ADNOC GROUP PROJECTS AND ENGINEERING

MATERIAL SELECTION GUIDELINES

Specification

AGES-GL-07-001

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شركة بترول أبوظبي الوطنية
Abu Dhabi National Oil Company

GROUP PROJECTS & ENGINEERING / PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
ADNOC	Specification applicable to ADNOC & ADNOC Group Companies

Group Projects & Engineering is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering is responsible for communication and distribution of any changes to this Specification and its version control.

This specification will be reviewed and updated in case of any changes affecting the activities described in this document.

INTER-RELATIONSHIPS AND STAKEHOLDERS

a) The following are inter-relationships for implementation of this Specification:

   i. ADNOC Upstream and ADNOC Downstream Directorates and

   ii. ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOG Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertilisers, Borouge, Al Dhafra Petroleum, Al Yasat

b) The following are stakeholders for the purpose of this Specification:

   ADNOC PT&CS Directorate.

c) This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group company included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance

d) Each ADNOC Group company must establish/nominate a Technical Authority responsible for compliance with this Specification.

DEFINED TERMS / ABBREVIATIONS / REFERENCES

'ADNOC' means Abu Dhabi National Oil Company.

'ADNOC Group' means ADNOC together with each company in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

'Approving Authority' means the decision-making body or employee with the required authority to approve Policies and Procedures or any changes to it.

'Business Line Directorates' or '**BLD**' means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

'Business Support Directorates and Functions' or **'Non- BLD'** means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

'CEO' means chief executive officer.

'Group Company' means any company within the ADNOC Group other than ADNOC.

'Standard' means normative references listed in this specification.

'COMPANY' means 'Abu Dhabi National Oil Company or any of its group companies. It may also include an agent or consultant authorized to act for, and on behalf of the COMPANY'.

'CONTRACTOR' means the party which carries out the project management, design, engineering, procurement, construction, commissioning for ADNOC projects.

'VENDOR' means the party which manufactures and/or supplies ESD System, technical documents/drawings and services to perform the duties specified by the COMPANY/CONTRACTOR.

'SHALL' Indicates mandatory requirements.

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GENERAL

1 PURPOSE

Input from the metallurgy/corrosion engineering disciplines is of vital importance during the Concept Definition/Pre-FEED, FEED and EPC phases of the projects as the cost and reliability depend on accurate and correct decisions regarding material selection and corrosion management. Material selection and corrosion management must receive in-depth consideration to achieve an optimum cost-effective project. This document shall be the guideline covering all materials of construction for COMPANY assets. The basis of this document are COMPANY standards and specifications, and operational experience, project lessons learned, plant failure reports and studies, as well additional input from shareholders' specifications and standards and lesson learned where applicable.

The document should be used as only a guide by COMPANY personnel and CONTRACTORS and CONSULTANTS working on COMPANY projects. This document is not a specification for any particular project but shall be used as mandating and minimum requirement when producing project specifications. It provides guidelines for design safe, reliable and cost effective facilities.

It is COMPANY's policy to utilize carbon and low alloy steels whenever possible. Where corrosion would be excessive and/or there are other limitations, then corrosion resistant alloys shall be used and the selection to be justified after a life cycle-cost analysis.

The document provides information on the most commonly corrosion issues and the properties of generic materials, and then discusses corrosion and material issues for specific production and utility systems.

2 SCOPE

This document provides insight to general corrosion mitigation philosophies and guidance on specific materials selection for plant, equipment, components and facilities that may be integrated into any COMPANY brownfield or greenfield, offshore or onshore projects.

The document shall be used during the FEED and detailed design (EPC) stages of the project. The guidelines should also be used as part of the Concept Definition/Pre-FEED phases where the optimum materials are pre-selected arbitrarily and incorporated in the project Statement of Requirements (SOR) for the FEED.

In addition, technical support and assurance for materials selection are given for specific COMPANY requirements (with recommendations or options) for various productions and drilling businesses.

This document is not intended to address specific corrosion control measures, downhole material selection, non-metallic materials selection, cathodic protection, or coatings.

3 DEFINED TERMS / ABBREVIATIONS / REFERENCES

3.1 List of Abbreviations

Table 1 – List of Abbreviations

Abbreviations	
API	American Petroleum Institute
ASTM	American Society for Testing and Material
CA	Corrosion Allowance
CAPEX	Capital Expenditures
CO_2	Carbon Dioxide
CMM	Corrosion Monitoring Manual
CRA	Corrosion-Resistant Alloy
CRAS	Corrosion Risk Assessment Study
Cr Steel	Chrome Stainless Steel
22Cr	Duplex Stainless Steel type 2205 (for example UNS S31803/S32205)
25Cr	Super duplex stainless steel 2507 (for example UNS S32750)
CS	Carbon Steel
CTOD	Crack Tip Opening Displacement
DSS	Duplex Stainless Steels
ENP	Electroless Nickel Plating
EPC	Engineering, Procurement and Construction
GRP	Glass Reinforced Plastic
HAZ	Heat Affected Zone
HV	Vickers Hardness
HIC	Hydrogen-Induced Cracking
H_2S	Hydrogen Sulphide

ISO	International Organization of Standardization
LTCS	Low Temperature Carbon Steel
MCA	Materials and Corrosion Audit
MSDs	Materials Selection Diagrams
MSR	Material Selection Report
N.A.	Not Applicable
NACE	National Association of Corrosion Engineers
OPEX	Operating Expenditures
PFDs	Process Flow Diagrams
pH	Hydrogen Number
PMI	Positive Material Identification
PREN	Pitting Resistance Equivalent Number = %Cr + 3.3 (%Mo+0.5 %W) + 16 %N
(C-)PVC	(Chlorinated) Polyvinyl Chloride
PWHT	Post-Weld Heat Treatment
QA	Quality Assurance
QC	Quality Control
RBI	Risk based inspection
SAW	Submerged arc welded
SDSS	Super Duplex Stainless Steel
SOR	Statement of Requirement
SOW	Scope of Work
SS	Stainless Steel
WPQR	Welding Procedure Qualification Record
UFDs	Utility Flow Diagrams

3.2 List of Terms and Definitions

(a) 'Shall' indicates a mandatory course of action.

(b) 'May' indicates one acceptable course of action.

(c) 'Should' indicates a recommended course of action.

(d) 'Company' refers to ADNOC.

(e) 'Contractor' refers to the party that carries out the duties of engineering, procurement and management of the project.

'Manufacturer/Supplier' means the party that manufactures or supplies equipment, materials or services to perform duties specified by the COMPANY

4 NORMATIVE REFERENCES

The documents listed in Table 2 are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Table 2 – Normative References

Ref.	Document No.	Title
(1)	ASTM A262	Standard practice for detecting susceptibility to intergranular attack
(2)	NACE MR0175 / ISO 15156	Petroleum, petrochemical and natural gas industries – Materials for use in H_2S containing environments in oil and gas production
(3)	NACE SP0407	Format, content, and guidelines for developing a materials selection diagram
(4)	ISO 21457	Petroleum, petrochemical and natural gas industries – Materials selection corrosion control for oil and gas production systems
(5)	NACE TM0177	Laboratory testing of metals for resistance to sulfide stress cracking and stress corrosion
(6)	NACE TM0316	Four-point bend testing of materials for oil and gas applications
(7)	NACE TM0284	Standard test method – evaluation of pipeline and pressure vessel steels for resistance to hydrogen induced cracking
(8)	API 6DSS	Specification for subsea pipeline valves
(9)	API RP 945	Avoiding environmental cracking in Amine units
(10)	API RP 571	Damage mechanisms affecting fixed equipment in the refining industry
(11)	ASTM A263	Standard specification for stainless chromium steel-clad plate
(12)	ASTM A264	Standard specification for stainless chromium-nickel steel-clad plate
(13)	ASTM A265	Standard specification for nickel and nickel-base alloy-clad steel plate

(14)	ASTM A578	Standard specification for straight-beam ultrasonic examination of rolled steel plates for special applications
(15)	ASTM A153	Standard specification for Zinc coating (hot-dip) on iron and steel hardware
(16)	NACE MR0103/ISO 17945	Petroleum, petrochemical and natural gas industries – Metallic materials resistant to sulphide stress cracking in corrosive petroleum refining environments
(17)	ASTM A672	Standard specification for electric-fusion-welded steel pipe for high-pressure service at moderate temperatures
(18)	NACE SP0742	Methods and controls to prevent in-service environmental cracking of carbon steel weldments in corrosive petroleum refining environments
(19)	API 5L	Specification for Line Pipe
(20)	NACE SP0304	Design, installation, and operation of thermoplastic liners for oilfield pipelines
(21)	DNV RP O501	Erosive wear in piping systems

5 REFERENCE DOCUMENTS

5.1 ADNOC Specifications

Table 3 – Referenced ADNOC Specifications and Standards

Ref.	Document No.	Title
(a)	AGES-SP-07-001	Cathodic Protection Specification
(b)	AGES-SP-07-002	External Pipeline Coatings Specification
(c)	AGES-SP-09-001	Piping Basis of Design
(d)	AGES-SP-09-002	Piping Material Specification
(e)	AGES-SP-09-003	Piping & Pipeline Valve Specification
(f)	AGES-SP-06-002	Pressure Vessel Specification
(g)	AGES-SP-05-001	Centrifugal Pumps (API 610) Specification
(h)	AGES-SP-06-003	Shell and Tube Heat Exchanger Specification

SECTION A

6 DOCUMENTS PRECEDENCE

The specifications and codes referred to in this specification shall, unless stated otherwise, be the latest approved issue at the time of Purchase Order placement.

It shall be the CONTRACTOR'S responsibility to be, or to become, knowledgeable of the requirements of the referenced Codes and Standards.

The CONTRACTOR shall notify the COMPANY of any apparent conflict between this specification, the related data sheets, the Codes and Standards and any other specifications noted herein.

Resolution and/or interpretation precedence shall be obtained from the COMPANY in writing before proceeding with the design/manufacture.

In case of conflict, the order of document precedence shall be:

(a) UAE Statutory requirements;

(b) ADNOC Codes of Practice;

(c) Equipment datasheets and drawings;

(d) Project Specifications and standard drawings;

(e) Company Specifications;

(f) National/International Standards.

7 QUALITY ASSURANCE AND QUALITY CONTROL

The CONTRACTOR shall always have in effect a Quality Assurance and Quality Control (QA/QC) program which clearly establishes the authority and responsibility of those responsible for the quality system. Persons performing quality functions shall have sufficient and well-defined authority to enforce quality requirements that initiate, identify, recommend and provide solutions to quality problems and verify the effectiveness of the corrective action.

CONTRACTOR's Quality Management Systems shall comply with all the requirements of ISO 9001 ‘Quality Management Systems - Requirements’ and ISO 9004 ‘Managing for the sustained success of an organization - A quality management approach’.

A copy of the CONTRACTOR's *QA/QC* program shall be submitted to the COMPANY with its quotation for review and concurrence prior to award. If CONTRACTOR *QA/QC* program is ISO 9001 certified, then only a copy of the ISO 9001 certificate is required. In addition, if CONTRACTOR's facility is ISO certified, QA audit requirements will be waived in favour of ISO 9001 registrar audits, unless the COMPANY's trend analysis program indicates areas of concern.

The CONTRACTOR shall identify in documents to its MANUFACTURERS, SUPPLIERS, CONTRACTORS and subcontractors all applicable QA/QC requirements imposed by the COMPANY, and shall ensure compliance. CONTRACTOR shall provide objective evidence of its QA/QC surveillance for all levels of its activity.

8 DOCUMENTATION

The CONTRACTOR shall comply with the documentation requirements as specified in the contract.

SECTION B

9 EXPERTISE

The CONTRACTOR shall have metallurgical and corrosion specialist(s) with at least 15 years' experience in materials selection, welding, fabrication, coating, Cathodic protection and corrosion inhibition dedicated to the Project.

In case the CONTRACTOR does not have dedicated expertise, he will appoint an expert(s) to cover materials selection and corrosion control discipline. COMPANY shall approve the resume of the expert(s).

10 DELIVERABLES

The CONTRACTOR shall produce the following documents related to Materials Selection and Corrosion Control for all new engineering projects for COMPANY. These documents shall be submitted as minimum to the COMPANY for review and approval before action is taken.

Table 4 – List of Deliverables

Deliverable	STAGES		
	CONCEPT	FEED	EPC
Materials Selection Report	X		
Materials Selection and Corrosion Control Report Including a Materials Selection Summary Table, Field Conditions & Corrosion Control Techniques		X	X
Material Selection Diagrams		X	X
Life Cycle Cost Analysis Report (If required)	X	X	X
Risk Based Inspection BI SOW		X	
Risk Based Inspection Study (By third party)			X
Corrosion Risk Assessment Study (By third party/Contractor)		X	
Materials and Corrosion Audit (By third party)		X	
Corrosion Control Design and Specifications		X	X
Corrosion Management Manual			X

10.1 Materials Selection Report

The Materials Selection Report (MSR) shall document the justification of material selection for process and utility piping, pressure equipment, process and utility components and other facilities specified within the contract's SOW. The following elements should be included:

(a) Brief description of the process.

(b) Brief description of the corrosion and metallurgical degradation mechanisms applicable to the unit (including literature sources).

(c) The process stream data/requirements based on the variables outlined in Section 11.1, Table 5.

(d) Corrosion rate calculations made by any industry standard corrosion modelling software with COMPANY approval, including ECE-4 & 5, Predict 6.0.

(e) Basis of materials selection specific for the unit.

(f) Explanation of material selection for piping, equipment and other corrosion control approaches to resist the degradation mechanisms, including:

(i) Requirements for PWHT;

(ii) Impact testing requirements;

(iii) Severity of Sour service (High or low) and compliance with NACE MR0175 / ISO 15156;

(iv) Requirements for corrosion inhibitor efficiency and availability (specific injection locations shall be indicated on marked-up P&IDs);

(v) Requirements for corrosion control, for example CP and coatings;

(vi) Requirements for corrosion monitoring (this should just include the general details. Specific locations shall be indicated on marked-up P&IDs).

(g) PMI (Positive Material Identification) requirements;

(h) Criticality rating of piping and equipment;

(i) Identification of uncertainties from a materials perspective, new application for materials, use of new grades;

(j) Need for material qualification testing; and

(k) A summary table of material selection per service item.

10.2 Materials Selection Diagrams

Material Selection Diagrams (MSDs) shall be marked-up replicas of the project's Process Flow Diagrams (PFDs) and Utility Flow Diagrams (UFDs) in accordance with the requirements of NACE SP0407. They should be included in the appendices of the MSR.

The following elements should be included:

(a) Colour coded material selection for process and utility piping, including any Corrosion Allowance (CA);

(b) Materials for pressure retaining equipment, including any specification for lining or cladding materials;

(c) Relevant process stream information used for material selection; and

(d) Locations of piping or equipment material breaks/changes where two different materials are required (change of material shall be made from nearest flanged connection).

10.3 Corrosion Control Manual

The Corrosion Control Manual (CMM) should address all the requirements for:

(a) Corrosion inhibition;

(b) Corrosion monitoring;

(c) Cathodic protection; and

(d) Internal and external coatings.

10.4 Corrosion Risk Assessment Study

The Corrosion Risk Assessment Study (CRAS) shall be carried out about a third party and shall be fully quantitative or semi-quantitative to component level in line with the API RP-581. The document should include all the potential corrosion-based damage mechanisms that are applicable to the design considering the materials that have been defined in the MSR for each piece of equipment and piping, such as general localized metal loss, chloride stress corrosion cracking, caustic embrittlement, galvanic corrosion etc.

Corrosion risk analysis shall be performed and reported within the CRAS and used to assign a Risk Rating due to corrosion. This Risk Rating is a function of the probability of corrosion failure and the consequence of failure. The consequence of failure considers safety, health, environmental, as well as business impact of failure. The Risk Rating is determined by combining the probability of failure and the consequence of failure.

The Risk Rating using ADNOC risk matrix shall be marked-up on the MSDs, PFDs or P&IDs where corrosion is a factor. Additionally, recommendations to reduce the 'high' and 'medium' risks to a 'low' risk category shall be provided for COMPANY assessment.

10.5 Risk Based Inspection

The SOW for the Risk Based Inspection (RBI) shall be defined by the CONTRACTOR based on the conclusions of the CRAS. The RBI study shall be conducted by a COMPANY approved third party.

The RBI should use the likelihood of failure and the consequence of failure to formulate risk analysis to prioritise and manage inspection programs of plant equipment and piping.

The analysis looks not only at inspection programs, but also at equipment designs and numerous process safety management issues and all other significant issues that may affect the overall mechanical integrity and safety of the process installation. In order to develop this program, understanding of the potential deterioration mechanisms that can lead to equipment failure, the likelihood of occurrence, assessing and managing the risk, and assessing the consequences of failures, are key elements that should be included.

As a minimum, the RBI shall include the following:

(a) Prepare RBI policy;
(b) Create an asset register;
(c) Carry out process review and define pressure system;
(d) Determine likelihood of failure;
(e) Determine consequence of failure;
(f) Determine operational critical risk ratings;
(g) Authoritative review to check completeness of all data, its validity and coverage of entire facilities;
(h) Define an inspection program (internal, methods and scope);
(i) Conduct initial inspection and fill-up first or base inspection reports;
(j) Create Feedback loop.

The CONTRACTOR shall use a well-established software with approval from COMPANY to develop the Risk-Based Inspection Program. The RBI software and database shall be fully compatible with the COMPANY's Inspection Management System to enable merging by the CONTRACTOR of the new database with the one existing in the COMPANY. CONTRACTOR shall collect pre-start up data (including baseline thickness measurements results) and establish on-going monitoring facilities to implement the approved strategy in construction and in coordination with COMPANY.

10.6 Materials and Corrosion Audit

A COMPANY approved Metallurgical/Corrosion expert hired by the CONTRACTOR shall perform the Materials and Corrosion Audit (MCA) at the end of the FEED phase. The COMPANY shall approve the methodology for MCA. The MCA shall be carried out jointly along with the COMPANY's nominated engineers. This audit shall include the review of all MSDs, MSRs, CMMs and CRASs.

The MCA shall review proposed metallurgy, special materials requirements applied to items in severe corrosive service, special materials specifications, corrosion control aspects and programs, health, safety and environment concerns, painting and internal lining requirements, possible improvements, and cost saving suggestions.

The results of this audit shall be forwarded to the CONTRACTOR, who shall prepare a document to specify the modifications that shall be implemented during detail engineering as a result of this audit. CONTRACTOR shall accordingly implement all COMPANY approved changes and adjust all relevant project documents. The CONTRACTOR shall follow up and report progress made on all action items to COMPANY.

10.7 Life Cycle Cost Analysis

A Life cycle cost analysis shall be done to justify material selection within the specified design life of the project, particularly where alternatives of material selection and corrosion control method are to be considered. This shall consider maintenance risk and OPEX cost vs. upfront CAPEX. This shall be submitted to COMPANY for approval.

The metallurgical and corrosion specialists of CONTRACTOR shall also participate in the value engineering to recommend cost saving ideas for implementation in the Project with COMPANY approval.

11 PHILOSOPHY OF CORROSION MITIGATION

11.1 Principles of Material Selection and Corrosion Protection

Material selection shall be used as the primary means of corrosion control. Various types of short-and-long-term undesirable metallurgical changes or corrosion that may be induced during fabrication and/or service shall be given careful considerations. Any measures, which may be required to prevent or limit risks of failure, shall be indicated and incorporated.

Material selection shall be made in alignment with this guideline, the Project's Basis of Design (BoD), and the Project's field/service parameters which shall be used to determine the corrosion conditions. The field conditions to be used shall include the variable listed in Table 5.

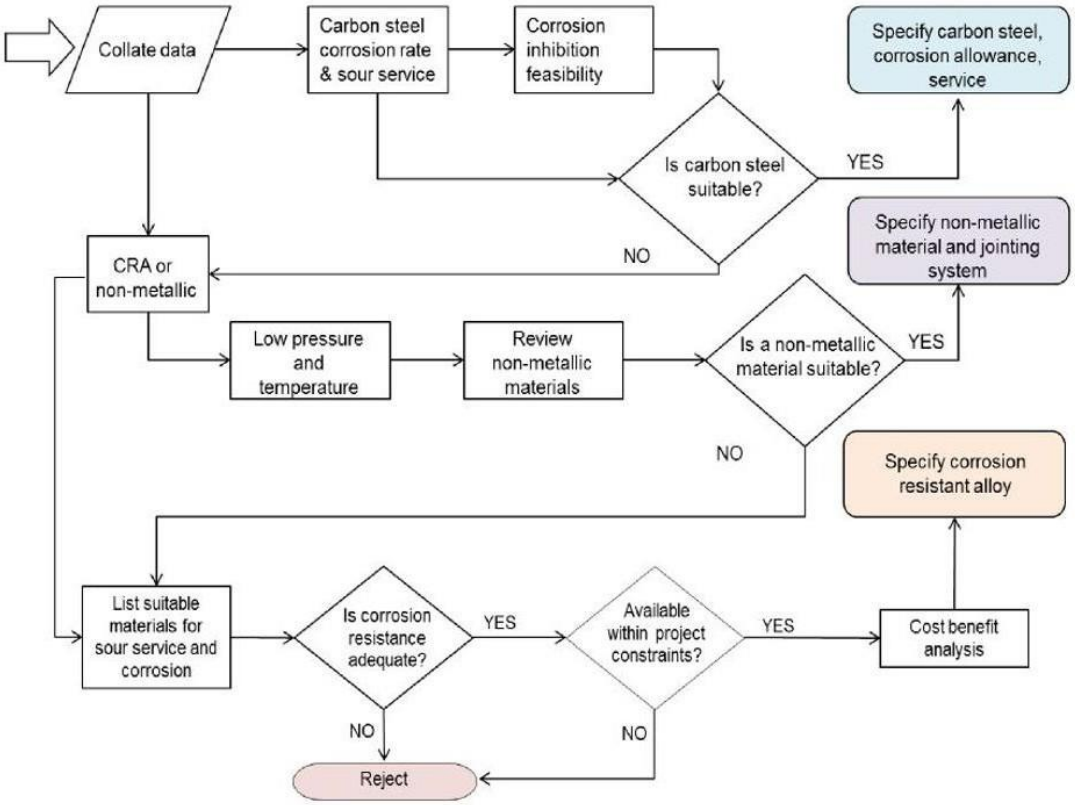
Table 5 – Parameters used for Corrosion Evaluation

Parameter	Units
Design Life	Years
Operating Temperature Range	°C
Pipe Diameter	mm
Design Pressure	MPa
Dewpoint Temperature	°C
Gas to Oil Ratio (GOR)	SCF / SBO
Gas, Oil & Water Flow Rate	tonnes/day
CO_2 Content & partial pressure	Mole % / ppm
H_2S Content & partial pressure	Mole % / ppm
Water Content	%
pH	N.A.
Chloride Content	ppm
Oxygen	ppm / ppb
Sulphur	wt% / ppm
Mercury	wt% / ppm
Acetic Acid Concentration	mg/l
Bicarbonate Concentration	mg/l
Calcium Concentration	mg/l
Sand/Solid Particle Content (Erosion)	kg/hour
Potential for Microbially Induced Corrosion (MIC)	N.A.

It is COMPANY policy to use Carbon Steel (CS) whenever possible for the construction of production systems, processing equipment and pipelines. A Corrosion Allowance (CA), adequate for the asset to achieve the required service life is provided to accommodate corrosion (Section 11.2), and wherever feasible, corrosion inhibition (Section 11.4) is supplied to reduce the risk of pitting and reduce the rate of corrosion.

Where the use of CS is not a technical and economic option and/or where a failure by corrosion would pose an acceptable risk to personnel, the environment or COMPANY assets, Corrosion Resistant Alloy (CRA) may be used. Alternatively, if the service life corrosion of CS with inhibitor treatment exceeds 6 mm, CRA will be selected (Solid or Clad CRA). Selection of a CRA should ensure that the optimum alloy is selected based on cost-performance criterion. A material selection flow diagram is shown in Figure 1 to outline the process by which material selection alternate to CS may be justified.

Figure 1 – Material Selection Flow Diagram



11.2 Corrosion Allowance

CA, for CS shall be specified based on anticipated corrosion rates or material degradation rates under the most severe combination of process parameters. Specifying CA should be properly engineered and justified noting that when short-term material performance or transient conditions are anticipated to increase general or localized corrosion risks, upset duration shall be estimated based on prorated corrosion rates. Based on these, extra corrosion allowances may be required. Therefore, the CRAS needs to be carried out at an early stage of the project.

The CA itself shall not be considered as an assured corrosion control measure. It shall be considered only as a measure to provide time to detect measure and assess the rate of corrosion.

Depending on Project's requirements and conditions, the permittable CA can be increased above 6 mm where the estimated corrosion rate exceeds 0.25 mm/y. However, this will be discussed on a case by case basis. When corrosion allowances are excessive, material upgrade shall be considered and evaluated. Selection of CRA should ensure that the optimum alloy is selected based on cost-performance criterion.

The following guideline shall be used to specify the level of CA:

(a) The CA is the product of multiplying the estimated corrosion rate of the selected material by the design life (including possible life extension), rounded to the nearest 3.0, 4.5 or 6.0 mm.

(b) Corrosion due to CO_2 can be assessed using COMPANY approved corrosion models such as ECE-4 & 5, Predict 6.

(c) The corrosion rate used to estimate the CA shall be based on based on past plant experience and the available published data for process conditions which should include:

(i) Corrosivity of fluid, for example , presence of water combined with hydrogen sulphide (sour corrosion), CO_2 (sweet corrosion), oxygen, bacteriological activity, temperature and pressures;

(ii) Velocity of fluid that determines the flow regime in the pipeline;

(iii) Deposition of solids that may prevent adequate protection by inhibitors and create conditions for growth of bacteria; and

(iv) Conditions that may cause pipe wall erosion.

(d) CS and low alloy steel of pressure parts shall have a minimum of 3.0 mm. In special cases 1.5 mm may be specified with COMPANY approval; considering the design life of the item under consideration. Examples of mild or non-corrosive services, where 1.5 mm CA may be specified, are steam, deaerated boiler feed water (< 10 ppb O_2), treated (non-corrosive, chloride controlled, bacteria free) fresh cooling water, dry compressed air, hydrocarbons containing no water, LPG, LNG, dry natural gas etc. Nozzles and manhole necks shall have the same CA as specified for the pressure containing equipment.

(e) Maximum CA shall be 6.0 mm. Depending on Project's requirements and conditions, the permittable CA can be increased above 6 mm where the estimated corrosion rate exceeds 0.25 mm/y. However, this will be discussed on a case by case basis. When corrosion allowances are excessive, material upgrade shall be considered and evaluated. Selection of CRA should ensure that the optimum alloy is selected based on cost-performance criterion.

(f) The layout of the installation and its effect on flowrate (including deadlegs).

(g) Failure probabilities, failure modes and failure consequences for human health, environment, safety and material assets, all determined by carrying out a risk assessment not only for Materials but other disciplines as well.

(h) Access for maintenance and repair.

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

(a) Priority shall be given to materials with good market availability and documented fabrication and service performance, for example , weldability, inspect ability;

(b) The number of different materials shall be minimized considering stock, costs, interchangeability and availability of relevant spare parts;

(c) Strength to weight (for offshore); and

(d) Frequency of pigging/cleaning.

No CA shall be required for:

(a) The backing material of items with alloy cladding or weld overlay.

(b) On the gasket facing of flanges.

(c) For CRAs. However, for CRA's in erosive service, a 1 mm CA shall be specified. This shall be addressed and supported by erosion modelling via DNV RP O501 [Ref.(e)(21)] (or similar models when approved for use by the COMPANY).

Note: When short-term or transient conditions are anticipated to increase general or localized corrosion risks, upset duration shall be estimated based on prorated corrosion rates. Based on these, higher corrosion

allowances may be required. Additionally, CRA piping or CRA internally clad / lined piping shall be used for areas of high fluid velocity and expected erosion-corrosion.

11.3 Metallic Cladding

To mitigate the risk of corrosion where corrosion rates are in excess of a 6 mm CA, it may be suitable to specify a CS parent material with a layer of CRA cladding or weld overlay material. Where there is any doubt the specifier of materials shall seek advice from COMPANY. Where CRA cladding of vessels is specified or CRA cladding is applied by explosive weld bonding, metallic roll bonding or weld overlay, SSC resistant quality base plate is required, but HIC resistant base plate is not required.

If explosion bonding or roll bonding is the selected option, a minimum thickness if 3 mm shall be achieved across 100% of the parent material. If overlay is the selected option, there should be a minimum of 2 passes and a minimum thickness of 3 mm shall be achieved. If there is a weldability issue, then explosive bonding can be considered.

Common cladding materials include:

(a) 316 SS (type 317 SS may be specified where there is a higher risk of chloride pitting);

(b) Alloy 904;

(c) Alloy 825 (limited to roll bonding as welding may result in inferior corrosion resistance in clad plate); and

(d) Alloy 625.

Where the thickness of the vessel is relatively thin (up to 20 mm), a lifecycle cost analysis shall be used to decide whether a solid CRA material selection is more commercially viable. This shall be considered on a case by case basis.

Clad or lined pipe may be used for flowlines that transport highly corrosive fluids. The requirements of API 5LD apply. For economic reasons, these pipelines will be of modest diameter and short length. Clad pipe is formed from steel plate that has a 3 mm layer of CRA bonded to its internal surface. The CRA clad can be either metallurgically bonded, co-extruded or weld overlaid, or for subsea applications, process/mechanical bonding can be used when depressurising risk is low. For welded pipe specification CRA cladded pipe is formed to the pipe and the seam is welded with CRA consumables.

The CONTRACTOR shall issue separate specification based on existing COMPANY specific specifications for alloy clad or weld overlay on CS, covering the requirements for the design, fabrication, and inspection of applied lining and integral cladding for pressure vessels and heat exchangers. The ASTM specifications A263, A264, A265, A578 and E164, and NACE MR0175/ISO 15156 may be used for reference.

11.4 Application of Corrosion Inhibitor

Selection of corrosion inhibitor and evaluation shall be as per Company's Procedure. For design purposes, 95% corrosion inhibition efficiency shall be assumed for gas condensate and 90% for oil. Additionally during design, the inhibitor availability shall be based on 90% availability, during the operational phase the minimum inhibitor availability shall be >90%. The inhibitor availability shall be specified during the FEED stage on a project to project basis. However, the use of corrosion inhibitor shall not act as a substitute for NACE MR0175/ISO 15156 sour service material selection requirements.

To enable the effectiveness of the inhibition system to be verifiable during operation, the following shall be included in the design:

(a) The locations of highest potential corrosion rate.

(b) Accessibility of high potential corrosion rate locations for wall thickness measurement during operation.

(c) Ability to take samples for solids/debris analysis.

(d) Corrosion measurement equipment should be used to monitor the effectiveness of the inhibition system.

(e) Facilities to allow iron counts should be included in the design for monitoring inhibited systems.

Provision shall be made in the design so that the following Key Performance Indicators (KPI) can be measured and trended for inhibited systems:

(a) The number hours the inhibition system is not available.

(b) Actual injected concentration compared with target injection concentration.

(c) Inhibitor residual concentration compared to target concentration.

(d) Average corrosion rate as compared to target inhibited corrosion rate.

(e) Changes of corrosion rate or dissolved iron levels as a function of time.

(f) Unavailability of the corrosion monitoring data.

11.5 Material for Sour Service

Materials selection for piping and equipment for use in H_2S containing environments shall comply with the latest COMPANY Specification for Materials in Sour Environments and be verified to NACE MR0175/ISO15156 for upstream processes and NACE MR0103/ISO 17945 for downstream processes.

316L SS shall be considered for most sour services except where higher temperatures >60 °C occur together with a high H_2S and chloride content of the fluid, however this will be considered on a case by case basis. For operating conditions outside of these limitations, higher alloy materials may be considered in compliance with NACE MR0175/ISO15156. Additionally, consideration should be given to vapour separation where the chloride content carryover will be reduced.

316L SS cladding may be considered for vessels when following the environmental and materials limits from Table A2 in ISO 15156, part 3. Vessels clad with 316L must be allowed to cool below 60 °C before opening as there is risk of chloride stress cracking of the cladding when exposed to oxygen. For operating conditions outside of these limitations, higher alloy materials may be considered in compliance with NACE MR0175/ISO15156. Cladding shall be inspected to ensure that it is continuous over 100% of the complete surface including any nozzles and any other attachments.

Steel for sour service piping shall be HIC resistant and have a sulphur content <0.01% and be secondary treated with calcium for inclusion shape control. Steel for longitudinally welded pipe shall have a sulphur content <0.003% and be secondary treated with calcium for inclusion shape control.

Specific guidelines for bolting in sour service environments can be found in the bolting section of this guideline; Section 12.8.

When sour service requirements are specified by the purchaser, the following shall apply:

(a) All materials shall be marked to ensure full traceability to melt and heat treatment lot.

(b) Heat treatment condition. For tempered condition, tempering temperature shall be stated.

(c) The supplementary suffix ‘S’ shall be used to designate a material delivered in accordance with the MDS plus the additional supplementary requirements for sour service but excluding HIC testing and UT examination.

(d) The supplementary suffix ‘SH’ shall be used to designate a material delivered in accordance with the MDS including the additional supplementary requirements for sour service plus HIC testing and UT examination.

(e) The material manufacturer shall have a quality system certified in accordance with ISO 9001 or another quality requirements standard accepted by the purchaser.

(f) The inspection documents shall be issued in accordance with ISO 10474 /EN 10204 Type 3.1 and shall confirm compliance with this specification.

(g) Fully killed materials must be used.

(h) For sour service pipe, materials shall comply with the requirements of API 5L Annex H - PSL2. For severe sour service, low strength normalised grades are specified, limited up to X65 grades.

(i) Sour service testing is required on both base material and weldments and routine testing for SSC and HIC shall accord with NACE TM0177 and NACE TM0284. Testing for SOHIC and soft zone cracking may require full ring testing with the welds produced using the actual manufacturing weld procedures. Four-point bend testing shall be carried out in accordance with NACE TM0316.

(j) Hardness as per ISO 15156 for upstream, and NACE MR0173/NACE SP0742 for downstream.

11.6 Specific Considerations

The following list contains specific material selection considerations that are not specific to any given system and shall be applied to all COMPANY Projects:

(a) The CONTRACTOR shall be fully responsible for material selection made by any LICENSOR I in any packaged equipment. The CONTRACTOR shall provide for that all information including MSDs, material selection philosophies, CRAS, RBI and MCA in line with this specification for COMPANY approval. Any change of material will be warranted under the CONTRACTOR.

(b) Attention shall be given to fracture toughness properties of pipe materials to prevent the possibility of brittle fracture.

(c) Aluminium bronze material shall not be used in welded parts because of poor weldability and maintenance problems.

(d) Electroless Nickel Plating (ENP) shall not be used unless approved by COMPANY.

(e) Material for Lube and Seal Oil system shall be SS316L if its suitability is confirmed.

(f) Rubber linings in water boxes of surface condensers and other exchangers shall not be used without COMPANY approval.

(g) Use of GRE/HDPE material for low pressure oil and gas, water, oily and storm water, drains within acceptable service parameters and loading (when buried) limits by manufacturer is permitted with COMPANY's approval.

(h) The design of any and all heat exchangers shall be based on its process requirements. Therefore, material selection is bespoke for all heat exchangers and cannot/should not be standardised.

(i) Stainless steel 304, 304L shall not be used as external material application where it’s not suitable for the humid laden atmosphere of UAE.

12 MATERIALS SELECTION RECOMMENDATION FOR SPECIFIC APPLICATIONS AND SYSTEMS

This section gives material guidelines for specific systems that are present within the COMPANY’s range of facilities including its upstream (both onshore and offshore) and downstream (refinery) assets. An overview

of the units found within these facilities, the material options, potential damage mechanisms and mitigation for such mechanisms are given in the following tables. Further detail for each unit is given throughout the remainder of this Section. For further details on the listed corrosion mechanisms, see API RP 571.

Note: Material options given in this section shall be taken as a guideline only. The CONTRACTOR shall be responsible for Project specific material selection throughout each phase of the Project through the deliverables specified in Section 10.

Table 6 – Material Recommendations for Upstream Process Equipment and Piping

Service	Material Options	Damage Mechanisms	Mitigation
Wellhead rigid spools / Jumper and Manifolds	CS + CRA Cladding, CRA, CS +CA	CO_2 corrosion, Wet H_2S Damage, Chloride Stress Corrosion Cracking (CSCC)	Material Selection. (When Corrosion Inhibition is deemed ineffective at such locations / highly corrosive service - CRA / CRA clad option recommended) Design for sour service. UNS N06625 / UNS N08825 clad option. NACE MR0175 /ISO 15156 sour service requirements apply for sour service.
Pipeline/Flowline	CS + CA	Hydrogen embrittlement, CO_2 corrosion, Wet H_2S Damage, CSCC, MIC	Cathodic protection and coating to protect buried metallic section. Use of biocide and corrosion inhibitor, and pig/scrapper. Periodic Inline Inspection (Intelligent pigging) to measure wall thickness and periodic cleaning using appropriate cleaning pig.
Wet Hydrocarbon Gas	CS + CA (+CA/CRA Cladding), 316 SS, DSS, SDSS	CO_2 corrosion, Wet H_2S Damage, CSCC, chloride pitting,	Material Selection Design for sour service TOL corrosion to be assessed, mitigation is to specify CRA clad when corrosion allowance exceeds 6mm. Use of corrosion inhibitor NACE MR0175 /ISO 15156 sour service requirements apply for sour service. Selection at inlet is predominantly based on sour service requirements
Dry Hydrocarbon Gas	CS + CA (+ CRA Cladding), 316 SS	CO_2 corrosion, Wet H_2S Damage.	Material Selection Ensure operation is within specified conditions envelope

			Corrosion monitoring is vital to ensure gas remains dry. CA may be required if periods of wetness are possible.
Stabilised Condensate	CS + CA	CO_2 corrosion, Wet H_2S Damage, MIC	Material Selection Monitoring of bacterial activity
Produced Water	CS + CA, 316 SS, DSS, SDSS. CS+ CRA liner, CS+ CRA (metallurgical bonded)	CO_2 Corrosion, Wet H_2S Damage, CSCC, MIC, O_2 corrosion	Material selection Design to prevent oxygen ingress Use of biocide, O_2 scavenger and corrosion inhibitor CS + internal lining may be selected for vessels. Specification of pipe material is highly dependent on process/fluid conditions. NACE MR0175 /ISO 15156 sour service requirements apply for sour service.
Export Oil / Gas Export / Feed Gas	CS + CA	CO_2 corrosion, Wet H_2S Damage, MIC	Material Selection For Gas export Dew point temperature monitoring If gas export is considered 'wet', upgrade to CRA (clad /solid) material may be required based on corrosion assessment results.
Gas Dehydration (TEG)	CS + CA, 316 SS, CS+CRA	Corrosion form acid condensation in still column overheads	Material selection is licensor driven; however, responsibility lies with the CONTRACTOR.
Injection Chemicals (for example corrosion inhibitor)	CS (+ CA), 316 SS, C-PVC	Chemical compatibility, corrosion.	Materials selection shall be discussed with VENDOR/SUPPLIER in terms of chemical compatibility.
Mercury Removal	CS + CA	CO_2 corrosion, Wet H_2S Damage, CSCC, chloride pitting *Liquid metal embrittlement	Material selection *Aluminium or copper bearing titanium alloys shall not be used where there is a risk of liquid mercury.
Amine	CS + CA / CRA Cladding, 316 SS	CO_2 corrosion, wet H_2S damage, Amine Stress Corrosion Cracking (ASCC), amine corrosion, erosion (from heat stable salts)	Suitable operation velocities, temperatures for designed system, and regular sampling to check for amine salts. Rich amine shall be 316 SS. Vessel internal shall be 316 SS. Velocity limits. PWHT shall be specified for CS to prevent ASCC when design

			temperature is > 53 °C. PWHT temperature to be used shall be as per API RP 945.
Flare	CS + CA, 316 SS *310 SS, 308 SS, Alloy 800, Alloy 625	Low temperature fracture, atmospheric corrosion, creep rupture (thermal fatigue), CSCC.	CS + lining is an option for flare drums Design for both minimum and maximum design temperature Issue of low temperature brittle fracture to be addressed. Internal corrosion mechanisms more likely in marine environments. * materials for flare tip.
PLR (PIG Launcher Receiver)	CS + Weld overlay for sealing surface	CO_2 corrosion, Wet H_2S Damage, under-deposit corrosion, MIC, Dead Leg Corrosion	Material selection Periodic Inspection Use of biocide and corrosion inhibitor.

Table 7 – Material Recommendations for Downstream Process Equipment and Piping

Service	Material Options	Damage Mechanisms	Mitigation
Crude Oil Unit	CS, 5Cr-1/2 Mo, 9Cr - 1Mo , 12Cr , 317L, 904L or other alloys with higher Mo (to avoid NAC), CS+SS Clad	Sulphur attack, Sulfidation, naphthenic acid corrosion (NAC), wet H_2S damage, HCL corrosion	Material Selection Desalting Flow velocity limit. Use of corrosion inhibitor
Fluid Catalytic Cracking	CS + CA, 1Cr-1/2Mo, 2-1/4Cr- 1Mo, 5 Cr and 9Cr Steels, 12Cr SS, 300 series SS, 405 / 410 SS , alloy 625 Internal erosion / insulating refractory linings	Catalyst Erosion High Temperature Sulfidation, High Temperature Carburisation, Creep, Creep embrittlement, Ploythionic Acid Stress corrosion cracking. High Temperature Graphitisation, High temperature oxidation. 885°F Embrittlement.	Material selection Erosion resistant lining Design minimum turbulence of catalyst and catalyst carryover
FCC Light End Recovery	CS + CA (+ 405 / 410 SS Cladding), DSS, alloy C276, alloy 825	Corrosion caused by combination of aqueous H_2S, ammonia, and hydrogen cyanide (HCN), Wet H_2S damage-SSC, SOHIC, HIC ammonium stress corrosion cracking, carbonate stress corrosion cracking	Material selection Ploysulfide injection into wash water to lower HCN content. Velocity limit Corrosion inhibitor injection. Prevention of oxygen ingress
Sulphuric Acid Alkylation	CS + CA, Low Alloy Steel, alloy 20, 316 SS, C-276	Sulphuric acid corrosion, Hydrogen grooving, acid dilution, fouling, CUI.	Material selection – however higher alloys are uncommon

			Velocity control (CS- 0.6m/s - 0.9m/s, 316L limited to 1.2m/sec) Acid Tanks as per NACE SP0294 Antifouling injection
Hydro-processing	CS, 1Cr- 1/2Mo, 2-1/4Cr-1Mo, 18Cr-8Ni SS, 316 SS, 321,347SS, 405 / 410 SS, alloy 20, alloy 800/825, Monel 400	High Temperature Hydrogen Attack (HTHA), Sulfidation by Hydrogen-H_2S mixtures, Wet H_2S damage, CSCC, naphthenic acid corrosion, ammonium bisulfide corrosion.	Material selection as per API 941-HTHA. Velocity control (high enough to maintain fluid distribution) PWHT as per ASME VIII / B31.3
Catalytic Reforming	1-1/4Cr-0.5Mo, 2-1/4Cr- 0.5Mo,	Creep cracking, HTHA, SSC- Ammonia, SSC- chlorides, hydrogen embrittlement, ammonium chloride corrosion, creep rupture	Material selection as per API 941-HTHA. Hardness control, PWHT
Delayed Coker	1-1/4Cr-.0.5Mo clad with 410S or 405SS, 5Cr-Mo or 9Cr-Mo steels, 316L, 317L	High temperature sulphur corrosion, naphthenic acid corrosion, High Temperature oxidation / carburization / sulfidation, Erosion-corrosion, Aqueous corrosion (HIC, SOHIC, SSC, Ammonium chloride/ bisulfide, CSCC), CUI, Thermal Fatigue (thermal cycling)	Minimise stress raisers, Cr-Mo steel of Fine grain, Good toughness properties.
Amine	CS + CA / CS+ 316L Cladding, 316 SS	CO_2 corrosion, wet H_2S damage, Amine Stress Corrosion Cracking (ASCC), rich amine corrosion, erosion (from heat stable salts)	See Amine in Table 6.
Sulphur Recovery (Licensed Units)	CS, 310SS, 321SS, 347SS,	Sulfidation of carbon steel, Wet H_2S damage/ cracking, (SSC, HIC, SOHIC), weak acids corrosion,	Operating piping above dew point temperature to avoid severe corrosion of CS. PWHT of welds to avoid cracking Hardness control HIC resistant steel.

12.1 Pipelines

Pipeline material will be in accordance with existing COMPANY specific Pipeline Material Specification. Carbon steel + corrosion allowance shall be the default material. The corrosion allowance shall be as high as possible as consideration for operation well beyond the design life and will be decided on a case by case basis on each Project. Pipeline coatings are specified in AGES-SP-07-002, the External Pipeline Coatings Specification.

Use of corrosion inhibitors in hydrocarbon pipeline systems with condensed water is recommended and shall be the default option for sub-sea pipelines. i.e. CS + CA + Corrosion Inhibitor. Additional corrosion management techniques such as Pigging, CP etc. shall be considered. Selection and evaluation of corrosion inhibitor shall be as per Company's procedure.

The selection of a CRA option for pipeline must be evaluated thoroughly via Life Cycle Costing analysis. HSE considerations cost of chemicals and corrosion management techniques, logistics of transporting and handling chemicals, shall all be built into the analysis, as well as inspection requirements.

12.2 Hydrocarbon Piping

Material selection for process piping shall be performed by the CONTRACTOR as per the requirements of Section 11. Material guidelines per service are given for both upstream and downstream facilities in the prior table 6 and 7, respectively. All welds and acceptance criteria shall be conducted to the requirements of ASME B31.3. Piping material shall be specified by piping in conformance to ADNOC piping material specification AGES-SP-09-002.

Particular and separate material selection may be required for dead legs where a CRA or CRA cladding may be required for corrosion control in areas of stagnant flow. However, the piping design should consider avoiding dead legs to reduce the probability and severity of corrosion. Where dead legs cannot be avoided, internal coating, dosing with inhibitors and biocides, and periodic corrosion monitoring is recommended. This is also applicable to static equipment.

During design, care shall be taken, particularly by piping discipline, not to have SS in contact with galvanised parts, to avoid zinc embrittlement. This is a concern at temperatures were Zn can diffuse, such as in welding operations.

12.3 Utility Systems

Table 8 – Material Recommendations for Utility Services

Service	Material Options	Damage Mechanisms	Mitigation
Fuel Gas	CS, 316 SS	If fuel gas is wet: CO_2 corrosion, chloride pitting, CSCC, wet H_2S damage	Material Selection Controlled operation conditions during start-up when alternate fuel gas may be used.
Inert Gas	CS + min. CA	General contaminants from fuel gas product	Material selection (level corrosion is dependent on what inert gas is used, for example fuel gas from exhaust.)
Diesel Fuel	CS + CA, 316 SS, CS + CA+ Lining *Cast Iron	Risk of contaminants	CS + Lining is suitable for tanks *Pumps shall be cast iron.
Instrument/Plant Air	Galvanised CS, 316 SS	Atmospheric corrosion	Controlled filtration
Nitrogen	Galvanised CS, 316 SS	None, corrosion may come from O_2 ingress during blanketing operations	Upgrade spec where ingress is more likely, or cleanliness is required
Hypochlorite	CS + PTFE lining, C-PVC, C-276, Ti	Crevice corrosion, oxidization	Material selection Dosing/temperature control
Sewage	316 SS, GRP	Chloride Pitting, CSCC, CO_2 corrosion, O_2 corrosion, MIC	Material selection
Fresh Water	Epoxy coated CS, CuNi, Copper, Non-metallic	O_2 corrosion, MIC	Cleanliness monitoring / use of biocide if not used for potable water
Cooling Water	CS + CA, Non-metallic	Cooling water corrosion	Use of O_2 scavenger and corrosion inhibitor

			Mixed glycol-water cooling system in contact with CS components are known to cause corrosion. Glycol should be mixed with corrosion inhibitor.
Seawater	CS + lining, SDSS, Alloy 625, Ti, CuNi, GRP	Chloride Pitting, CSCC, O_2 corrosion, crevice corrosion, MIC	Material selection Temperature control
Demineralised Water	Epoxy coated CS, 316 SS, Non-metallic	O_2 corrosion	Material selection
Potable Water	Non-metallic (for Example C-PVC/HDPE), Cu, CuNi, 316 SS	MIC	Sacrificial anodes shall not be used in potable water system.
Firewater	CuNi, CS+3mmCA(minimum)+internal coating, GRVE, GRE, HDPE	Chloride Pitting, CSCC, O_2 corrosion, crevice corrosion, MIC	Corrosion mechanisms dependent on firewater medium. Non-metallic option needs to consider fire hazard risk
Open Drains	Non-metallic CS + epoxy lining	Chloride Pitting, CSCC, O_2 corrosion, crevice corrosion, MIC, atmospheric corrosion	Piping from clad vessels shall be CRA.
Closed Drains	CS + CA, 316 SS, DSS, SDSS, CS +CRA Clad	CO_2 corrosion Wet H_2S Damage, CSCC, crevice corrosion, O_2 corrosion, ASCC, MIC	Material selection

12.3.1 Fuel Gas

Fuel gas is either supplied as dried gas from downstream of the dehydration columns, like export gas, or as separated low pressure gas that is not completely dried and may be heated to prevent water condensation in the delivery piping.

Dried gas will be transported in CS pipes with a nominal CA of 1 mm and will not be inhibited. Depressurisation temperature must be analysed, and if it is lower than -29 °C, low temperature CS must be specified. Undried fuel gas should be treated similarly to produced wet gas (anything <10 °C above the dewpoint). If cleanliness is required, then 316 SS should be specified.

12.3.2 Inert Gas

Considered noncorrosive. See Table 8.

12.3.3 Diesel Fuel

Considered non-corrosive and CS is suitable, however, may contain some contamination depending on diesel quality. In such cases, diesel storage tanks fabricated in CS with a 3 mm CA shall be required to be internally coated to prevent corrosion and precipitation of corrosion products into the diesel that may interfere with equipment. The complete tank should be coated as condensation on the upper surface can also produce corrosion product. The alternative is to use tanks fabricated from a non-metallic such as GRP.

12.3.4 Instrument/Plant Air & Nitrogen

Galvanized CS is commonly used for high quality air and nitrogen systems for larger diameter piping and 316 SS for smaller diameter piping, despite its non-corrosiveness. Where ingress of moisture may be present, or cleanliness is required downstream of any filters, the alternative option of 316 SS shall be considered throughout. DSS connectors and fittings should be used.

12.3.5 Fresh Water

If treated (as defined in Section 11.2), CS with a CA is allowable. If untreated, freshwater systems should be upgraded to a suitable CRA or CS with CRA cladding.

Potable water should be stored in CS tanks that are internally coated with a coating acceptable to health standards or in tanks fabricated from GRP. When GRP tanks are used the tanks must be externally coated to prevent light entry into the tanks and algal growth in the stored water. To prevent from degradation of the external coating, UV resistant grades must be specified. Piping should be non-metallic materials and conventional copper piping when of the appropriate diameter. Alternatively, 316 SS may be specified for cleanliness reasons.

12.3.6 Seawater

Material selection for seawater systems is highly dependent on temperature and should be selected with reference to ISO 21457. Recommended materials are included in Table 8. CS with internal lining shall only be selected for de-aerated seawater systems as per API 15LE and NACE SP0304.

For firewater systems using seawater as a medium, see Section 12.3.8.

12.3.7 Demineralised Water

Demineralised water is corrosive to CS; hence these systems should be 316 SS. A non-metallic may be selected with input from the material MANUFACTURER and approval from the COMPANY is given. Tanks may be CS with a CA and a suitable internal lining.

12.3.8 Firewater

For most permanently wetted firewater systems with seawater as the medium, the material recommendation is 90/10 CuNi or titanium (refer to the Utility Table 8 in ISO 21457).

Firewater systems may contain, and transport aerated fresh water. The above ground mains may be constructed from 90/10CuNi and the underground mains may be constructed from GRVE (Glass Reinforced Vinyl Esther) which does not require coating or cathodic protection. Larger valves should be CS with CRA clad for internal wetted surface and CRA trim. Critical valves will require to be fully fabricated from CRA materials. To avoid galvanic corrosion issues isolation spools shall be specified wherever electrical isolation between dissimilar materials is required.

NiAl bronze valves is compatible with 90/10CuNi piping, however NiAl Bronze and CuNi are unsuitable for sulphide polluted water.

The selection of material will depend on the quality of the water and its temperature. Black body temperature must be considered in the design.

Internally epoxy coated carbon steel piping for firewater system is subject to COMPANY approval.

12.3.9 Open Drains

Material selection for open drains equipment shall be CS with an internal lining. The recommendation for piping is an appropriate non-metallic pending COMPANY approval. Alternatively, CS with a 6 mm CA may

be specified when the service has low criticality. Open drain tanks shall be internally lined by a qualified organic coating system and supplemented with a Cathodic Protection system.

12.3.10 Closed Drains

Material selection for closed drains shall consider the conditions of any potential hydrocarbons within the system. Where closed drains receive sour hydrocarbon, the requirements for sour service (as per Section 11.5) shall apply. The design of the blanketing system for all drums and tanks shall consider the possibility of residual oxygen, and therefore be considered within the material selection.

12.4 Valves

Material selection for valves shall be appropriate for the piping class that they are classified within, and in accordance with the requirements of ASME B16.34. Further details on valve materials may be found in AGES-SP-09-003, the Piping & Pipeline Valve Specification.

Valves for subsea applications will be selected in accordance with API 6DSS.

Valves shall be selected in conformance to ADNOC specification AGES-SP-09-003.

12.5 Static Equipment

Material guidelines for pressure vessels are given in Tables 6 and 7 above. This is commonly CS with an internal lining or CRA cladding. The guidelines for selection between CS with cladding verses a solid CRA option are given in Section 11.3 but should be considered on a case by case basis. Welds and acceptance requirements shall be as per ASME IX.

Where sour service material selection applies for vessels, refer to Section 11.5. Where outside of the NACE MR0175 / ISO 15156-3 limits for 316 SS, vessels shall be internally cladded/weld overlaid with Alloy 625.

As mention in Section 11.6, the design, and therefore material selection, of heat exchangers is dependent on its service requirements. However, in all cases materials shall follow these guidelines:

(a) The material to be selected to meet the design life requirements of the equipment.

(b) The material selection shall be driven by the design temperature.

(c) Titanium ASTM B265 Grade 2 is the recommended grade for heat exchanger applications containing seawater and rich glycol. The potential for titanium hydriding shall be considered in the design of all titanium heat exchangers, ensuring conditions do not exceed 80 °C, a pH is either below 3 or above 12 (or above 7 with high H_2S content), and there is no mechanism available for generating hydrogen; for example, galvanic coupling.

(d) CA should not generally be available for CS in heat exchangers; therefore, it may require an upgrade in specification to a suitable CRA.

(e) If using CuNi for tubes in a shell and tube design, the minimum and maximum velocities in Table 9 shall be adhered to. However, these values will change with pipe diameter and shall be designed on a case by case basis.

Table 9 – Maximum and Minimum flow Velocities for CuNi Heat Exchanger Tubes

Tube Material	Velocity (m/s)	
	Maximum	Minimum
90 / 10 CuNi	2.4	0.9
70 / 30 CuNi	3.0	1.5

Further detail on design may be found in AGES-SP-06-003, the Shell and Tube Heat Exchanger Specification.

12.6 Rotating Equipment/Pumps

Selection of pump material class shall be made by the CONTRACTOR on a case by case base for any COMPANY Project using AGES-SP-05-001, the Centrifugal Pumps (API 610) Specification. Below in Table 10, guidelines are given on selection of material class for pumps per system. Further material details, including when upgrade to the specification is required for specific operating conditions, may be found in AGES-SP-05-001.

Table 10 – Material Classification for Pumps

Service	Material Class
Sour Hydrocarbon	S-5, A-8
Non-corrosive hydrocarbon	S-4
Corrosive Hydrocarbon	A-8
Condensate, non-aerated	S-5
Condensate, aerated	C-6, A-8
Propane, butane, liquefied petroleum gas, ammonia, ethylene, low temperature services	S-1, A-8
Diesel oil, gasoline, naphtha, kerosene, gas oils, light, medium and heavy lubricating oils, fuel oil, residuum, crude oil, asphalt, synthetic crude bottoms	S-1, S-6, C-6
Xylene, toluene, acetone, benzene, furfural, MEK, cumene	S-1
Oil products containing sulphur compounds	C-6, A-8
Oil products containing a corrosive aqueous phase	A-8
Liquid sulphur	S-1
Liquid Sulphur Dioxide, dry (max. 0.3% weight H_2O), with or without hydrocarbons	S-5
Aqueous Sulphur Dioxide, all concentrations	A-8
Sulfolane (Shell proprietary chemical solvent)	S-5
Short residue containing naphthenic acids (acid number above 0.5 mg KOH/g)	C-6, A-8
Sodium carbonate	I-1
Sodium hydroxide, < 20% concentration	S-1
Glycol	Specified by Licensor
DEA, MEA, MDEA, TEA, ADIP or Sulfinol solutions containing either H_2S or CO_2 with more than 1% H_2S	S-5
DEA, MEA, MDEA, TEA, ADIP or Sulfinol solutions, fat, containing CO_2 with less than 1% H_2S or ≥120 °C	A-8
Boiling and process water	C-6, S-5, S-6
Boiler Feed Water	C-6, S-6
Foul water and reflux drum water	C-6, S-6
Brackish water	A-8, D-2
Seawater	Case by case basis
Sour water	D-1
Fresh water, aerated	C-6
Drain water, slightly acidic, non-aerated	A-8

12.7 Instrument Tubing and Fittings

In general, small tubing less than 1’ NO for Instrumentation / chemicals / Lube/seal oil systems shall be made of 904L material if not specified otherwise.

Instrument tubing/ fitting in utility services with no sour service requirements (instrument air, hydraulic fluid, lube oil, seal oil etc.) for onshore facilities, shall be 316L SS.

For process gas medium involving sour service, application of a CRA material (316L/ 6Mo / Inconel 825) for the Instrument tubing shall be selected in conformance to NACE MR0175 / ISO 15156-3 material limits considering chlorides, H_2S partial pressure, pH and design temperature, or in conformance to NACE MR0103 / ISO 17495 for instrument tubing used in refining environment.

Instrument tubing material selection shall also consider the risk of external chloride induced stress corrosion cracking and risk of external pitting and crevice corrosion, especially in chloride bearing environments. Hence Instrument tubing in offshore facilities (irrespective of services) PVC coated (2 mm thick) 316 SS tube should be considered for exposed marine environments on a case by case basis. Alternatively, 6Mo austenitic SS are deemed suitable up to 120 °C in marine environments, the use of which shall be decided upon on a case by case basis.

12.8 Bolting

All bolts and nuts shall be supplied with certification according to EN 10204, Type 3.1, as minimum, and Type 3.2 for low temperature service.

Bolting materials shall comply with bolting tables for ferrous metals, unalloyed and alloyed, provided in Appendix 1– Metallic Materials Selected Standards. Bolting suitable for defined temperature ranges may be found in Table 11, below.

Table 11 – Material Specification for Bolting Temperature Ranges

Temperature Range (°C)	Material Specification		Size Constraints
	Bolts	Nuts	
-100 to +400	A 320 Grade L7	A194 Grade 4/S3 or grade 7/S3	≤ 65
	A 320 Grade L43	A194 Grade 7/S3 or A194 grade 4/S3	< 100
-46 to + 400[4]	A 193 Grade B7	A194 Grade 2H	All
-29 to + 540[4]	A 193 Grade B16[1]	A194 Grade 7	All
-196/+ 540	A 193 Grade B8M[2]	A194 Grade M/8MA[3]	All

Notes:

(1) This grade should not be used for permanent immersed equipment. Grade B16 is intended for high temperature service, outside the temperature range for Grade B7.

(2) Type 316 bolts and nuts shall not be used at temperature above 60°C if exposed to a wet saline atmosphere.

(3) Use 8MA with class 1 bolts.

(4) The lower temperature limits are subject to interpretation and shall be clarified for each project.

CS and/or low alloy bolting material shall be hot dip galvanised to ASTM A153 or have similar reliable corrosion protection. For LNG service great care must be taken for the possibility of SS being in contact with galvanised items.

For applications, where dissolution of a thick zinc layer may cause loss of bolt pretension, phosphating shall be used. Bolts coated with poly-tetra-fluoro-ethylene (PTFE) or ADNOC approved suppliers for example Takecoat & Xylan or equivalent can be used but where these bolts rely on cathodic protection then they shall only be used provided electrical continuity is verified by measurements. Cadmium plated bolts shall not be used.

Where external bolts, nuts and spacers are to be protected by non-metallic coating, they shall be coated with a PTFE coating that passes a 6,000-hour salt spray test carried out in an ISO 17025 accredited third-party laboratory for these tests. Samples shall be taken from the Applicator facility, not form the paint manufacturer.

Bolting for potential non-metallic coating is applicable to:

(a) All external flanged connections (shop and field assembled), including insulated flange bolting where the service temperature is less than 200 °C.

(b) Equipment bolting that requires removal for scheduled maintenance and inspection.

Non-metallic coatings on bolting is not applicable for:

(a) All structural bolting;

(b) Fasteners/bolting used in assembly of various components within a SUPPLIER package or a MANUFACTURER's standard equipment, miscellaneous standard value assemblies and instrumentation. The CONTRACTOR shall review SUPPLIER / MANUFACTURER's standard coatings for its suitability on a case by case basis;

(c) Alloy fasteners;

(d) Bonnet bolts and Gland bolts for Valves;

(e) Bolts for blow-off connection of Strainers;

(f) Bolts for MANUFACTURER's standard piping specialty items (Sight Glasses, Level Gauges and Silencers).

Bolting materials for sour service shall meet the requirements of Table 12.

Table 12 – Bolting Materials for Sour Service

Service Conditions	Materials	Material Specification		Comments
		Bolts	Nuts	
Medium and High temperature > -29 °C	Alloy steel	ASTM A193, Grade B7M	ASTM A194 Grade 2, 2H, 2HM	Due to danger of hydrogen embrittlement caused by cathodic protection, controlled hardness bolts & nuts are required hence the 'M' grades are also specified.
Low temperature (-100 °C to -29 °C)	Alloy steel	ASTM A320, Grades L7M or L43	ASTM A194 Grade 4 or 7	
Medium and High down to -50 °C	DSS and SDSS	ASTM A276 & ASTM A479	ASTM A194	
Medium and high down to -196 °C Low pressure applications only	Austenitic SS (316)	ASTM A193 B8M Class1 (Carbide solution treated and hardness controlled 22HRC max)	ASTM A194 Grade 8M, 8MA (Hardness controlled to 22HRC max)	
Medium and high down to -196 °C	Super Austenitic SS	(6%Mo 254 SMO) ASTM A276	ASTM A194	
	Nickel base alloy	ASTM B164 ASTM B408 (Monel K-500 or Incoloy 625, Inconel 718, Incoloy 925)	Monel K-500 or Incoloy 625, Inconel 718, Incoloy 925	

APPENDIX – METALLIC MATERIAL'S STANDARDS

13 SPECIFICATION OF MATERIALS

Materials standards identified on drawings, requisition sheets or other documents shall be specified fully in accordance with the guidance given in Sections 10, 11 and 12, including all additional requirements applicable to the standard. For materials identified with a Materials and Equipment Standards Code (MESC) number, the additional requirements stated therein shall also be met.

The latest issue of the selected materials standard shall be used. As this latest issue (including amendments) always prevails, the year of issue of the standard need not be shown.

Metal Temperature Limits

The temperature limits shown in Table A.1 show the minimum limits allowed for the average temperature through the cross-section of the construction material during normal operation.

Table A.1 – Minimum Temperature Limits for Piping and Equipment Steels

Temperature (°C)	Item	Material
Up to -29	Piping/ Equipment	CS
-29 to -46	Piping/ Equipment	LTCS
< -46	Piping	Austenitic SS
Up to -60	Pressure Vessel	LTCS (WPQR weldment, HAZ specimen to be impact tested at min design temperature. Acceptance criteria minimum 27J. In addition, LTCS with CTOD and engineering criticality assessment to be carried out.)
< -60	Pressure Vessel	Austenitic SS
-101°C to -196°C	Piping / Equipment	Austenitic SS / Ni steel with impact testing

It should be noted that the indicated temperature limits do not necessarily exclude the application of the materials beyond these limits, especially for non-pressure-retaining parts such as internal parts of columns, baffles of heat exchangers, supporting structures.

Maximum temperatures limits are presented in section 2, 3, and 4, temperatures shown in brackets, for example (+400), are unusual for the indicated application but are allowable from a materials point of view, if so required.

Special attention should be given to the specification and application of metals for service at low temperatures. For low temperature applications, refer to the appendices of Specifications 'Welding, NDE and Prevention of Brittle Fracture of Pressure Vessels and Heat Exchangers' and 'Welding, NDE and Prevention of Brittle Fracture of Piping.'

Categories of Metals

The following categories of metals are covered by this specification:

- Ferrous metals - unalloyed
- Ferrous metals - alloyed
- Nonferrous metals

In each category the following products are dealt with:

- Plates, sheets and strip;
- Tubes and tubing;
- Pipe;
- Forgings, flanges and fittings;
- Castings;
- Bars, sections and wire;
- Bolting.

Sequence of Materials
The sequence of materials in the column 'Designation' in Sections 2, 3, and 4 is generally such that the subsequent number indicates a material with an increase in the content and/or number of the alloying elements.

Chemical Composition
Chemical composition requirements shown in Sections 2, 3, and 4 relate to product analyses. Percentage compositions listed in Sections 2, 3, and 4 are by mass.

Additional Limits on Materials
The following requirements shall be met unless COMPANY approval for deviations is obtained:

(a) No grade 70 carbon steels shall be used, except SA-516 Grade 70 (subject to COMPANY approval for the particular application, the conditions applicable to Grade 65 and the additional conditions a and b listed below), ASTM A350 LF2, where specified, and ASTM A537 Cl.1 for tanks. Any other grade 70 materials or applications require COMPANY approval except for standard carbon steel forgings and castings for example ASTM A105, A216 WCB, A350 LF2 and A352 LCC.

(b) Steel maker to provide weldability data for SA-516, Grade 70 used on previous successful projects

(c) Heat treatment condition: Normalised, regardless of thickness.

(d) The carbon equivalent and maximum carbon content for all carbon steel components in non-sour service shall be in accordance with the following table:

Table A.2 – Maximum Carbon Content and Equivalents for Steel Components

Components	Max. Carbon Content (%)	Max. Carbon Equivalent (%)
Pressure containing plates, sheets, strips, pipes, wrought fittings	0.23%	0.43%
Non-pressure containing plates, bars, structural shapes and other components to be welded	0.23%	N/A
Pressure-containing forgings and castings	0.25%	0.43%

Notes:

$$CE = \%C + \frac{\%Mn + \%Si}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

(e) Various services and materials require supplemental requirements of normalizing and/or killing. These are covered by the equipment and piping specifications, or by reference to Specification DGS-MW-004, 'Materials and Fabrication Requirements for Carbon Steel Piping and Equipment in Severe Service.'

(f) All 300 series, chemically stabilized stainless steel materials to be used in applications with operating temperatures above 425°C shall be given a stabilization heat treatment at 900°C for 4 hours subsequent to solution heat treatment.

(g) Rubber linings in water boxes of surface condensers and other exchangers shall not be used without COMPANY approval.

(h) 300 series stainless steel tubing shall not be used for steam generating or steam superheating services.

(i) Cast iron shall not be used in seawater service.

(j) Whenever 'SS' or 'Stainless Steel' is indicated in specifications or other Project documents without reference to a specific grade it shall mean 316L SS.

(k) Substitution of 9Cr-1Mo-V, grade '91' materials for applications where 9Cr-1Mo, grade '9' has been specified is not permitted.

(i) All SS pipe and fittings, especially dual certified 316/316L and 321 shall be standardised as seamless up to 6' NPS (ASTM A312) and welded class 1 for 8' NPS and above (ASTM A358 Class 1).

2 FERROUS METALS – UNALLOYED

Plates, Sheet and Strip

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Carbon steel sheets of structural quality, galvanized	+100	A 446 - A/ G165	For general use	
Carbon steel plates of structural quality	(+350)	A 283 - C	For non-pressure-retaining parts for up to 50 mm thickness	C content 0.23% max. To be killed or semi-killed.
Carbon steel plates (killed or semi- killed)	+400	A 285 - C	For pressure-retaining parts. For up to 50 mm thickness (Use subject to specific COMPANY Approval)	C content 0.23% max.

Carbon steel plates (Si-killed) - low/medium strength	+400	A 515 - 60/65	For pressure-retaining parts (Use subject to specific COMPANY Approval)	C content 0.23% max.
C-Mn steel plates (Si-killed) - medium/high strength	+400	A 515 -70	For tube sheets not welded to shell and/or tubes. (Use subject to specific COMPANY approval.) For tube sheets to be welded totubes, see 8.1.7. For tube sheets to be welded to shell, see 8.4.3.	
C-Mn steel plates (killed or semi- killed) - high strength	+400	A 299	For pressure-retaining parts and for tube sheets to be welded to tubes For tube sheets to be welded to shell, see 8.4.3.	C content 0.23% max. Mn content 1.30% max.
Fine-grained C-Mn steels - low strength	+400	A 516 55/60 A 662 - A	For pressure-retaining parts also at low temperatures For pressure-retaining parts also at low temperatures For tube sheets to be welded to shell, see 8.4.3.	C content 0.23% max. Specify V+Ti+Nb<0.15% Specify V+Ti+Nb<0.15%
Fine-grained C-Mn steels - medium strength	+400	A 516 – 65 / 70	For pressure-retaining parts also at low temperatures	C content 0.23% max. Specify V+Ti+Nb<0.15%
		A 662 - B	For pressure-retaining parts also at low temperatures For tube sheets to be welded to shell, see 8.4.3.	Specify V+Ti+Nb<0.15%
Fine-grained C-Mn steels - high strength (normalized)	+400	A 537 - Class 1	For pressure-retaining parts also at low temperatures (Use subject to specific approval) For tube sheets to be welded to shell, see 8.4.3.	Specify V+Ti+Nb<0.15%
Fine-grained C-Mn steels - very high strength (Q+T)	+400	A 537 - Class 2	For pressure-retaining parts (Use subject to specific approval.)	Specify V+Ti+Nb<0.15%
Carbon steel sheet and strip	---	A1011/ A1011M	For structural purposes	
Steel floor plate	---	A 786	For structural purposes	

Tubes and Tubing

DESIGNATION	Metal Temp.(° C)	ASTM	REMARKS	ADDED REQUIREMENTS
Electric-resistance-welded carbon steel tubes	+400	A 214	For unfired heat transfer equipment.	To be killed. A non- destructive electric test in accordance with the requirements of ASTM A450 or equivalent shall be carried out in addition to the hydrostatic test.
Seamless cold-drawn carbon steel tubes	+400	A 179	For unfired heat transfer equipment	To be killed Only for ASME VIII- Div 1 Application
Electric-resistance-welded carbon steel tubes	+400	A 178 - A	For boilers and superheaters tubes up to and including 102 mm external diameter.	A non-destructive electric test in accordance with the requirements of ASTM A450 or equivalent shall be carried out in addition to the hydrostatic test. To be killed or semi-killed. Elevated temperature properties (Yield strength shall meet the requirements of ASME II Part-D).
Electric-resistance-welded carbon steel tubes (Si- killed)	+400	A 226	For boilers and super heaters tubes at high working pressures up to and including 102 mm external diameter.	A non-destructive electric test in accordance with the requirements of ASTM A450 or equivalent shall be carried out in addition to the hydrostatic test. Elevated temperature properties (Yield strength shall meet the requirements of ASME II Part-D).
Seamless carbon steel tubes (Si-killed)	+400	A 192	For air coolers, boilers and superheaters at high working pressures.	For boilers and superheaters elevated temperature properties (Yield strength shall meet the requirements of ASME II Part-D). A non-destructive electric test in accordance with the material specification shall be carried out in addition to the hydrostatic test.
Seamless carbon steel tubes (Si- killed)	+400	A 334-6 (Seam- less)	For unfired heat transfer equipment operating at low service temperatures.	C content 0.23% max. A non-destructive electric test in accordance with the material specification shall be carried out in addition to the hydrostatic test.
Seamless carbon steel tubes (Si-killed)	+400	A210 Grade A-1	For air coolers, boilers and superheaters at high working pressures.	C content 0.23% max. For boilers and superheaters elevated temperature properties (Yield strength shall meet the requirements of ASME II Part-D).

Pipe

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Seamless or Arc Welded Carbon steel pipe	+400	API 5L-B	For air and water lines only Galvanized pipe with screwed connections only.	Specify seamless API 5L-B pipe with NPT threaded couplings, galvanized to ASTM A53, para 17. For PSL 2 non galvanized pipe with WT<=25 mm (1 in) Si} = 0.1%. Specify SAW pipe thicker than 19 mm to be normalized or PWHT after welding. Specify Seamless pipe to be normalized or hot finished.
Electric-fusion-welded carbon steel pipe	+400	A 672 - C 65 Class 32/22	For inside plot product lines For sizes larger than NPS 16	C content 0.23% max.
Seamless carbon steel pipe	+400	ASTM A106 grade B	For most inside plot utility lines. (For most inside plot product and other services, ASTM A106-B pipe to be used - see 8.3.4.) Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes see 8.3.2.	C content 0.23% max. Mn may be increased to 1.30% max. To be killed or semi-killed.
Seamless C-Mn steel pipe (Si-killed)	+400	A 106 -B	For most inside plot process piping, including hydrocarbon + hydrogen, hydrocarbon + sulphur compounds, fuel gas. For seamless shells of vessels, for welded-on nozzles, for welded furnace coils and for certain special applications Seamless usually not obtainable in sizes larger than NPS 24. For larger sizes use ASTM A672 C65 Class 32 /22(see 8.3.6)	C content 0.23% max., Mn may be increased to 1.30% max.
Seamless fine-grained C-Mn steel pipe (Si-killed)	(+400)	A 333 - Grade 1 or 6	For process lines at low service temperatures Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes use ASTM A671, CC65, Class 32 (see 8.3.8)	C content 0.23% max., Mn may be increased to 1.30% max. Specify V+Ti+Nb < 0.15%
Electric-fusion-welded fine-grained C-Mn steel pipe (Si-killed)	(+400)	A 671 - CC65 Class 32	For process lines at moderate or low service temperatures with sizes larger than NPS 16	C content 0.23% max., Mn may be increased to 1.30% max. Specify V+Ti+Nb < 0.15%
Carbon steel pipe	---	A 53	For structural use only as handrails.	

Forgings, Flanges and Fittings

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Carbon steel butt-welding pipe fittings	+400	A 234 - WPB or WPBW	For general use. Sizes up to NPS 16 incl. shall be seamless. Sizes greater than NPS 16 may be either seamless or welded.	C content 0.23% max. Mn may be increased to 1.30% max. Normalized or hot finished Plate material for A 234 WPB – W to meet the sour service requirement. Plate material for A 234 WPB-W to meet the following: Sour service requirement C content-0.23 max Carbon Equivalent - 0.43 max
Carbon steel butt-welding pipe fittings	(+400)	A 420 - WPL6 or WPL6W	For low service temperature. Sizes up to NPS 16 incl. shall be seamless. Sizes greater than NPS 16 may be either seamless or welded.	C content 0.23% max. Mn may be increased to 1.30% max.
Carbon steel forgings	+400	A 105	For piping components, including flanges, fittings, valves and other pressure-retaining parts and also for tube sheets to be welded to shell.	C content 0.23% max. Mn may be increased to 1.20% max. Shall be normalized in wet H_2S, amine, caustic and Criticality 1 services, and when heat treatment is required by the ASTM specification based on rating.
Carbon steel forgings	+400	A 266 - Class 2	For pressure vessel components and associated pressure-retaining equipment, including tube sheets.	C content 0.25% max. Normalized
Carbon- manganese steel forgings	(+400)	A 350- LF2 Class 1	For piping components, including flanges, fittings, valves and other pressure-retaining parts at low service temperatures.	C content 0.23% max. Normalized
Carbon- manganese steel forgings	+350	A765 - Grade II	For pressure vessel components and associated pressure-retaining equipment, including tube sheets, at low service temperatures	C content 0.23% max.

Castings

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Grey iron castings	+300	A 48 Class 30 or 40	For non-pressure-retaining (internal) parts.	
Grey iron castings	+650	A 319 - Class II	For non-pressure-retaining (internal) parts at elevated temperatures.	
Grey iron castings	+350	A 278 Class 40	For pressure-retaining parts and cooler channels. Cast iron not to be used in hazardous service or above 10 bar.	

Ductile iron castings	+400	A 395	For pressure-retaining parts including fittings and valves.	Metallographic examination in accordance with ASTM A395 shall be made in addition to the tensile test.
Steel castings	(+400)	A 216 - WCA, WCB* or WCC	For pressure-retaining parts	* C content 0.25% max.
Steel castings	(+400)	A 352 - LCB* or LCC	For pressure-retaining parts at low service temperatures.	* C content 0.25% max.

Bars, Sections and Wire

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Carbon steel bars, sections and raised-tread plates of structural quality	+350	A 36	For general structural purpose.	C content 0.23% max. For non-welded items, and for items that will not be welded, restriction on C content may be disregarded. To be killed or Semi killed
Low-carbon steel bars	+400	A 576 -1022 or 1117	For machined parts.	To be killed or semi-killed. Where free-machining quality is required specify Grade 1117.
Medium-carbon steel bars	+400	A 576 - 1035, 1045, 1055, 1137.	For machined parts.	To be killed or semi-killed. Where free-machining quality is required specify Grade 1137.
High-carbon steel bars	+230	A 689/A 576 1095	For springs.	To be killed or semi-killed.
Music spring quality steel wire	+230	A 228	For springs.	
Carbon steel bars and sections	(+230)	A 36	For lifting lugs, sliding bars etc.	C content 0.23% max. For non-welded items, and for items that will not be welded, restriction on C content may be disregarded.
Steel welded wire, fabric	---			
Carbon steel structural tubing	---	A 500	For structural use only.	
Steel bars	---	A 615	For concrete reinforcement.	

Bolting

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Carbon steel bolts	+230	A 307 - B	For structural purposes. Approved free machining quality acceptable...	
Carbon steel nuts	+230	A 563 - A	For bolts specified under 8.7.1	
Medium-carbon steel nuts	+450	A 194 - 2H	For bolting specified under 8.7.1	
High strength structural bolts	---	ASTM F3125	For structural purposes.	
Heat treated steel structural bolts	---	A 490	For structural purposes.	
Hardened steel washers	---	F 436	For structural purposes.	

3 FERROUS METALS - ALLOYED

Plates, Sheets and Strip

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
1 Cr - 0.5 Mo steel plates	+600	A387 - 12 Class 2	For high service temperatures and/or resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered.
1.25 Cr - 0.5 Mo steel plates	+600	A 387 - 11 Class 2	For high service temperatures and/or resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered. Specify P 0.005% max. Plates to be solution annealed.
2.25 Cr - 1 Mo steel plates	+625	A 387 - 22 Class 2	For high service temperatures and/or resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered.
3 Cr - 1 Mo steel plates	+625	A 387 - 21 Class 2	For high service temperatures requiring optimum creep resistance and/or resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered.
5 Cr - 0.5 Mo steel plates	+650	A 387 - 5 Class 2	For high service temperatures and/or resistance to sulfur corrosion.	Specify to be normalized and tempered or quenched and tempered. Plates to be solution annealed.
3.5 Ni steel plates	(+400)	A 203 - D	For pressure-retaining parts at low service temperatures.	
9 Ni steel plates	-200	A 353	For pressure-retaining parts at low service temperatures.	Specify: C 0.10% max., Si 0.30% max., P 0.002% max., S 0.005% max.
13 Cr steel plates, sheets and strip	+540	A 240 - Type 410S or 405	For cladding of pressure-retaining parts under certain corrosive conditions. Type 405 shall not be used above 400°C.	
18 Cr-8 Ni steel plates, sheets and strip	-200 (+400)	A 240 - Type 304 or 304N	For non-welded, pressure-retaining parts at low service temperatures or to prevent product contamination.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262 Plates to be solution annealed.

18 Cr-8 Ni steel plates, sheets and strip	-200 +500	A 240 - Type 304L	For pressure-retaining parts under certain corrosive conditions and/or low and moderate service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel plates, sheets and strip	(-100) +600	A 240 - Type 321 or 347	For pressure-retaining parts under certain corrosive conditions and/or high service temperatures	For optimum resistance to intergranular corrosion when operating temperatures will be >426C, specify a stabilization heat treatment at 900°C for 4 hours, subsequent to solution heat treatment. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-10 Ni-2 Mo steel plates, sheets and strip	-200 +500	A 240 - Type 316 or 316L	For pressure-retaining parts under certain corrosive conditions and/or high service temperatures.	Type 316L shall be used for all welded components. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262 Plates to be solution annealed
18 Cr-10 Ni-2 Mo stabilized steel plates, sheets and strip	(-200) +500	A 240 - Type 316Ti or 316Cb	For pressure-retaining parts under certain corrosive conditions and/or high service temperatures.	For optimum resistance to intergranular corrosion, specify a stabilization heat treatment at 900°C for 4 hours, subsequent to solution heat treatment. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-10 Ni-3 Mo steel plates, sheets and strip	(-200) +500	A 240 - Type 317 or 317L	For pressure-retaining parts under certain corrosive conditions and/or high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
25 Cr-20 Ni steel plates, sheets and strip	+1000	A 240 - Type 310S	For pressure-retaining parts under certain corrosive conditions and/or extreme service temperatures.	
18 Cr-8 Ni steel plates, sheets and strip	+700	A 240 - Type 304H	For pressure-retaining parts at extreme service temperatures under certain corrosive conditions.	Specify C 0.06% max. and Mo+Ti+Nb 0.4% max.
22 Cr-5 Ni-Mo-N steel plates, sheets and strip	(-30) +300	A 240 - S31803	For pressure-retaining parts under certain corrosive conditions.	Specify N 0.15% min. Specify ferric chloride test in accordance with ASTM G 48 Method A. Plates to be solution heat treated and water cooled.
25 Cr-7 Ni-Mo-N steel plates, sheets and strip	(-30) +300	A 240 - S32750	For pressure-retaining parts under certain corrosive conditions.	Specify ferric chloride test in accordance with ASTM G 48 Method A. Plates to be solution heat treated and water cooled.
20 Cr-18 Ni-6 Mo- Cu-N steel plates, sheets and strip	(-200) (+400)	A 240 - S31254	For pressure-retaining parts under certain corrosive conditions.	Plates to be solution heat treated and water cooled
Carbon steel or low-alloy steel plates with ferritic stainless steel cladding		A 263	For high service temperatures and/or certain corrosive conditions Specify base metal and cladding.	

Carbon steel or low-alloy steel plates with austenitic stainless steel cladding	+400	A 264	For high service temperatures and/or certain corrosive conditions Specify base metal and cladding.	
Seamless 25Cr -5 Ni Mo-N steel tubes for certain corrosive services				To be annealed and water cooled. To be chemically passivated. Specify ferric chloride test in accordance with ASTM G 48 Method

Tubes and Tubing

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Seamless 1 Cr-0.5 Mo steel tubes	+600	A 213 - T12	For boilers, superheaters and unfired heat transfer equipment at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered For resistance to hydrogen attack refer API 941.
Seamless 1.25 Cr-0.5 Mo steel tubes	+600	A 213 - T11	For boilers, superheaters and unfired heat transfer equipment at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered. Specify P 0.005% max.
Seamless 2.25 Cr- 1 Mo steel tubes	+625	A 213 - T22	For boilers, furnaces, super-heaters and unfired heat transfer equipment at high service temperatures requiring optimum creep resistance and/or resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered.
Seamless 5 Cr-0.5 Mo steel tubes	+650	A 213 - T5	For high service temperatures and/or resistance to sulfur corrosion, for example furnace tubes.	Specify to be normalized and tempered or quenched and tempered.
Seamless 9 Cr-1 Mo steel tubes	+650	A 213 - T9	For high service temperatures and/or resistance to sulfur corrosion, for example furnace tubes.	Specify to be normalized and tempered or quenched and tempered.
Seamless 3.5 Ni steel tubes	(+400)	-	For low service temperatures.	
Seamless 9 Ni steel tubes	-200	-	For low service temperatures.	
Seamless 12 Cr steel tubes	+540	A 268 - TP 405 or 410	For unfired heat transfer equipment under certain corrosive conditions.	TP 405 not to be used above 400C. TP 410 shall be specified with C 0.08 max.
Seamless and welded 18 Cr-10 N-2Mo steel tubes	(-200) +500	A 269 - TP 316 or TP 316L or TP 317 or TP 317L	For certain general applications.	For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB. For tubes to be welded, bent or stress relieved, TP316L or TP 317L shall be used.
Welded 18 Cr-8 Ni steel tubes	-200 (+400)	A 249 - TP 304 or TP 304L	For superheaters and unfired heat transfer equipment to prevent product contamination or for low service temperatures.	Since the tubes are welded without the addition of filler metal, the inside diameter and the wall thickness of the tubes shall be restricted to NPS 4 max. and 5.5 mm max., respectively. A nondestructive electric test in accordance with ASTM A450 shall be carried out in addition to the hydrostatic test. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
Welded 18 Cr-8 Ni stabilized steel tubes	(-100) +600	A 249 - TP 321 or TP 347	For superheaters and unfired heat transfer equipment under certain corrosive conditions.	Since the tubes are welded without the addition of filler metal, the inside diameter and the wall thickness of the tubes

				shall be restricted to NPS 4 max. and 5.5 mm max., respectively. A nondestructive electric test in accordance with ASTM A450 shall be carried out in addition to the hydrostatic test. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
Welded 18 Cr-10 Ni-2 Mo steel tubes	-200 +500	A 249 - TP 316 or TP 316L	For superheaters and unfired heat transfer equipment under certain corrosive conditions.	Since the tubes are welded without the addition of filler metal, the inside diameter and the wall thickness of the tubes shall be restricted to NPS 4 max. and 5.5 mm max., respectively. A nondestructive electric test in accordance with ASTM A450 shall be carried out in addition to the hydrostatic test. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
Welded 20 Cr-18 Ni-6 Mo Cu-N steel tubes	(-200) (+400)	A 249 - S31254	For superheaters and unfired heat transfer equipment under certain corrosive conditions.	Since, the tubes are welded without the addition of filler metal, the inside diameter and the wall thickness of the tubes shall be restricted to NPS 4 max. and 5.5 mm max., respectively. A nondestructive electric test in accordance with ASTM A450 shall be carried out in addition to the hydrostatic test.
Seamless 18 Cr-8 Ni steel tubes	-200 +400	A 213 - TP 304 or TP 304L	For unfired heat transfer equipment to prevent product contamination or for low service temperatures	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Seamless 18 Cr-8 Ni stabilized steel tubes	(-100) +600	A 213 - TP 321 TP 347	For superheaters and unfired heat transfer equipment under certain corrosive conditions and/or at high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262 For Optimum resistance to intergranular corrosion specify a stabilization heat treatment subsequent to solution heat treatment.
Seamless 18 Cr-8 Ni steel tubes	+815	A 213 - TP 304H	For boilers, superheaters and unfired heat transfer equipment at extreme service temperatures under certain corrosive	Specify C 0.06% max. and Mo+Ti+Nb 0.4% max.

			conditions. (The use of this grade is subject to agreement of the COMPANY.)	
Seamless 18 Cr-8 Ni stabilized steel tubes	+815	A 213 - TP 321H or TP 347H	For boilers, superheaters and unfired heat transfer equipment at extreme service temperatures under certain corrosive conditions.	Specify C 0.06% max. and Mo+Ti+Nb 0.4% max.
Seamless 18 Cr-10 Ni-2 Mo steel tubes	-200 +500	A 213 - TP 316 or TP 316L	For superheaters and unfired heat transfer equipment under certain corrosive conditions and/or at high service temperatures.	TP 316 shall be used only for non-welded items. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
Seamless 18 Cr-8 Ni steel tubes	+815	A 271 - TP 321H or TP 347H	For furnaces under certain corrosive conditions with maximum wall thickness of 25mm.	
Seamless 22 Cr-5 Ni-Mo-N steel tubes	+300	A 789 - S31803	For certain corrosive conditions.	Specify seamless. Specify N 0.15% min. and Mo 3.0% min
Seamless 25 Cr-7 Ni-Mo-N steel tubes	+300	A 789 - S32750	For certain corrosive conditions.	Specify seamless.
Seamless 20 Cr-18 Ni-6 Mo-Cu-N steel tubes	(-200) (+400)	A 269 - S31254	For certain corrosive conditions.	Specify seamless.
Seamless 25 Cr-5 Ni Mo-N steel tubes for certain corrosive services	+300	A 789 S32550		Specify Seamless

Pipe

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Electric-fusion-welded 1 Cr-0.5 Mo steel pipe in sizes NPS 16 and larger	+600	A 691 1Cr Class 22 or 42	For high service temperatures, requiring optimum creep resistance and/or resistance to hydrogen attack	For Class 22, base material to be in N & T or Q&T condition, with tempering at 730°C min. Welds to be PWHT in range 680-780°C. For Class 42, tempering temperature to be 680°C min. Specify P 0.01% max.
Electric-fusion-welded 1.25 Cr-0.5 Mo steel pipe in sizes NPS 16 and larger	+600	A 691 - 1.25Cr Class 22 or 42	For high service temperatures, requiring optimum creep resistance and/or resistance to hydrogen attack	For Class 22, base material to be in N & T or Q&T condition, with tempering at 730°C min. Welds to be PWHT in range 680-780°C. For Class 42, tempering temperature to be 680°C min. Specify P 0.01% max.
Electric-fusion-welded steel pipe in sizes NPS 16 and larger	+625	A 691 - 2.25 Cr Class 22 or 42	For high service temperatures, requiring optimum creep resistance and/or resistance to hydrogen attack	For Class 22, base material to be in N & T or Q&T condition, with tempering at 730°C min. Welds to be PWHT in range 680-780°C.

				For Class 42, tempering temperature to be 680°C min. Specify P 0.01% max.
Electric-fusion-welded 5 Cr-0.5 Mo steel pipe in sizes NPS 16 and larger	+650	A 691 - 5 Cr Class 22 or 42	For high service temperatures and/or resistance to sulfur corrosion	For Class 22, base material to be in N & T or Q&T condition, with tempering at 730°C min. Welds to be PWHT in range 680-780°C. For Class 42, tempering temperature to be 680°C min. Specify P 0.01% max.
Electric-fusion-welded 18 Cr-8 Ni steel pipe in sizes above NPS 12	-200 +400	A 358 - Grade 304 or 304L Class 1	For certain corrosive conditions and/or high service temperatures	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262.
Electric-fusion-welded 18 Cr-8 Ni stabilized steel pipe in sizes above NPS 12	(-100) +600	A 358 - Grade 321 or 347 Class 1	For certain corrosive conditions and/or high service temperatures	For optimum resistance to intergranular corrosion, specify a stabilization heat treatment at 900°C for 4 hours subsequent to solution heat treatment, as detailed in ASTM A358 Supplementary Requirement S5. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262
Electric-fusion-welded 18 Cr-10 Ni- 2 Mo steel pipe in sizes above NPS 12	-200 +500	A 358 - Grade 316 or 316L Class 1	For certain corrosive conditions and/or high service temperatures	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262
Electric-fusion-welded 18 Cr-8 Ni steel pipe in sizes above NPS 12	(-200) (+500)	A 358 - Grade 304L Class 1	For certain corrosive conditions and/or high service temperatures	Specify C 0.06% Mn and Mo+Ti+Nb 0.04% max.
Seamless 0.3 Mo steel pipe	+500		NOT for hydrogen service. For high service temperatures	Specify total Al content 0.012% max.
Seamless 0.5 Mo steel pipe	+500	A 335 - P1	NOT for hydrogen service. For high service temperatures Seamless usually not obtainable in sizes larger than NPS 16.	Specify total Al content 0.012% max.
Seamless 1 Cr-0.5 Mo steel pipe	+600	A 335 - P12	For high service temperatures and/or resistance to hydrogen attack. Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes use ASTM A691 - 1 CR-Class 22 or 42 (see 9.3.1).	Specify to be normalized and tempered. For resistance to hydrogen attack refer API 941. Purchaser to advise the manufacturer if the service temperature is to be over 600°C
Seamless 1.25 Cr-0.5 Mo steel pipe	+600	A 335 - P11	For high service temperatures and/or resistance to hydrogen attack. Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes use	Specify to be normalized and tempered. Specify

			ASTM A691 - 1.25 CR-Class 22 or 42 (9.3.2).	P 0.005% max. For resistance to hydrogen attack refer API 941 Purchaser to advise the manufacturer if the service temperature is to be over 600°C
Seamless 2.25 Cr-1 Mo steel pipe	+625	A 335 - P22	For high service temperatures, requiring optimum creep resistance and/or resistance to hydrogen attack. Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes use ASTM A691 - 2.25 CR-Class 22 or 42 (see 9.3.3).	Specify to be normalized and tempered. For resistance to hydrogen attack refer API 941. Purchaser to advise the manufacturer if the service temperature is to be over 600°C
Seamless 5 Cr-0.5 Mo steel pipe	+650	A 335 - P5	For high service temperatures and/or resistance to sulfur corrosion. Seamless usually not obtainable in sizes larger than NPS 16. For larger sizes use ASTM A691 - 5 CR-Class 22 or 42 (see 9.3.4).	Specify to be normalized and tempered or quenched and tempered.
Seamless 9 Cr-1 Mo steel pipe	+650	A 335 - P9	For high service temperatures and/or resistance to sulfur corrosion.	Specify to be normalized and tempered. Purchaser to advise the manufacturer if the service temperature is to be over 600°C
Seamless 3.5 Ni steel pipe	(+400)	A 333 - Grade 3 Seamless	For low service temperatures	
Seamless 9 Ni steel pipe	-200	A 333 - Grade 8 Seamless	For low service temperatures	Specify: C 0.10% max. S 0.002% max. P 0.005% max.
Seamless and welded 18 Cr-8 Ni steel pipe in sizes to NPS 12 incl.	-200 +400	A 312 - TP 304	For low service temperatures or to prevent product contamination.	Welded pipe may be used up to and including 5.5 mm wall thickness. The materials shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262
Seamless and welded 18 Cr- 8 Ni steel pipe in sizes to NPS 12 incl.	-200 +400	A 312 - TP 304L	For certain corrosive conditions and/or high service temperatures.	Welded pipe may be used up to and including 5.5 mm wall thickness. The materials shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262
Seamless and welded 18 Cr-8 Ni steel pipe in sizes to NPS 12 incl.	(-100) +600	A 312 - TP 321 or TP 347	For certain corrosive conditions and/or high service temperatures.	Welded pipe may be used up to and including 5.5 mm wall thickness. For optimum resistance to inter-granular corrosion, specify a stabilization heat treatment at 900°C for 4 hours subsequent to solution heat

				treatment, as detailed in ASTM A358 Supplementary Requirement S5 The materials shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262
Seamless and welded 18 Cr-8 Ni stabilized steel pipe in sizes to NPS 12 incl.	+815	A 312 - TP 321H or TP 347H	For certain corrosive conditions and/or extreme service temperatures. The use of this grade is subject to agreement of the Company.	Welded pipe may be used up to and including 5.5 mm wall thickness.
Seamless and welded 18 Cr-10 Ni- 2 Mo steel pipe in sizes to NPS 12 incl.	-200 +500	A 312 - TP 316 or TP 316L	For certain corrosive conditions and/or high service temperatures.	Welded pipe may be used up to and including 5.5 mm wall thickness. The materials shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A 262.
Seamless and welded 18 Cr-8 Ni steel pipe in sizes to NPS 12 incl.	+500 (+815)	A 312 - TP 304H	For certain corrosive conditions and/or high service temperatures	Specify C 0.06% max. and Mo+Ti+Nb 0.4% max.
Seamless and welded 22 Cr-5 Ni- Mo-N steel pipe	+300	A 790 - S 31803	For certain corrosive conditions.	Specify N 0.15% min. Welded pipe may be used up to and including 5.5 mm wall thickness Specify in solution annealed and water quenched condition
Seamless and welded 25 Cr-7 Ni- Mo-N steel pipe	+300	A 790 - S 32750	For certain corrosive conditions.	Specify N 0.15% min. Welded pipe may be used up to and including 5.5 mm wall thickness Specify in solution annealed and water quenched condition
Seamless and welded 20 Cr-18 Ni-6 Mo-Cu-N steel pipe	-200 (+400)	A 312 - S31254	For certain corrosive conditions.	Welded pipe may be used up to and including 5.5 mm wall thickness

Forgings, Flanges and Fittings

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
0.5 Mo steel butt-welding fittings	+500	A 234 - WP1 or WP1W	NOT for hydrogen service. For high service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify total Al content 0.012% max.
1 Cr-0.5 Mo steel butt-welding fittings	+600	A 234 - WP12 Class 2 or WP12W Class 2	For high service temperatures and/or resistance to hydrogen attack.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be normalized and tempered or quenched and tempered.

1.25Cr-0.5Mo steel butt-welding fittings	+600	A 234 - WP11 Class 2 or WP11W Class 2	For high service temperatures and/or resistance to hydrogen attack.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be normalized and tempered or quenched and tempered. Specify P 0.005% max For resistance to hydrogen attack refer API 941 For weld metal specify 10P+5Sb+4 Sn+As {1400}, where values are in mg/kg (ppmw).
2.25 Cr-1 Mo steel butt-welding fittings	+625	A 234 - WP22 Class 3 or WP22W Class 3	For extreme service temperatures and/or resistance to sulfur corrosion	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be normalized and tempered or quenched and tempered. For resistance to hydrogen attack refer API 941 For weld metal specify 10P+5Sb+4 Sn+As {1400}, where values are in mg/kg (ppmw).
5 Cr-0.5 Mo steel butt-welding fittings	+650	A 234 - WP5 or WP5W	For high service temperatures and/or resistance to sulfur corrosion.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be normalized and tempered or quenched and tempered.
3.5 Ni steel butt-welding fittings	(+400)	A 420 - WPL3 or WPL3W	For low service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be normalized.
9 Ni steel butt-welding fittings	-200	A 420 - WPL8 or WPL8W	For low service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify to be double-normalized and tempered or quenched and tempered. Specify: C 0.10% max. S 0.002% max. P 0.005% max.
18 Cr-8 Ni steel butt-welding fittings	-200 +400	A 403 - WP304 - S/WX/WU	For low service temperatures or to prevent product contamination.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262. Specify all seam welds of austenite stainless steel welded fittings to have ferrite number between 3FN and 8FN

18 Cr-8 Ni steel butt-welding fittings	-200 +400	A 403 - WP304L - S/WX/WU	For certain corrosive conditions and/or high service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel butt-welding fittings	+815	A 403 - WP304H - S/WX/WU	For certain corrosive conditions and/or extreme service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify: C 0.06% max. and Mo+Ti+Nb 0.4% max.
18 Cr-8 Ni stabilized steel butt-welding fittings	(-100) +600	A 403 - WP321 - S/WX/WU or WP347 - S/WX/WU	For certain corrosive conditions and/or extreme service temperatures.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. For optimum resistance to intergranular corrosion, specify a stabilization heat treatment at 900°C for 4 hours subsequent solution heat treatment. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni stabilized steel butt-welding fittings	+815	A 403 - WP321H - S/WX/WU or WP347H - S/WX/WU	For certain corrosive conditions and/or extreme service temperatures	The use of this grade is subject to agreement of the Company.
18 Cr-10 Ni-2 Mo steel butt-welding fittings	-200 +500	A403 - WP316 - S/WX/WU or WP316L - S/WX/WU	For certain corrosive conditions and/or high service conditions.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
22 Cr-5 Ni-Mo-N steel butt-welding fittings	+300	A815 S31803 Class WP-S or WP-WX	For certain corrosive conditions.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded. Specify N 0.15% min.
25 Cr- 7 Ni-Mo-N Steel butt-welding fittings for corrosive conditions	+300	A815 S32750 Class WP- S or WP- WX		Specify Seamless.
20 Cr-18 Ni-6 Mo-Cu-N steel butt-welding fittings	(-200) (+400)	A403 WPS 31254 - S/WX/WU	For certain corrosive conditions.	Sizes up to NPS 16 incl. shall be seamless. Larger sizes may be either seamless or welded.
0.5 Mo steel forgings	+500	A 182 -F1	NOT for hydrogen service.	

			For tube sheets, flanges, fittings, valves and other pressure-retaining parts at high service temperatures.	
0.5 Mo steel forgings	+500	A 336 - F1	NOT for hydrogen service. For heavy parts, for example drum forgings, for high service temperatures	Specify total Al content 0.012% max.
1 Cr-0.5 Mo steel forgings	+600	A 182 - F12 Class 2	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered. For resistance to hydrogen attack refer API 941
1 Cr-0.5 Mo steel forgings	+600	A 336 - F12	For heavy parts, for example drum forgings, for high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered. For resistance to hydrogen attack refer API 941
1.25 Cr-0.5Mo steel forgings	+600	A 182 - F11	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered. Specify P 0.005% max. For resistance to hydrogen attack refer API 941
1.25 Cr-0.5 Mo steel forgings	+600	A 336 - F11	For heavy parts, for example drum forgings, for high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered. The use of liquid quenched and tempered grades is subject to agreement of the Company Specify P 0.005% max. For resistance to hydrogen attack refer API 941
2.25 Cr-1 Mo steel forgings	+625	A 182 - F22	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered. Refer API 934 for Materials and Fabrication requirement
2.25 Cr-1 Mo steel forgings	+625	A 336 - F22	For heavy parts, for example drum forgings, for high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered or quenched and tempered. The use of liquid quenched and tempered grades is subject to agreement of the Company Refer API 934 for Materials and Fabrication requirement
3 Cr-1 Mo steel forgings	+625	A 182 - F21	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at high service temperatures, requiring optimum creep resistance and/or requiring resistance to hydrogen attack.	Refer API 934 for Materials and Fabrication requirement
5 Cr-0.5 Mo steel forgings	+650	A 182 - F5	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at extreme service temperatures and/or requiring resistance to sulfur corrosion.	Specify to be normalized and tempered.
3.5 Ni steel forgings	(+400)	A 350 - LF3	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at low service temperatures.	
9 Ni steel forgings	-200	A 522 - Type I	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at low service temperatures.	Specify: C 0.10% max. Si 0.30% max. P 0.002% max. S 0.005% max.

12 Cr steel forgings	+540	A 182 - F6a	For certain corrosive conditions.	
12 Cr steel forgings	+540	A 182 - F6a	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	
18 Cr-8 Ni steel forgings	-200 +400	A 182 - F304	For low service temperatures or to prevent product contamination.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel forgings	-200 +400	A 182 - F304	For tube sheets, flanges, fittings, valves and other pressure-retaining parts at low service temperatures or to prevent product contamination.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel forgings	-200 +500	A 182 - F304L	For certain corrosive conditions and/or high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel forgings	-200 +500	A 182 - F304L	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni steel forgings	+815	A 182 - F304H	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at extreme service temperatures.	Specify C 0.06% max. and Mo+Ti+Nb 0.4% max.
18 Cr-8 Ni stabilized steel forgings	+600	A 182 - F321 or F347	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	For optimum resistance to intergranular corrosion, specify a stabilization heat treatment at 870-900°C for 4 hours, subsequent to solution heat treatment. The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-8 Ni stabilized steel forgings	+815	A 182 - F321H or F347H	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at extreme service temperatures.	The use of this grade is subject to agreement of the Company.
18 Cr-10 Ni-2 Mo steel forgings	-200 +500	A 182 - F316	For certain corrosive conditions and/or high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-10 Ni-2 Mo steel forgings	-200 +500	A 182 - F316	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-10 Ni-2 Mo steel forgings	-200 +500	A 182 - F316L	For certain corrosive conditions and/or high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
18 Cr-10 Ni-2 Mo steel forgings	-200 +500	A 182 - F316L	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	The material shall be capable of passing the Practice E intergranular corrosion test as specified in ASTM A262.
22 Cr-5 Ni- Mo-N steel forgings	(-30) +300	A 182 - F51	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions.	Specify N 0.15% min.

25 Cr-7 Ni-Mo-N steel forgings	(-30) +300	A 182 - F53	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions.	
20 Cr-18 Ni-6 Mo-Cu-N steel forgings	(-200) (+400)	A 182 - F44	For tube sheets, flanges, fittings, valves and other pressure-retaining parts under certain corrosive conditions.	
9Cr Mo Steel forgings. For tube sheets, flanges, fittings, valves and other pressure retaining parts at extreme service temperatures and / or requiring resistance to Sulphur corrosion	+650	ASTM A182-F9		Normalized and tempered
Wrought Ni-Cr-Mo-Nb alloy(Alloy 625) for corrosive conditions	425	ASTM B366		Chemically passivated and free from any scale or oxides. Specify in solution annealed condition
Ni-Cr-Fe Alloy (Alloy 600) forgings for corrosive conditions	+650	ASTM B564 N06600		Specify forgings in solution annealed condition

Castings

DESIGNATION	Metal Temp.(°C)	ASTM	REMARKS	ADDED REQUIREMENTS
14.5 Si iron castings	+250	A 518 - 1	For non-pressure-retaining (internal) parts in acid service.	Specify Si content 14.5% min. Other alloying elements, for example Mo, may be added.
15 Ni-6 Cu-2 Cr-Fe (Ni-Resist Type 1) iron castings	+500	A 436 - Type 1	For non-pressure-retaining (internal) parts under certain corrosive conditions.	
20 Ni-2 Cr ductile iron. (Ni-Resist Type D-2) castings	+500	A 439 - Type D-2	For pressure-retaining parts under certain corrosive conditions.	
22 Ni-4 Mn ductile iron. (Ni-Resist Type D-2M) castings	-105 +500	A 571 - Type D-2M	For pressure-retaining parts at low service temperatures.	
0.5 Mo steel castings	+500	A 217 - WC1	NOT for hydrogen service For fittings, valves and other pressure-retaining parts at high service.	Specify total Al content 0.012% max.
1.25 Cr-0.5 Mo steel castings	+600	A 217 - WC6	For fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to hydrogen attack.	Specify to be normalized and tempered. Specify P 0.01% max. For resistance to hydrogen attack refer API 941
2.25 Cr-1 Mo steel castings	+625	A 217 - WC9	For fittings, valves and other pressure-retaining parts at	

			extreme service temperatures requiring optimum creep resistance and/or resistance.	
5 Cr-0.5 Mo steel castings	+650	A 217 - C5	For fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to sulfur corrosion.	
9 Cr-1 Mo steel castings	+650	A 217 - C12	For fittings, valves and other pressure-retaining parts at high service temperatures and/or requiring resistance to sulfur corrosion.	
3.5 Ni steel castings	(+400)	A 352 - LC3	For low service temperatures.	
9 Ni steel castings	(+400)	A 352 - LC9	For low service temperatures.	Specify: C 0.10% max. S 0.002% max. P 0.005% max.
12 Cr steel castings	+540	A 743 - CA15	For non-pressure-retaining parts under certain corrosive conditions.	
12 Cr steel castings	+540	A 217 - CA15	For pressure-retaining parts under certain corrosive conditions.	
12 Cr – 4 Ni steel castings for pressure retaining parts under corrosive conditions	+540	A487 CA-6NM		
18 Cr-8 Ni steel castings	-200 +400	A 744 - CF8	For non-pressure-retaining (internal) parts under certain corrosive conditions and/or at high service temperatures.	Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
18 Cr-10 Ni-Nb stabilized steel castings	(-100) +600	A 744 - CF8C	For non-pressure-retaining (internal) parts under certain corrosive conditions and/or at high service temperatures.	If intended for working temperatures above 500°C, specify Si content 1.0% max. Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
18 Cr-10 Ni-2 Mo steel castings	-200 +500	A744-CF8M	For non-pressure-retaining (internal) parts under certain corrosive conditions and/or at high service temperatures.	Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
25 Cr-20 Ni steel castings	+1000	A 297 - HK	For non-pressure-retaining (internal) parts requiring heat	

			resistance.	
25 Cr-12 Ni steel castings	+1000	A447- Type II	For furnace tube supports.	
18 Cr-8 Ni steel castings	-200 +500	A 351 - CF8	For pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
18 Cr-8 Ni-Nb stabilized steel castings	(-100) +600	A351- CF8C	For pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	If intended for working temperatures above 500°C, specify Si content 1.0% max. Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
18 Cr-10 Ni-2 Mo steel castings	-200 +500	A 351 - CF8M	For pressure-retaining parts under certain corrosive conditions and/or at high service temperatures.	Castings for corrosive service shall be capable of meeting the requirements of ASTM A262, Practice E.
22 Cr-5 Ni-Mo-N steel castings	+300	A 890 - 4A, S32 & S33	For pressure-retaining parts under certain corrosive conditions.	
25 Cr-7 Ni-Mo-N steel castings	+300	A 890 - 5A, S32 & S33	For pressure-retaining parts under certain corrosive conditions.	
20 Cr-18 Ni-6 Mo- Cu-N steel castings	(-200) (+400)	A351- CK3MCuN	For pressure-retaining parts under certain corrosive conditions.	
25 Cr-12 Ni steel castings	+1000	A351 CH20	For pressure-retaining parts under certain corrosive conditions at extreme service temperatures.	
25 Cr-20 Ni steel castings	+1000	A351- CK20	For pressure-retaining parts under certain corrosive conditions at extreme service temperatures.	
25 Cr-20 Ni steel castings	+1000	A351- HK40	For pressure-retaining parts under certain corrosive conditions at extreme service temperatures.	
20 Cr- 29 Ni-Mo-Cu steel castings	(+400)	A744- CN7M	For fittings, valves and other pressure- retaining parts requiring resistance to sulfuric acid corrosion.	
Cr-Ni steel centrifugal and static castings 20 Cr-33 Ni-Nb 25 Cr-20 Ni 25 Cr-35 Ni-Nb			For pressure-retaining furnace parts at extreme service temperatures.	

Bars, Sections and Wire

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
1 Cr-0.25 Mo steel bars	+450 (+540)	A 322 - 4140	For machined parts	
9 Ni steel bars	-200	-	For machined parts for low-temperature service	
12 Cr steel bars	+425	A 276 - Type 410 or Type 420	For machined parts Free-machining quality ASTM A582 Type 416 or 416Se acceptable, subject to approval by the COMPANY.	For welded items specify Type 405.
18 Cr-8 Ni steel bars	-200 +500	A 479 - Type 304	For machined parts.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni steel bars	-200 +500	A 479 - Type 304L	For machined parts.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni steel bars	+500 (+815)	A 479 - Type 304H	For machined parts	Specify C: 0.06% max. and Mo+Ti+Nb: 0.4% max.
18 Cr-8 Ni stabilized steel bars	(-200) +815	A 479 - Type 321 or Type 347	For machined parts	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni stabilized steel bars	+500 (+815)	A 479 - Type 321H or Type 347H	For machined parts The use of this grade is subject to agreement of the Company	
18 Cr-10 Ni-2 Mo steel bars	-200 +500	A 479 - Type 316	For machined parts.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-10 Ni-2 Mo steel bars	-200 +500	A 479 - Type 316L	For machined parts.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
22 Cr-5 Ni-Mo-N steel bars	-30 +300	A 479 - S31803	For machined parts	N 0.15% min.
25 Cr-7 Ni-Mo-N steel bars	-30 +300	A 479 - S32750	For machined parts	N 0.15% min.
20 Cr-18 Ni-6 Mo-Cu-N steel bars	(-200) (+400)	A 276 - S31254	For machined parts	
Si-Mn steel bars	+230	A 689/A 322-9260	For springs	
Cold drawn steel wire	(+230)	A 227	For springs	
Cold drawn 18 Cr-	-200	A 313 -	For springs	The material shall be

8Ni steel wire	+230	Type 302		capable of meeting the requirements of ASTM A262 Practice E.

Bolting

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
1 Cr-0.25 Mo steel bolting material	+450 (+540)	A 193 - B7	For general use. For nuts see 8.7.3.	
1 Cr-0.25 Mo steel bolting material	+450 (+540)	A 193 - B7M	For sour service. For nuts see 9.7.13.	
1 Cr-0.5 Mo-0.25 V steel bolting material	+525 (+600)	A 193 - B16	For high-temperature service. For nuts see 9.7.14.	
1 Cr-0.25 Mo steel bolting material	-105 +450 (+540)	A 320 - L7	For low-temperature service. For nuts see 9.7.15.	
1 Cr-0.25 Mo steel bolting material	-30 +450	A 320 - L7M	For sour service and low-temperature service. For nuts see 9.7.16.	
9 Ni steel bolting material	-200	-	For low-temperature service. For nuts see 9.7.17.	
12 Cr steel bolting material	+425 (+540)	A 193 - B6X	For certain corrosive conditions. For nuts see 9.7.18.	
18 Cr-8 Ni steel (strain hardened) bolting material	-200 +815	A 193 - B8 Class 2	For certain corrosive conditions and/or extreme-temperature service. For nuts see 9.7.19.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni stabilized steel bolting material	-200 +815	A 193 - B8T or B8C	For certain corrosive conditions and/or extreme-temperature service. For nuts see 9.7.21.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-10 Ni-2 Mo steel (strain hardened) bolting material	-200 +500	A 193 - B8M Class 2	For certain corrosive conditions and/or high-temperature service. For nuts see 9.7.22.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni steel bolting material	-200	A 193 - B8N	For low-temperature service. For nuts see 9.7.20.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
Precipitation hardening austenitic Ni-Cr steel bolting material	(+540)	A 453-660 Class A	For certain corrosive conditions and/or high-temperature service. Expansion coefficient comparable with austenitic steels For nuts see 9.7.23.	
0.25 Mo steel nuts	+525	A 194 2HM	For bolting made from material specified under 9.7.2	

0.25 Mo steel nuts	+525 (600)	A 194 - 4	For bolting made from material specified under 9.7.3	
0.25 Mo steel nuts	-105 +525 (+600)	A 194 - 4, S4	For bolting made from material specified under 9.7.4	
0.25 Mo steel nuts	+525	A 194 - 7M,S4	For bolting made from material specified under 9.7.5	
9 Ni steel nuts	-200	-	For bolting made from material specified under 9.7.6	
12 Cr steel nuts	+425 (+540)	A 194 - 6	For bolting made from material specified under 9.7.7 Free-machining Grade 6F acceptable, subject to approval of the Company.	
18 Cr-8 Ni steel (strain hardened) nuts	-200 +815	A 194 - 8,S1	For bolting made from material specified under 9.7.8 Free-machining Grade 8F acceptable, subject to approval of the Company.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni steel nuts	-200	A 194 - 8N	For low-temperature service.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-8 Ni stabilized steel nuts	-200 +815	A 194 - 8T or 8C	For bolting made from material specified under 9.7.9 Free-machining Grade 8F acceptable, subject to approval of the Company.	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
18 Cr-10 Ni-2 Mo steel (strain hardened) nuts	-200 +500	A 194 - 8M,S1	For bolting made from material specified under 9.7.10	The material shall be capable of meeting the requirements of ASTM A262 Practice E.
Precipitation hardening austenitic Ni-Cr steel nuts	(+540)	A 453-660 Class A	For bolting made from material specified under 9.7.12	
0.75 Cr- 1.75 Ni, 0.25 Mo steel bolting material for low temperature services	+400	A320-L43		

4 NONFERROUS METALS

Plates, Sheets and Strip

DESIGNATION	Metal Temp.(°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Aluminum plates and sheets	- 200 +200	B 209 - Alloy 1060	For certain corrosive conditions	Specify annealed condition for all grades.
Al-2.5Mg alloy plates and sheets	- 200 +200	B 209 - Alloy 5052	For general use under certain corrosive conditions	Specify annealed condition for all grades.
Al-2.7Mg-Mn alloy plates and sheets	- 200 +200	B 209 - Alloy 5454	For general use under certain corrosive conditions	Specify annealed condition for all grades.
Al-4.5Mg-Mn alloy plates and sheets	- 200 + 65	B 209 - Alloy 5083	For low temperature applications	Specify annealed condition for all grades.
Copper plates, sheets and strip	- 200 +150	B 152 - C12200	For certain corrosive conditions	Specify annealed condition for all grades.
Cu-Zn alloy plates and sheets	- 200 +175	B 171 - C46400	For baffles of coolers and condensers in brackish and seawater service and for general use under certain corrosive conditions	Specify annealed condition for all grades.
Cu-Al alloy plates and sheets	- 200 +250	B 171 - C61400	For tube sheets of coolers and condensers in sweet and brackish water service and for general use under certain corrosive conditions	Specify annealed condition for all grades.
Cu-Al alloy plates and sheets	- 200 +350	B 171 - C63000	For tube sheets of coolers and condensers in brackish and seawater service and for general use under certain corrosive conditions. Tube sheets produced by special casting methods from approved manufacturers, are acceptable provided mechanical properties and chemical composition are compatible with this specification.	Al content max. 10.0%
Cu-Ni (90/10) alloy plates and sheets	- 200 +350	B 171 - C70600	For tube sheets of coolers and condensers in brackish and seawater service and for general use under certain corrosive conditions	
Cu-Ni (70/30) alloy plates and sheets	- 200 +350	B 171 - C71500	For certain corrosive conditions	
Nickel plates, sheets and strip	-200 (+350)	B 162 - N02200	For certain corrosive conditions	Specify annealed condition for all grades.
Low-carbon nickel plates, sheets and strip	- 200 +350	B 162 - N02201	For certain corrosive conditions	Specify annealed condition for all grades.
Ni-Cu alloy	- 200	B 127 -	For certain corrosive conditions	Specify annealed condition for

(Monel 400) plates, sheets and strip	+400	N04400		all grades.
Ni-Cr-Fe alloy (Inconel 600) plates, sheets and strip	+650	B 168 - N06600	For high-temp. conditions and/or certain corrosive conditions	Specify annealed condition for all grades.
Ni-Fe-Cr alloy (Incoloy 800) plates, sheets and strip	+815	B 409 - N08800	For high-temp. conditions and/or certain corrosive conditions	Specify C 0.05% maximum Specify annealed condition for all grades.
Ni-Fe-Cr alloy (Incoloy 800H) plates, sheets and strip	+1000	B 409 - N08810	For high-temp. conditions and/or certain corrosive conditions	Specify annealed condition for all grades.
Ni-Fe-Cr alloy (Incoloy 800HT) plates, sheets and strip	(+1000)	B 409 - N08811	For high-temp. conditions and/or certain corrosive conditions	
Ni-Fe-Cr-Mo-Cu alloy (Incoloy 825) plates, sheets and strip	+425	B 424 - N08825	For certain corrosive conditions	The material shall be capable of passing the Practice C intergranular corrosion test as specified in ASTM A262 (Corrosion rate in this test shall not exceed 0.3 mm/year).
Ni-Cr-Mo-Nb alloy (Inconel 625) plates, sheets and strip	+425	B 443 - N06625	For certain corrosive conditions	
Ni-Mo alloy (Hastelloy B2) plates, sheets and strip	+425	B 333 - N10665	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C4) plates, sheets and strip	+425	B 575 - N06455	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C276) plates, sheets and strip	+425 (+650)	B 575 - N10276	For certain corrosive conditions	
Ni-Cr-Mo alloy (Hastelloy C22) plates, sheets and strip	(+425)	B 575 - N06022	For certain corrosive conditions	
Titanium plates, sheets and strip	(+300)	B 265 - Grade 2	For certain corrosive conditions. For linings, tensile properties indicated in the material specifications to be used for information only.	For linings, specify soft-annealed material with hardness 140 HV10 max. The softer Grade 1 may also be used for lining.

Tantalum plates, sheets and strip	Temp. limits depend on nature of services	B 708 - R05200	For certain corrosive conditions. For linings, tensile properties indicated in the material specifications to be used for information only.	For linings, specify soft-annealed material with hardness 120 HV10 max.

Tubes and Tubing

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Seamless aluminum tubes	- 200 +200	B 234 - Alloy 1060	For unfired heat transfer equipment under certain corrosive conditions.	Specify annealed condition for all grades
Seamless Al-2.5 Mg alloy tubes	- 200 +200	B 234 - Alloy 5052	For unfired heat transfer equipment under certain corrosive conditions	Specify annealed condition for all grades
Seamless Al-2.7 Mg- Mn alloy tubes	- 200 +200	B 234 - Alloy 5454	For unfired heat transfer equipment under certain corrosive conditions	Specify annealed condition for all grades
Seamless copper tubing in small sizes	- 200 +150	B 68 - C12200 06 O	For instrument lines	Specify annealed condition for all grades
Seamless Cu-Zn-Al alloy (Aluminum Brass) tubes	(- 200) +175	B 111 - C68700	For coolers and condensers in brackish and seawater service	Specify annealed condition for all grades
Seamless copper nickel (90/10 Cu-Ni) alloy tubes	- 200 +350	B 111 - C70600	For unfired heat transfer equipment under certain corrosive conditions	Specify annealed condition for all grades
Seamless copper nickel (70/30 Cu-Ni) alloy tubes	- 200 +350	B 111 - C71500	For unfired heat transfer equipment under certain corrosive conditions	Specify annealed condition for all grades
Seamless copper nickel (66/30/2/2 Cu-Ni-Fe-Mn) alloy tubes.	- 200 +350	B 111 - C71640	For unfired heat transfer equipment under certain corrosive conditions	Specify annealed condition for all grades
Seamless nickel tubes	-200 +350	B 163 - N02200	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless low- carbon nickel tubes	- 200 +350	B 163 - N02201	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Cu alloy (Monel 400) tubes	- 200 +400	B 163 - N04400	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Cr-Fe alloy (Inconel 600) tubes	+650	B 163 - N06600	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with

				compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Fe-Cr alloy (Incoloy 800) tubes	+815	B 163 - N08800	For unfired heat transfer equipment under certain corrosive conditions	Specify C 0.05% max. Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Fe-Cr alloy (Incoloy 800H) tubes	+1000	B 407 - N08810	For furnaces and unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Fe-Cr alloy (Incoloy 800 HT) tubes	(+1000)	B 407 - N08811	For furnaces and unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Fe-Cr- Mo-Cu alloy (Incoloy 825) tubes	(-200) +425	B 163 - N08825	For unfired heat transfer equipment under certain corrosive conditions	Specify stabilised annealed Condition if tubes are to be welded to Headed Boxes Intergranular Corrosion Testing to be carried out
Seamless Ni-Cr- Mo-Nb alloy (Inconel 625) tubes	+425	B 444 - N06625	For unfired heat transfer equipment under certain corrosive conditions	Grade-1(annealed) material should be used at service temperature of 539 OC and less Intergranular corrosion testing to be carried out
Seamless Ni-Mo alloy (Hastelloy B2) tubes	+425	B 622 - N10665	For unfired heat transfer equipment under certain corrosive conditions	Intergranular corrosion testing to be carried out
Welded Ni-Mo alloy (Hastelloy B2) tubes	+425	B 626 - N10665 Class 1A	For unfired heat transfer equipment under certain corrosive conditions	Intergranular corrosion testing to be carried out
Seamless Ni-Mo-Cr alloy (Hastelloy C4) tubes	+425	B 622 - N06455	For unfired heat transfer equipment under certain corrosive conditions	Intergranular corrosion testing to be carried out
Welded Ni-Mo-Cr alloy (Hastelloy C4) tubes	+425	B 626 - N06455 Class 1A	For unfired heat transfer equipment under certain corrosive conditions	Intergranular corrosion testing to be carried out.
Seamless Ni-Mo-Cr alloy (Hastelloy C276) tubes	+425 (+650)	B 622 - N10276	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Welded Ni-Mo-Cr alloy (Hastelloy C276) tubes	+425 (+650)	B 626 - N10276 Class 1A	For unfired heat transfer equipment under certain corrosive conditions	Specify solution annealed condition for all grades. For tubes intended for use with compression fittings, hardness shall not exceed 90 HRB.
Seamless Ni-Cr-Mo alloy	(+425)	B 622 - N06022	For unfired heat transfer equipment under certain corrosive conditions	

(Hastelloy C22) tubes				
Welded Ni-Cr-Mo alloy (Hastelloy C22) tubes	(+425)	B 626 - N06022 Class 1A	For unfired heat transfer equipment under certain corrosive conditions	
Seamless titanium tubes	(+300)	B 338 - Grade 2	For unfired heat transfer equipment under certain corrosive conditions	
Welded titanium tubes	(+300)	B 338 - Grade 2	For unfired heat transfer equipment under certain corrosive conditions	

Pipe

DESIGNATION	Metal Temp.(°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Seamless aluminum pipe	- 200 +200	B 241 - Alloy 1060	For certain corrosive conditions	Specify annealed condition for all grades.
Seamless Al-Mg-Si alloy pipe	- 200 +200	B 241 - Alloy 6061	For certain corrosive conditions	Specify annealed condition for all grades.
Seamless Al-Mg-Si alloy pipe	- 200 +200	B 241 - Alloy 6063	For pipelines under certain corrosive conditions	Specify annealed condition for all grades.
Seamless Al-2.5Mg alloy pipe	- 200 +200	B 241 - Alloy 5052	For general use under certain corrosive conditions	Specify annealed condition for all grades.
Seamless Al- 2.7Mg-Mn alloy pipe	- 200 +200	B 241 - Alloy 5454	For general use under certain corrosive conditions	Specify annealed condition for all grades.
Seamless Al- 4.5Mg-Mn alloy pipe.	- 200 + 65	B 241 - Alloy 5083	For low-temperature service only	Specify annealed condition for all grades.
Seamless copper pipe	- 200 +150	B 42 - C12200	For certain corrosive conditions	Specify annealed condition for all grades.
Seamless Cu-Zn-Al alloy (Aluminum Brass) pipe	(-200) +175	B111 C68700	For brackish and seawater service	Specify annealed condition for all grades.
Seamless Cu-Ni alloy (90/10 Cu-Ni) pipe	(-200) +350	B 466 - C70600	For seawater service	Specify annealed condition for all grades.
Seamless Cu-Ni alloy (70/30 Cu-Ni) pipe	-200 +350	B 466 - C71500	For certain corrosive conditions	Specify annealed condition for all grades.
Seamless nickel pipe	-200 +350	B 161 - N02200	For certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades.
Seamless low-carbon nickel pipe	- 200 +350	B 161 - N02201	For certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades.
Seamless Ni-	-200	B 165 -	For certain corrosive conditions	Specify cold-worked,

Cu alloy (Monel 400) pipe	+400	N04400		annealed and pickled condition for all grades.
Seamless Ni-Cr-Fe alloy (Inconel 600) pipe	+650	B 167 - N06600	For high temperature conditions and/or certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades.
Seamless Ni-Fe-Cr alloy (Incoloy 800) pipe	(-200) +815	B 407 - N08800	For high temperature conditions and/or certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades. Specify C 0.05% max.
Seamless Ni-Fe-Cr alloy (Incoloy 800H) pipe	+1000	B 407 - N08810	For high temperature conditions and/or certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades.
Seamless Ni-Fe-Cr alloy (Incoloy 800HT) pipe	(+1000)	B 407 - N08811	For high temperature conditions and/or certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades.
Seamless Ni-Fe-Cr- Mo-Cu alloy (Incoloy 825) pipe	(-200) +425	B 423 - N08825	For certain corrosive conditions	Specify cold-worked, annealed and pickled condition for all grades. The material shall be capable of passing the Practice C intergranular corrosion test as specified in ASTM A262. (Corrosion rate in this test shall not exceed 0.3 mm/year).
Welded Ni-Fe-Cr- Mo-Cu alloy (Incoloy 825) pipe	(-200) +425	B705 - N08825 Class 2	For certain corrosive conditions	Specify cold-worked and bright annealed condition. The material shall be capable of passing the Practice C intergranular corrosion test as specified in ASTM A262. (Corrosion rate in this test shall not exceed 0.3 mm/year).
Seamless Ni-Cr- Mo-Nb alloy (Inconel 625) pipe	+425	B 444 - N06625	For certain corrosive conditions	Specify cold-worked and bright annealed condition for all grades.
Welded Ni-Cr-Mo- Nb alloy (Inconel 625) pipe	+425	B705 - N06625 Class 2	For certain corrosive conditions	Specify cold-worked and bright annealed condition.
Seamless Ni-Mo alloy (Hastelloy B2) pipe	+425	B 622 - N10665	For certain corrosive conditions	
Welded Ni-Mo alloy (Hastelloy	+425	B 619 - N10665	For certain corrosive conditions	

B2) pipe		Class II		
Seamless Ni-Mo-Cr alloy (Hastelloy C4) pipe	+425	B 622 - N06455	For certain corrosive conditions	
Welded Ni-Mo-Cr alloy (Hastelloy C4) pipe	+425	B 619 - N06455 Class II	For certain corrosive conditions	
Seamless Ni-Mo-Cr alloy (Hastelloy C276) pipe	+425 (+650)	B 622 - N10276	For certain corrosive conditions	
Welded Ni-Mo-Cr alloy (Hastelloy C276) pipe	+425 (+650)	B 619 - N10276 Class II	For certain corrosive conditions	
Seamless Ni-Cr-Mo alloy (Hastelloy C22) pipe	(+425)	B 622 - N06022	For certain corrosive conditions	
Welded Ni-Cr-Mo alloy (Hastelloy C22) pipe	(+425)	B 619 N06022 Class II	For certain corrosive conditions	
Seamless titanium pipe	(+300)	B 337 - Grade 2	For certain corrosive conditions	
Welded titanium pipe	(+300)	B 337 - Grade 2	For certain corrosive conditions	
Seamless titanium pipe for corrosive condition	+300	B861 Grade 2 bright annealed		
Welded titanium pipe for corrosive conditions	+300	B862 Grade 2 Bright annealed		

Forgings, Flanges and Fittings

DESIGNATION	Metal Temp.(° C)	ASTM	REMARKS	ADDED REQUIREMENTS
Al-2.5Mg alloy forgings	-200 +200	Alloy 5052	For general use under certain corrosive conditions	Specify annealed condition for all grades. Order to ASTM B 247, with reference to ASME VIII, Div. 1, para UG 15.
Al-2.7Mg-Mn alloy forgings	-200 +200	Alloy 5454	For general use under certain corrosive conditions	Specify annealed condition for all grades. Order to ASTM B 247, with reference to ASME VIII, Div. 1, para UG 15.
Al-4.5Mg-Mn alloy forgings	-200 + 65	B 247 - Alloy 5083	For low-temperature service only.	Specify annealed condition for all grades.

Al-Mg-Si alloy forgings	-200 +200	B 247 - Alloy 6061	For certain corrosive conditions and/or low-temperature service.	Specify annealed condition for all grades.
Al-Mg-Si alloy welding fittings	-200 +200	B 361 - WP 6061	For certain corrosive conditions and/or low-temperature service.	Specify annealed condition for all grades.
Al-2.5Mg alloy welding fittings	-200 +200	Alloy WP 5052 or WP 5052W	For use in marine atmosphere and for general use under certain corrosive conditions	Specify annealed condition for all grades. Order to ASTM B 361, with reference to ASME VIII, Div. 1, para UG 15.
Al-2.7Mg-Mn alloy welding fittings	-200 +200	Alloy WP 5454 or WP 5454W	For use in marine atmosphere and for general use under certain corrosive conditions	Specify annealed condition for all grades. Order to ASTM B 361, with reference to ASME VIII, Div. 1, para UG 15.
Nickel welding fittings	(+325)	B 366 - WPNS or WPNW	For certain corrosive conditions	Specify annealed condition for all grades.
Low-carbon nickel welding fittings	(+600)	B 366 - WPNLS or WPNLW	For certain corrosive conditions	Specify annealed condition for all grades.
Ni-Cu alloy (Monel 400) forgings	-200 +400	B 564 - N04400	For certain corrosive conditions	Specify annealed condition for all grades.
Ni-Cu alloy (Monel 400) welding fittings	-200 +400	B 366 - WPNCS or WPNCW	For certain corrosive conditions	Specify solution annealed condition for all grades.
Ni-Cu alloy (Monel) 400) forgings	+650	B 564 - N06600	For high temperature conditions and/or certain corrosive conditions	Specify solution annealed condition for all grades.
Ni-Cr-Fe alloy (Inconel 600) fittings	+650	B 366 - WPNC1S or WPNC1W	For high temperature conditions and/or certain corrosive conditions	Specify solution annealed condition for all grades.
Ni-Fe-Cr alloy (Incoloy 800) forgings	+815	B 564 - Alloy N08800	For extreme temperature service	Specify solution annealed condition for all grades. Specify C 0.05% max.
Ni-Fe-Cr alloy (Incoloy 800H) forgings	+1000	B 564 - N08810	For extreme temperature service	Specify solution annealed condition for all grades. Intergranular Corrosion Testing to be carried out
Ni-Fe-Cr-Mo-Cu alloy (Incoloy 825) forgings	(-200) +450	B 564 - N08825	For extreme temperature service	Specify solution annealed condition for all grades. The material shall be capable of passing the Practice C intergranular corrosion test as specified in ASTM A262. (Corrosion rate in this test shall not exceed 0.3 mm / year). Intergranular Corrosion Testing to be carried out
Ni-Fe-Cr-Mo-	(-200)	B 366 -	For extreme temperature service	Specify solution annealed

Cu alloy (Incoloy 825) welding fittings	+450	WPNI CMCS or WPNI CMCW		condition for all grades. The material shall be capable of passing the Practice C intergranular corrosion test as specified in ASTM A262. (Corrosion rate in this test shall not exceed 0.3 mm/year).
Ni-Mo alloy (Hastelloy B2) welding fittings	+425	B 366 - WPHB2S or WPHB2W	For certain corrosive conditions	Specify solution annealed condition for all grades.
Ni-Mo-Cr alloy (Hastelloy C4) welding fittings	+425	B 366 - WPHC4	For certain corrosive conditions	Specify solution annealed condition for all grades. Intergranular Corrosion Testing to be carried out
Ni-Mo-Cr alloy (Hastelloy C276) welding fittings	(+800)	B 366 - WPHC276	For certain corrosive conditions	Specify solution annealed condition for all grades. Intergranular Corrosion Testing to be carried out
Ni-Cr-Mo alloy (Hastelloy C22) forgings	(+425)	B 564 - N06022	For certain corrosive conditions	Specify solution annealed condition for all grades. Intergranular Corrosion Testing to be carried out
Ni-Cr-Mo alloy (Hastelloy C22) welding fittings	+425	B 366 - WPHC22S or WPHC22W	For certain corrosive conditions	Specify solution annealed condition for all grades. Intergranular Corrosion Testing to be carried out
Titanium forgings	(+300)	B 381 - Grade F2	For certain corrosive conditions	Specify annealed condition for all grades.
Titanium welding fittings	(+300)	B 363 - WPT2 or WPT2W	For certain corrosive conditions	Specify annealed condition for all grades.

Castings

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Al-5Si alloy castings	-200 +200	B 26 - Alloy B443.0	For certain corrosive conditions	Specify B108 Alloy B443.0 for permanent mold castings.
Al-12Si alloy castings	-200 +200	-	For certain corrosive conditions	
Composition bronze (Bronze 85/5/5/5) castings	-200 +175	B 62 - C83600	For flanges, fittings and valves	
Tin bronze (Bronze 88/10/2)	-200 +175	B 584- C90500	For equipment parts to be used in brackish and seawater service and for certain corrosive conditions	

castings				
Ni-Al bronze castings	-200 +350	B 148 - C95800	For equipment parts to be used in brackish and seawater service and for certain corrosive conditions	
Lead in pig form	+100	B 29 - Chemical - Copper Lead UNS L551121	For homogeneous linings of equipment under certain corrosive conditions	
Ni-Cu alloy (Monel 400) castings	-200 +400	A 494- M35-1	For certain corrosive conditions	
Ni-Mo alloy (Hastelloy B2) castings	+425	A494 - N-7M Class 1	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C4) castings	+425	A494 - CW-2M	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C276) castings	+425 (+650)	A494 - CW-12MW Class 1	For certain corrosive conditions	
50Cr-50Ni-Nb alloy castings	+1000	A560 - 50Cr-50Ni-Cb	For furnace tube supports exposed to vanadium attack	
Titanium castings	(+250)	B367 -Grade C2	For certain corrosive conditions	

Bars, Sections and Wire

DESIGNATION	Metal Temp. (°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Extruded aluminum bars, rods, sections (incl. hollow sections), tube and wire	-200 +200	B 221 - Alloy 1060	For certain corrosive conditions	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Extruded Al-2.5 Mg alloy bars, rods, sections (incl. hollow sections), tube and wire	-200 +200	B 221 - Alloy 5052	For general use under certain corrosive conditions	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Extruded Al-2.7 Mg- Mn alloy bars, rods, sections (incl. hollow sections), tube and wire	-200 +200	B 221 - Alloy 5454	For general use under certain corrosive conditions	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Extruded Al-Mg-Si alloy bars, rods, sections	-200 +200	B 221 - Alloy 6063	For general purposes	For bars, rods and sections, specify annealed condition for all grades.

(incl. hollow sections), tube and wire				For wire, condition to be agreed upon for each case individually.
Copper bars, rods and sections	-200 +150	B 133 - C11000	For electrical purposes	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Copper bars, rods and sections	-200 +150	B 133 - C12200	For general purposes	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Free cutting Cu-Zn alloy bars, rods and sections	-200 +175	B 16 - C36000	For general purposes	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Cu-Zn-Pb alloy bars, rods and sections	-200 +150	B140 - C32000 or C31400	For general purposes	For bars, rods and sections, specify annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Cu-Al alloy bars, rods and sections	-200 +350	B 150 - C63200	For general purposes under certain corrosive conditions	
Cu-Ni (90/10) alloy bars, rods and sections	-200 +350	B 122 - C706	For certain corrosive conditions	
Cu-Ni (70/30) alloy bars, rods and sections	-200 +350	B 122 - C71500	For certain corrosive conditions	
Phosphor bronze wire	-200 +175	B 159 - C51000 Condition H08 (Spring Temper)	For springs	
Nickel bars and rods	(+325)	B 160 - N02200	For certain corrosive conditions	For bars and rods, specify solution annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Low-carbon nickel bars and rods	-200 +350	B 160 - N02201	For certain corrosive conditions	For bars and rods, specify solution annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Ni-Cu alloy (Monel 400) bars, rods and wire	-200 +400	B 164 - N04400	For certain corrosive conditions	For bars and rods, specify solution annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Ni-Cu-Al alloy (Monel K500) bars, rods and wire	-200 +400	-	For certain corrosive conditions requiring high tensile strength	Bars and rods should be supplied in the solution treated and precipitation hardened condition.

				For wire, condition to be agreed upon for each case individually.
Ni-Cr-Fe alloy (Inconel 600) bars, rods and wire	+650	B 166 - N06600	For high-temperature conditions and/or certain corrosive conditions	For bars and rods, specify solution annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Ni-Cr-Mo-Nb alloy (Inconel 625) bars and rods	+425	B 446 - N06625	For certain corrosive conditions	For bars and rods, specify solution annealed condition for all grades. For wire, condition to be agreed upon for each case individually.
Ni-Fe-Cr alloy (Incoloy 800) bars, rods and wire	+815	B 408 - N08800	For high-temperature conditions and/or certain corrosive conditions	Specify C 0.05% max.
Ni-Fe-Cr alloy (Incoloy 800H) bars, rods and wire	+1000	B 408 - N08810	For high-temperature conditions and/or certain corrosive conditions	
Ni-Fe-Cr alloy (Incoloy 800HT) bars, rods and wire	(+1000)	B 408 - N08811	For high-temperature conditions and/or certain corrosive conditions	
Ni-Fe-Cr-Mo-Cu alloy (Incoloy 825) bars, rods and wire	(+425)	B 425 - N08825	For certain corrosive conditions	Intergranular Corrosion Testing to be carried out
Ni-Mo alloy (Hastelloy B2) rods	+425	B 335 - N10665	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C4) rods	+425	B 574 - N06455	For certain corrosive conditions	
Ni-Mo-Cr alloy (Hastelloy C276) rods	(+800)	B 574 - N10276	For certain corrosive conditions	
Ni-Cr-Mo alloy (Hastelloy C22) rods for certain corrosive conditions	(+425)	B 574 - N06022	For certain corrosive conditions	
Titanium bars	(+300)	B 348 - Grade 2	For certain corrosive conditions	Specify annealed condition.

Bolting

DESIGNATION	Metal Temp.(°C)	ASTM	REMARKS	ADDED REQUIREMENTS
Aluminum alloy bolts and nuts	-200 +200	F467/468 - A96061	Bolting material may also be selected from Bars specified in Table above.	
Cu-Al alloy bolts and nuts	-200 +365	F467/468 - C63000	Bolting material may also be selected from Bars specified in Table above.	
Cu-Ni (70/30) alloy bolts and nuts	-200 +350	F467/468 - C71500	Bolting material may also be selected from Bars specified in Table above.	
Ni-Cu alloy (Monel 400) bolts and nuts	-200 +400	F467/468 -N04400	Bolting material may also be selected from Bars specified in Table above.	
Ni-Cu-Al alloy (Monel K500) bolts and nuts	-200 +400	F467/468 -N05500	Bolting material may also be selected from Bars specified in Table above.	
Ni-Mo alloy (Hastelloy B) bolts and nuts	+425	F467/468 - N10001	Bolting material may also be selected from Bars specified in Table above.	
Ni-Mo-Cr alloy (Hastelloy C276) bolts and nuts	(+800)	F467/468 - N10276	Bolting material may also be selected from Bars specified in Table above.	
Titanium bolts and nuts	(+300)	F467/468 - Alloy Ti 2	Bolts primarily intended for use inside equipment.	