method that analyzes the costs associated with each candidate material. One such quantitative method is the Life-Cycle Cost Analysis (LCCA). LCCA helps us get the overall picture of the costs associated with 'each' material over its entire lifetime. It attempts to identify all CAPEX and OPEX heads involved in all stages encountered over the lifetime of a particular asset or facility and therefore operates over a longer-term horizon. LCCA uses the discounted cash flow technique to reduce the future costs to present-day values. This makes LCCA an even fairer means to rationally compare the candidate materials. As a first step in LCCA, we need to collect detailed information about the initial and future operating philosophy of the asset or facility. This may include arriving at the corrosion management philosophy, which will tell us the detailed procedures and consumables that will be required while performing corrosion management in the future. We need to get answers to questions including the following:

- The types of corrosion inhibitors required and their quantities and injection frequencies
- Extent of marine spread required to perform inspection and monitoring
- Special requirements to carry out the corrosion management program
- Any other special costs associated with a particular candidate material that may come up during initial and future operation

Material Properties

- ✓ Tensile Strength
- ✓ Toughness
- ✓ Hardness
- ✓ Hardenability
- ✓ Resistance to Pitting

Materials for structural purposes

Steel

Material requirements to the applicable grades are defined in NORSOK Material Data Sheets. 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.

Concrete

❖ Material selection

Design limitations for application of structural concrete shall be according to NS 3473 including

Aluminium

Aluminium may be used 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 design temperature is above 60 °C, as these alloys are sensitive to stress corrosion cracking. Special consideration shall be given to loss of strength above approximately +200 °C.

Oil and gas processing

When assessing corrosivity throughout a processing system, the partial pressure of CO₂ and H₂S in the gas phase in separators and scrubbers can be used as basis for evaluating corrosivity.

To compensate for the fact that these gases are not at equilibrium in each separator, the following assumptions shall be made unless otherwise justified by experience:

When the corrosivity in a separator and the liquid carrying piping downstream this separator

- is evaluated, the mean partial pressure of the foregoing separator and the actual separator shall be used.
- For gas scrubbers and piping downstream separators carrying gas, the actual partial pressure can be used directly.

	Materials
Oil and gas production and processing	Corrosivity evaluations shall be based on 5.3.2. and 6.5.2.
Wellhead equipment/ X-mas trees	13Cr4Ni, Low alloy steel with alloy 625 weld overlay. API 6A
Piping and vessels	22Cr duplex, 6Mo, 316.
Thick wall vessels	Carbon steel with 316, Alloy 625, N08825 or N08904 clad or weld overlay.
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, 6Mo, Titanium or GRP.

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Wellhead equipment/ X-mas trees	Carbon steel with weld overlay according to 5.4
Vessels	Titanium, GRP, carbon steel with internal rubber lining or organic coating in combination with cathodic protection.
Piping materials	6Mo, Titanium, GRP.
Piping components	6Mo, 25Cr duplex, Titanium, Alloy 625, Alloy C276, Alloy C22.
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. 5-10 years.
Pumps	25Cr duplex, 6Mo, Titanium,
Wellhead equipment/ X-mas trees	Low alloy steel with Alloy 625 weld overlay in sealing surfaces. Design must allow for corrosion on non overlayed parts. API 6A
Piping	Carbon steel, GRP.
Deaerated 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.
Produced water and aquafier injection	Carbon steel, 316, 22Cr duplex, 6Mo, Titanium, GRP. Wellhead and X-mas trees as for deaerated seawater injection.
Fresh and potable water	Hot dip galvanized carbon steel, GRP, Polypropylene, 316, Copper base alloys.

Pipeline systems

For pipeline systems for processed oil and gas and for injection water, carbon steel according to API 5L, grade X65 or lower shall be used.

The line pipe material shall be specified and tested to verify acceptable weldability under field welding conditions accounting for welding during barge installation and contingency hyperbaric repair welding situations during construction and operation. The latter shall also address replacement of anodes, unless doubler plates are used.

Where "sour" service requirements apply, this requirement shall also be fulfilled under hyperbaric welding conditions down to the maximum water depth along the pipeline route. Pipeline systems containing gas shall be designed for a minimum design temperature that takes into account possible blow down situations.

For the reel laying method, it shall be documented that the base material and weld zones have acceptable properties after the total accumulated plastic strain that can be experienced during reeling and installation.

Pipelines for unprocessed or partially processed oil and gas shall follow the material selection

Polymeric materials

The selection of polymeric materials, herein included elastomeric materials, shall be based on a

thorough evaluation of the functional requirements for the specific application.

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.

❖ Material selection

Equipment	Materials	Disadvantages	Advantages
Heat Exchanger	Carbon Steel	Susceptible to corrosion	Cost-effective
	Stainless Steel	Higher cost compared to carbon steel	Corrosion resistance
Furnace	Refractory Material	- Limited strength and mechanical properties	- High temperature resistance
Reactors	Glass-lined Steel	- Limited operating temperature range	- Excellent corrosion resistance
	Stainless Steel	- Higher cost compared to other materials	- Corrosion resistance
Pumps	Carbon Steel	- Susceptible to corrosion	- Cost-effective
	Stainless Steel	- Higher cost compared to carbon steel	- Corrosion resistance
Valves	Carbon Steel	- Susceptible to corrosion	- Cost-effective
	Alloy Steel	- Higher cost compared to carbon steel	- High strength and temperature resistance
Vessels	Carbon Steel	- Susceptible to corrosion	- Cost-effective
	Stainless Steel	- Higher cost compared to carbon steel	- Corrosion resistance
Compressors	Carbon Steel	- Susceptible to corrosion	- Cost-effective
	Alloy Steel	- Higher cost compared to carbon steel	- High strength and temperature resistance
Trays	Carbon Steel	- Susceptible to corrosion	- Cost-effective
	Stainless Steel	- Higher cost compared to carbon steel	- Corrosion resistance

MATERIAL SELECTION FOR MAIN EQUIPMENTS IN PETROCHEMICAL INDUSTRY

CONCLUSION

In conclusion, material selection plays a crucial role in the design of equipment for the oil and gas industry and petrochemical applications. It directly impacts the performance, safety, and longevity of the equipment. Several factors, including corrosion resistance, temperature and pressure requirements, mechanical strength, compatibility, and cost-effectiveness, must be carefully considered during the selection process. Each type of equipment has unique material requirements and trade-offs that need to be evaluated. Optimal material selection ensures reliable and efficient equipment operation, minimizing downtime and maintenance costs. Compliance with industry standards and regulations is essential to ensure the integrity and reliability of the equipment. Material selection is a critical aspect of designing equipment that meets the specific needs and challenges of the oil and gas industry and petrochemical sector.

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