Metallic Materials Specification

03.01.158-Metallic_Materials-Specification

Contents

Document History

Version No.	Date	Author	Approver	Description of Amendment
1.0	16/03/2022	Rashed Al Kamyani	Mahmood Al Aamri	First issue

1.0 Purpose

The purpose of this specification, together with referenced standards, specifications, and project documents, is to define the minimum functional and technical requirements for the engineering, design, materials, fabrication, inspection, testing and certification of Metallic material for all OQ group of Company's projects.

The purpose of this document is to provide all the metallic material requirements to ensure integrity of the material during service.

2.0 Scope

This specification defines the minimum requirements for the materials of construction for pressure containing equipment/components fabricated according to ASME design code, API and ISO Standards. The basic materials to be used shall be specified on the equipment datasheets. Where conflicting requirements appear the most stringent requirement, as determined by the Company, shall prevail. This is regardless of the order of precedence provided in this or any other contract document.

The requirements covered in this standard are in addition to the international standards, as required by Oil & Gas plants and facilities designed/constructed by the OQ.

The detailed material and testing requirements for linepipes are not covered in this document. Reference is made to API 5L and ISO3183 and other Company specifications like 03.01.79-Carbon_Steel_Line Pipe_LSAW-Specification, 03.01.80-Carbon_Steel_Line Pipe_HFW-Specification and 03.01.81-Carbon_Steel_Line Pipe_SMLS-Specification.

3.0 Confidentiality and Distribution

- This document is the property of OQ Group of Companies. Unless otherwise authorized by the Company, the distribution and use of this specification is limited to Company authorities and the Contractors' nominated by the Company. Unauthorized sharing is strictly prohibited and Company shall not bear any responsibility further.
- This document should be part of the ITT/Contract and thus becomes a contract requirement for the Contractor / Vendor to comply with as applicable.
- This document shall be revised only by the document custodian that is OQ Projects, CoE team.

4.0 Codes and Standards

Unless otherwise stated, latest editions shall be followed for all reference code, standards and practices mentioned below.

CODE/STANDARD	TITLE
NACE MR0175/ISO 15156 Parts 1, 2 & 3	Petroleum and Natural Gas Industries – Materials for Use in H2S Containing Environments in Oil & Gas Production
NACE MR0103	Petroleum, petrochemical and natural gas industries — Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments

CODE/STANDARD	TITLE
NACE TM0284	Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking
NACE TM0177	Laboratory Testing of Metals for Resistance to Sulphide Stress Cracking and Stress Corrosion Cracking in H2S Environments
API RP 582	Welding guidelines for the chemical, oil and gas industries
API RP 934-A	Materials and Fabrication of 21/4Cr-1Mo, 21/4Cr-1Mo-1/4V, 3Cr-1Mo, and 3Cr-1Mo-1/4V Steel Heavy Wall Pressure Vessels for High-temperature, High-pressure Hydrogen Service
API RP 934-C	Materials and Fabrication of 1 1/4Cr-1/2Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825 °F (441 °C)
API RP 934-E	Materials and Fabrication of 1 1/4Cr-1/2Mo Steel Pressure Vessels for Service Above 825°F (440°C)
API TR 938-C	Use of Duplex Stainless Steels in the Oil Refining Industry
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME B31.12	Hydrogen Piping and Pipelines
ASME BPVC Sec II Part A, B and C	Material Specifications
ASME BPVC Sec II, Part D	Material Properties
ASME BPVC Sec V	Non-destructive Examination
ASME BPVC Sec VIII Div. 1	Boiler & Pressure Vessel Code: Rules for Construction of Pressure Vessels
ASME BPVC Sec VIII Div. 2	Boiler & Pressure Vessel Code: Alternative Rules for Construction of Pressure Vessels
ASME BPVC Sec IX	Welding and Brazing Qualifications

CODE/STANDARD	TITLE
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASME SA-264	Specification for Stainless Chromium-Nickel Steel-Clad Plate
ASME SA-265	Standard Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate
ASTM A380	Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
ASME A578	Straight – Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications
ASTM A967	Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts
ISO 17781	Petroleum, petrochemical and natural gas industries - Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels
ISO/TR 15608	Welding — Guidelines for a metallic materials grouping system
ISO/TR 20173	Welding — Grouping systems for materials — American materials

5.0 Company Specifications

SPECIFICATION	TITLE
03.01.19	Positive Material Identification (PMI) Program Specification
03.01.124	Mechanical Design Specification
03.01.212	Pipe Class Service Index Specification
03.01.278	Material Requirements Hydrogen Service
03.01.279	Material Requirements H2S Service
03.01.280	Material Requirements Alkaline Service
03.01.79	Carbon_Steel_Line Pipe_LSAW-Specification

SPECIFICATION	TITLE
03.01.80	Carbon_Steel_Line Pipe_HFW-Specification
03.01.81	Carbon_Steel_Line Pipe_SMLS-Specification

6.0 Abbreviations

TERM / ACRONYM / ABBREVIATION	EXPLANATION / DEFINITION
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CE	Carbon Equivalent
CS	Carbon Steel
DSS	Duplex Stainless Steel
SDSS	Super Duplex Stainless Steel
EPC	Engineering, Procurement, and Construction
HIC	Hydrogen Induced Cracking
IGC	Intergranular Corrosion
ISO	International Organization for Standardization
LAS	Low Alloy Steel
LTCS	Low Temperature Carbon Steel
MDMT	Minimum Design Metal Temperature
MT	Magnetic Particle Test
NACE	National Association of Corrosion Engineers

TERM / ACRONYM / ABBREVIATION	EXPLANATION / DEFINITION
NDT	Non-Destructive Testing
PMI	Positive Material Identification
PWHT	Post Weld Heat Treatment
SR	Stress Relief
SSC	Sulphide Stress Cracking
UT	Ultrasonic Testing
WO	Weld Overlay

7.0 Exception, Deviation and Concession Control

The SUPPLIER & CONTRACTOR shall list all the deviations to the specifications, codes and standards. Unless any deviations are identified and accepted by the COMPANY, the SUPPIER & CONTRACTOR shall confirm compliance with all the listed specifications, codes and standards.

Any deviations or exceptions shall be raised in a “Concession Request Form”. COMPANY shall give their resolution/approval in writing and this decision shall be binding on SUPPLIER & CONTRACTOR without any time/cost impact to COMPANY unless specifically identified and agreed in the form.

8.0 Health, Safety and Environmental Requirement

The SUPPLIER and CONTRACTOR shall be responsible for ensuring that the equipment/system supplied meets all applicable regulations regarding health, safety and environment. It shall be designed to operate safely and satisfactorily at all expected combinations of process, utilities and site conditions which include those at start-up, operation, shutdown and emergency cases while retaining the overall system security, reliability and availability.

9.0 Materials

All materials shall be new, smooth and supplied with a good workmanship finish and conform to required codes and standards, including the following:

9.1 Material Standards

The materials of pressure vessels shall comply with ASME BPVC Sec. II Part A for ferrous materials, ASME BPVC Sec. II Part B for nonferrous materials. Materials of piping shall comply with the listed material specifications in ASME B31.3, ASME B31.4 and ASME B31.8.

Mechanical and chemical analysis tests for base materials shall be performed by the material manufacturer. This includes impact tests, where applicable.

9.2 General Chemical Composition Restrictions

The chemical composition of steels intended for welding or forming shall not exceed the values in below table.

	MAXIMUM CONTENT OF LADLE ANALYSIS		
STEEL GROUP AS PER ISO/TR 15608 C)	**%C**	**%P**	**%S**
Steels (1 to 6 and 9)	0.23 a)	0,035	0,025
Ferritic stainless steels (7.1)	0,08	0,040	0,015
Martensitic stainless steels (7.2)	0,06	0,040	0,015
Austenitic stainless steels (8.1)	0,08 d)	0,045	0,015 b)
Austenitic stainless steels (8.2)	0,10 d)	0,035	0,015
Austenitic-ferritic stainless steels (10)	0,030	0,035	0,015

a) Maximum content of product analysis 0,25 %.
b) For products to be machined a controlled sulphur content of 0,015 % to 0,030 % is permitted by agreement provided the resistance to corrosion is satisfied for the intended purpose.
c) For ASME/ASTM material group numbering refer to ISO/TR 20173
d) Autstenitic stainless steels of weldable grades should have a carbon content of maximum 0.03 wt% (L grade).

9.3 Flange Bolting Materials

If the materials for bolts and nuts are specified on the equipment data sheet these shall prevail.

Bolting selection shall be in accordance with the Piping Class selected for the vessel trim of subject equipment and be provided by COMPANY.

Default selections is specified in below table.

FLANGE MATERIAL	BOLTING MATERIAL
Carbon and Low Alloy Steel	A/SA-193 Grade B7/ SA-194 Grade 2H

FLANGE MATERIAL	BOLTING MATERIAL
Low Temperature Carbon Steel >-50C	
Austenitic Stainless Steel 304, 304L, 316, 316L, 321 Ferritic-Austenitic (Duplex) Stainless Steel UNS S32304 (Lean DSS), UNS S32205 (DSS), UNS S32750 (Super DSS) UNS N06022 (Alloy C-22) UNS N04400 (Monel)	In refinery and petrochemical plants: A/SA-193 Grade B7/ A/SA-194 Grade 2H In oil and gas production unit and chemical plants A/SA-193 B8M/ SA-194 Grade 8M
Bolting for sour service shall comply with NACE MR0103	

Note, in high temperature creep service and a design temperature above 427°C, flange bolting material shall comply to A/SA 453 grade 660

9.4 Inspection Documents

All material intended for use as pressure-bearing parts shall be accompanied by inspection documents in accordance with EN 10204 “type 3.1” traceable to the material. This includes bolting and attachments welded directly to the pressure vessel and structural member(s) essential for the structural integrity of the vessel (e.g. support feet, skirts, lifting lugs, baffles, pipe supports, stiffening rings). Other materials and inspection document types as per EN 10204, Annex ZA.

For manufactured parts which are not made to a materials specification, such as cones or heads, either from one part or more, a component certificate shall be prepared by the material manufacturer of the part.

The inspection documents shall contain all required testing results as indicated in the relevant product standards, in this specification and of any additional specified material testing requirements referenced in the requisition.

The inspection documents shall be in the English language.

9.5 Material Traceability

The manufacturer shall have and maintain an identification system for materials used in fabrication, so that all material subject to stress due to pressure and those welded thereto in the completed work can be traced to its origin. This includes the use of welding consumables.

9.6 PMI

Positive Material Identification (PMI) shall be performed in accordance with COMPANY specification *“03.01.19 - Positive Material Identification (PMI) Program Specification.”*

9.7 Heat Treatments

When normalizing for grain refinement is applied for forged parts, normalizing heat treatment for grain refinement shall be done in a separate heat treatment.

If Post Weld Heat Treatment (PWHT) or Stress Relieving (SR) is applied for (parts of) the equipment then materials of shell plates, head plates, body flanges, tube sheets and forged shell rings shall be purchased with material properties certified in the simulated maximum anticipated PWHT duration and temperature. This does not apply to the piping components, e.g. pipes, fittings and flanges.

When Charpy V-notch impact testing is required for plates that will be heat treated, test specimens shall be provided in both the minimum and maximum heat treated condition.

The minimum heat treated condition means subjected to the fewest heat treatment cycles and/or time – at-temperature anticipated for the component.

The maximum heat treated condition means subjected to the maximum number of heat treatment cycles and/or time at temperature anticipated during fabrication (including intermediate stress relief and multiple heat treatment exposures) including possible shop repairs plus a minimum of one additional heat treatment to simulate a future repair by COMPANY.

If heat treatment above the austenite transition temperature is applied for (parts of) the equipment during fabrication, a new material certificate shall be issued by the Supplier in accordance with the contents of original material certificate and material specification requirements.

For quenched and tempered or normalized and tempered steels the PWHT temperature shall be at least 30°C below the tempering temperature to avoid an unacceptable decrease of mechanical properties. Special attention to this rule is required in relation to the special process services post weld heat treatment requirements of API RP 582 table 6, when applicable. When PWHT is required for special process services, acceptance to deviate from this 30C rule shall be discussed with and accepted to proceed by the COMPANY in writing.

Post forming- and Post weld- heat treatments shall be recorded on time and temperature charts.

9.8 Testing

For carbon steel and low alloy steel plates where loads perpendicular to the surface and through thickness tension of the plate are expected, e.g. with set-on nozzles or full penetration corner welds (like for header boxes), Z35 quality in accordance with ASME SA 770 shall be required.

9.9 Marking

Each material shall be legibly and permanently marked as per the relevant product standard.

10.0 Carbon Steel

10.1 Chemical Composition

All chemical elements specified in the material specification and where additional limitations are specified in this specification, shall be analysed and indicated on the material test certificate.

The required type of test certificate shall be as indicated in paragraph titled “Inspection Documents” of this specification.

The chemical composition of carbon steels intended for welding shall not exceed the values indicated in section 9.2.

Carbon equivalent CEV shall be ≤ 0.43 wt %, except for forgings that shall be ≤ 0.45 wt %, acc. to the formula:

$$CEV = \left(C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15} \right)$$

Higher CEVs require Company pre order consent and acceptance and shall among others require the consequence of weld preheating of subject items, regardless of code requirements.

A/SA-105N, A/SA-106 and A/SA-234 carbon steel forgings, pipes and fittings shall have a carbon manganese ratio of Mn/C ≥ 5. For impact tested carbon steels the Mn/C ratio ≥ 5 is not required. When Mn compensation for carbon reduction is applied, the Manganese content is limited to max. 1.2% Manganese.

It is not allowed to use the deliberately Micro-Alloyed Quenched and Tempered type of carbon steels.

10.2 Carbon Steel Components

Carbon Steel Pressure Containing Parts:

a. Shall be fully killed steels.

b. All Pipes, Forgings, Flanges and Fittings shall be normalized

c. For components that will be heat treated, test specimens shall be provided in both the minimum and maximum heat-treated condition in accordance with paragraph titled “Heat Treatments” of this specification.

Carbon Steel for structural purposes shall be semi-killed or killed steels.

For ASTM/ASME A/SA 765 forgings (non-standard), supplementary requirement ASTM/ASME A/SA 765, S4, optional test MT of all finished forgings is required. Any linear indication is unacceptable.

In hydrogen service all cold formed carbon steel components shall be heat treated (i.e. stress relieved or normalized after forming).

Where the skirt lower section, anchor bolt chairs / base plate is exposed to MDMT < -20C impact testing at MDMT or A/SA-516 Grade 60/65/70 + S5 shall be used.

11.0 Carbon Steel and Low Alloy Steel Clad Products

For clad material other than SS304L, SS316L, 321&347 grade of stainless steels, explosion bonded cladding is preferred but rolled bonded cladding can be also acceptable subject to review and approval from Company

11.1 General Requirements for Carbon Steel and Low Alloy Steel Clad Material

The carbon steel or low alloy steel base material/substrate shall comply with the requirements of the applicable paragraphs in this specification.

The alloy type selected for the cladding shall be strictly in accordance with the data sheet. Only one single grade shall be used.

The minimum clad/WO thickness shall be 3mm, unless specified otherwise in the data sheet or the requisition. The chemical composition of the weld overlay shall be checked by laboratory chemical analysis of a sample taken at a minimum depth of 3mm from the final surface. The composition shall meet the required chemistry of the specified overlay material.

For tubesheets, as per ISO 16812 and API STD 660, the minimum clad/WO thickness at the tube side face of a tubesheet shall not be less than 10 mm when tubes are expanded only, and 5 mm when tubes are welded to the tubesheet. The minimum cladding thickness on the shell side face shall not be less than 10 mm.

11.2 Clad Plates

Plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium-nickel steel, shall comply with ASME SA-264.

Plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of nickel or nickel-base alloy, shall comply with ASME SA-265.

The bond between the cladding and the base metal shall be tested by and shear strength values comply with the requirement of the “shear strength” test as described in the applicable cladding specification.

Clad plates shall be 100% ultrasonically inspected for bond integrity in accordance with ASME SA-264/265 prior to shipment. The bond quality shall be:

- Class 3 for general corrosive service applications.
- Class 1 for Hydrogen service and Wet H2S service applications.

The corrosion resistance of alloy cladding shall be tested after bonding. Testing shall be performed by the Material Manufacturer. The following tests apply:

- For austenitic stainless steels of grades; AISI 304, 304L, 316, 316L, 321, 347, testing shall be performed in accordance with ASTM A262 Method E (Strauss test) and shall be acceptable if the test is passed.
  Alternatively ISO 3651-2, Method A may be used.
- For ferritic-austenitic (duplex) stainless steels of grades; S32205, S32507, corrosion testing in accordance with ISO 17781 is required
- For nickel base alloys like Alloy C22, C-276 and 625the corrosion testing shall be performed in accordance with ASTM G28, Method B (Mixed Acid-Oxidating Salt Test). No presence of intergranular corrosion after 24 hours.
- For post weld heat treated (PWHT) equipment testing is required in the simulated heat treated maximum anticipated PWHT duration and temperature (ASME SA-264/265 + S3).

Monel-400 (UNS-N04400):

- Contain max 0.2wt% Zn and max 0.02wt% S.
- be microscopically examined after final annealing / stress relieving at a magnification of 400x to disclose any iron containing precipitations.

Finish of the alloy cladding shall include pickling.

11.3 Repair

Whenever unacceptable NDE indication on the base metal are removed by chipping or grinding and the wall thickness of the base material at the excavated area becomes less than minimum required prior approval for repair from the COMPANY shall be obtained.

Prior approval shall be obtained from the COMPANY for any repair where the Individual defect covering an area in excess of 5% of the clad surface and/or exceeding 1200 cm2 in extent.

11.4 Weld Overlay (WO)

Welding qualification, non-destructive examinations, chemical composition and ferrite testing requirements shall be in accordance with ASME BPVC Sec. IX and API RP 582.

Ferritic-austenitic (duplex) stainless steels weld overlay requires Company approval.

The corrosion resistance of alloy weld overlay (including clad restoring) shall be tested as part of the welding procedure qualification. The following tests apply:

- For austenitic stainless steel weld deposit of grades; AISI 304L, 316L, 347, if PWHT of the PQR is required, testing shall be performed in accordance with ASTM A262 Method E (Strauss test) and shall be acceptable if the test is passed.
  Alternatively ISO 3651-2, Method A may be used.

- For ferritic-austenitic (duplex) stainless steels of weld consumable grades; 2209/2595, corrosion testing in accordance with ISO 17781 is required on a 25x50x3mm sample machined from the top surface of the welding procedure qualification test

- For Nickel Alloys the corrosion testing shall be performed in accordance with the requirements for corrosion testing of plates as specified in chapter 15.0 of this specification. Corrosion resistance of the weld overlay shall be mutually tested with the solid clad plate alloy. The weld overlay material shall for minimum be equally corrosion resistant as the solid clad plate alloy material.

- For post weld heat treated (PWHT) equipment testing is required in the simulated heat treated maximum anticipated PWHT duration and temperature.

For Monel-400 (UNS-N04400) weld overlay the PQR shall include a microstructural analysis at a magnification of 400x to disclose any iron containing precipitations.

All weld overlaid surfaces shall be liquid penetrant tested according ASME Section V, Article 6, acceptance criteria according applicable design code eg ASME Section VIII, Div 1, Appendix 8.

Unless more stringent requirements are defined elsewhere (eg API RP 582, API RP 934-A, API RP 934-C and API RP 934-E), as a minimum, weld deposit overlay shall be spot ultrasonically examined after completion but before final post weld heat treatment. A minimum of 10% of the surface area shall be examined. Any unbonded area which exceeds 75 mm (3 in) in its longest dimension shall be repaired by removing and re-welding.

When alloy 625 and other nickel-based alloys are used as overlay metal, the maximum iron content at the finished surface should be 10 % (mass fraction).

12.0 Cr-Mo Low Alloy Steel

For 1¼Cr–½Mo LAS with operating temperature <= 440°C all materials including welding consumables shall comply with the requirements of API RP 934-C.

For 1¼Cr–½Mo LAS with operating temperature > 440°C all materials including welding consumables shall comply with the requirements of API RP 934-E.

For 1¼Cr–½Mo LAS the weld joint thickness shall not exceed 100mm. For forged components other areas than the weld seam may be thicker. For higher thicknesses 2.25Cr-1Mo material shall be selected for the entire equipment.

For 2¼Cr–½Mo LAS with operating temperature >= 345°C all materials including welding consumables shall comply with the requirements of API RP 934-A.

The carbon steel plates applied for the skirt and the welds shall have the mechanical properties tested in simulated post weld heat treatment condition, to the temperature and duration as required for the applicable principal material of the vessel.

12.1 Pipe fittings and flanges in P11 and P22

Accelerated cooling from the austenitising temperature is acceptable, where permitted by the applicable product form specification.

For the manufacture of pipe from plate, ASTM A387 Class 1 plates shall be used. Only longitudinally welded pipe is acceptable. No circumferential welds are allowed in the manufacture of welded pipe.

Finished product shall be normalised and tempered.

Hydrostatic testing of finished pipe is required in accordance with ASTM A999 / A530 as applicable.

For welded pipe radiographic examination of the longitudinal weld shall be performed after heat treatment and hydrostatic testing.

Maximum hardness shall be 201BHN.

12.2 Pipe, fitting and flanges in P5 material

Finished product shall be normalised and tempered.

For the manufacture of pipe from plate, ASTM A387 Class 1 plates shall be used. Only longitudinally welded pipe is acceptable. No circumferential welds are allowed in the manufacture of welded pipe.

For welded pipe, radiographic examination of the longitudinal weld shall be performed after heat treatment and hydrostatic testing.

Hydrostatic testing of finished pipe is required in accordance with ASTM A999 / A530 as applicable.

Maximum hardness shall be 225BHN.

12.3 Pipe, fitting and flanges in P9 material

Finished product shall be normalised and tempered.

For the manufacture of pipe from plate, ASTM A387 Class 1 plates shall be used. Only longitudinally welded pipe is acceptable. No circumferential welds are allowed in the manufacture of welded pipe.

For welded pipe radiographic examination of the longitudinal weld shall be performed after heat treatment and hydrostatic testing.

Hydrostatic testing of finished pipe is required in accordance with ASTM A999 / A530 as applicable.

Maximum hardness shall be 241BHN.

12.4 Pipe, fitting and flanges in P91 material

Finished product shall be normalised and tempered.

Only longitudinally welded pipe is acceptable. No circumferential welds are allowed in the manufacture of welded pipe.

For welded pipe, radiographic examination of the longitudinal weld shall be performed after heat treatment and hydrostatic testing.

Hydrostatic testing of finished pipe is required in accordance with ASTM A999 / A530 as applicable.

Maximum hardness shall be 250BHN.

Finished product shall be Brinell hardness tested, with acceptance criteria 250 BHN maximum. Measured values shall be reported on the pipe material test certificates. Hardness test specimen selection shall be in accordance with ASTM A335 Section 14.2.

All P91 material shall be normalized in the range of 1040°C to 1080°C and tempered in the range of 760°C to 780°C. The heat treatment temperature and the soaking time shall be reported on the material test certificate. PWHT shall be carried out at 755°C +/- 10°C.

100% Flux leakage examination shall be carried out in accordance ASTM E570. Calibration against longitudinal and transverse notches- one of each-inside and outside sample. Notch depth shall be 5% of minimum wall thickness.

13.0 Austenitic Stainless Steel

Stainless steel shall be in solution annealed heat treatment condition.

Stainless steel items shall be supplied in pickled and passivated condition as per ASTM A380 and ASTM A967. In case of bright annealing, pickling and passivation is not required.

For plates the minimum standard surface finish quality shall be pickled and passivated (equivalent to No. 1 Finish, ASTM A480M).

Intergranular corrosion testing shall be performed in accordance with ASTM A262 Method E (Strauss test) and shall be acceptable if the test is passed.

Heads to be solution annealed and quenched after forming.

Use of longitudinally welded austenitic stainless steel tubes is restricted and requires COMPANY approval.

For tubes (welded) as per A/SA-249 the minimum amount of reduction in cross-sectional area or wall thickness shall be 10 %.

14.0 Ferritic-Austenitic (Duplex) Stainless Steel

For ferritic-austenitic (duplex) stainless steel the specification, chemical composition limits, fabrication, NDE and marking of materials shall comply with the additional requirements of API TR 938-C, Annex A. Testing shall comply with ISO 17781. Destructive testing shall include impact testing and corrosion testing of 22Cr duplex and higher alloyed grades.

22 Cr Duplex and 25 Cr Super Duplex shall be supplied in solution annealed heat treatment condition.

Heads shall be solution annealed and quenched after forming.

15.0 Nickel Base Alloys

15.1 Nickel-Rich C Alloys

Alloys N06022 N06059 N10276 shall be tested for corrosion resistance in accordance with G28, Method B (Mixed Acid-Oxidating Salt Test). Acceptance criteria is micrographic absence of intergranular corrosion for all alloys and a corrosion rate for alloy N06022 of 0.51 mm/year for N06059, 2.54 mm/year and for N10276, 2.54 mm/year.

15.2 Alloy 825

Shall have minimum 39% Ni and PREN > 30.

Shall be supplied in the solution annealed condition.

Shall be supplied in pickled and passivated condition as per ASTM A380.

Shall be IGC tested as per ASTM A262 Pr. C with the acceptance criteria of 0.9 mm/yr and a micrographic absence of intergranular corrosion.

15.3 Alloy 625

Shall be supplied in solution annealed condition.

Shall be supplied in pickled and passivated condition as per ASTM A380.

Shall be IGC tested as per ASTM G28 Method A with the acceptance criteria of 0.9 mm/yr and a micrographic absence of intergranular corrosion

16.0 Thick Plate and Forgings

16.1 General

Plates and forgings **over 50mm** thick shall comply with the requirements of ASME BPVC SEC VIII Div. 2, section 3.3 and 3.6

For Low Alloy Steels with criteria as mentioned in section 17.2 or section 17.3 the additional requirements as mentioned therein shall apply.

16.2 1¼Cr–½Mo Low Alloy Steel, <= 440°C and 2¼Cr/3Cr Low Alloy Steels, >= 345°C

Hardness test shall be carried out in accordance with the requirements of section 6 of this Standard.

Plates and forgings **>= 50mm** thick shall be (both):

a. Ultrasonically examined with 100% scanning (before forming) in accordance with the following:
    - Plates shall be ordered with optional UT in accordance with ASME Section V and ASME SA-578, Level C, Supplementary Requirement S1
    - Forgings shall be examined in accordance with ASME A/SA-388 and ASME BPVC Section VIIII, Division2, paragraph 3.3.4.

b. Examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:
    - The entire surface of all forgings, after finish machining.
    - Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 50mm of neighbouring surfaces.
    - Formed plate surfaces where weld overlay will be applied.
    - Any indication is unacceptable.

16.3 1¼Cr–½Mo Low Alloy Steel, > 440°C

Plates **> 25 mm** and forgings **>= 50mm** thick shall be ultrasonically examined with 100% scanning (before forming) in accordance with the following:

- Plates shall be ordered with optional UT in accordance with ASME Section V and ASME SA-578, Level C, Supplementary Requirement S1
- Forgings shall be examined in accordance with ASME A/SA-388 and ASME BPVC Section VIIII, Division2, paragraph 3.3.4.

Plates and forgings **> 25mm** thick shall be examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:

- The entire surface of all forgings, after finish machining.
- Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 50mm of neighbouring surfaces.
- Formed plate surfaces where weld overlay will be applied.

  Any indication is unacceptable.

17.0 Hydrogen Service

Materials shall comply with API RP 941.

Additionally, plates in hydrogen service with operating temperature > 200C shall be 100% ultrasonically examined in accordance with ASTM/ASME A/SA 578, S1 with acceptance standard Level C.

18.0 Sour service / Wet H2S service

Materials for oil and gas production assets subject to H2S containing conditions, where cracking including hydrogen-induced cracking (HIC) is possible, shall follow the requirements given in ISO 15156 (all parts) (NACE MR0175).

Materials for refinery and petrochemical assets subject to wet H2S service shall comply with the applicable service category in accordance with NACE 8X194 and ISO 17945 (NACE MR0103).

18.1 Additional Requirements Carbon Steel, (CS), WET H2S SERVICE, SSC Low Severity / Cat 1

Requirements on top of the carbon steel requirements elsewhere described in this specification.

All carbon steels for pressure containing parts shall be fully killed, except air cooler and heat exchanger tubing.

Base material hardness shall be tested for maximum 200HBN

Additional requirement for plates, deliberate additions of microalloying elements is not permitted. Limits are:

- Nb(Cb) <= 0.015 wt%
- V <= 0.015 wt%
- Nb(Cb)+V <= 0.020 wt%
- Ti <= 0.020 wt%

For SA-266 forgings, supplementary requirement S4 is required: MT testing of finished forging. Any linear indication is unacceptable.

SA-179 tubes shall be subjected to a non-destructive electric test in addition to a hydrotest. Referred tests mentioned in SA-179 para 11.5.

For header box plates of air cooled heat exchangers, SA-516 grade 65 or 70 is allowed only for expanded tube to tube-sheet connections (not welded). In case of welded tube sheet joint the steel grade is limited to max Gr. 60

Welded pipe intended for plant service shall have the longitudinal seam stress relieved

Plates and forgings shall be (both):

a. Ultrasonically examined with 100% scanning in accordance with the following:
    - Plates shall be ordered with optional UT in accordance with ASTM/ASME A/SA 578, S1 with Level A acceptance standards. Level C for plates >30mm.
    - Forgings shall be examined in accordance with ASME A/SA-388 and ASME BPVC Section VIIII, Division2, paragraph 3.3.4.

b. Examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:
    - The entire surface of all forgings, after finish machining. Forgings shall be examined in accordance with ASME Section VIIII, Division2, paragraph 7.5.7.
    - Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 50mm of neighbouring surfaces.
    - Formed plate surfaces where weld overlay will be applied.
    - Any indication is unacceptable.

18.2 Additional Requirements Carbon Steel, (CS), WET H2S SERVICE, SSC Moderate Severity / Cat 2

Requirements on top of the carbon steel requirements elsewhere described in this specification.

Carbon content shall be <= 0.18wt%. Carbon Equivalent shall be CEIIW ≤ 0.43 wt%, irrespective of the thickness.

All carbon steels for pressure containing parts shall be fully killed, except air cooler and heat exchanger tubing.

Steels shall be Normalized, Quenched and Tempered or Normalized and Tempered.

Base material hardness shall be tested for maximum 200HBN

Additional requirement for plates, deliberate additions of microalloying elements is not permitted. Limits are:

- Nb(Cb) <= 0.015 wt%
- V <= 0.015 wt%
- Nb(Cb)+V <= 0.020 wt%
- Ti <= 0.020 wt%
- P <= 0.007 wt%
- S <= 0.002 wt%

Plates shall be vacuum degassed

For SA-266 forgings, supplementary requirement S4 is required: MT testing of finished forging. Any linear indication is unacceptable.

SA-179 tubes shall be subjected to a non-destructive electric test in addition to a hydrotest. Referred tests mentioned in SA-179 para 11.5.

For header box plates of air cooled heat exchangers, SA-516 grade 65 or 70 is allowed only for expanded tube to tube-sheet connections (not welded). In case of welded tube sheet joint the steel grade is limited to max Gr. 60

Welded pipe intended for plant service shall have the longitudinal seam stress relieved

Plates and forgings shall be (both):

a. Ultrasonically examined with 100% scanning in accordance with the following:
    - Plates shall be ordered with optional UT in accordance with ASTM/ASME A/SA 578, S1 with Level C acceptance standards.
    - Forgings shall be examined in accordance with ASME A/SA-388 and ASME BPVC Section VIIII, Division2, paragraph 3.3.4.

b. Examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:
    - The entire surface of all forgings, after finish machining. Forgings shall be examined in accordance with ASME Section VIIII, Division2, paragraph 7.5.7.
    - Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 50mm of neighbouring surfaces.
    - Formed plate surfaces where weld overlay will be applied.
    - Any indication is unacceptable.

18.3 Additional Requirements Carbon Steel, (CS), WET H2S SERVICE, SSC High Severity, HIC Service / Cat 3

Requirements on top of the carbon steel requirements elsewhere described in this specification.

Carbon content shall be <= 0.18wt%. Carbon Equivalent shall be CEIIW ≤ 0.43 wt%, irrespective of the thickness.

All carbon steels for pressure containing parts shall be fully killed, except air cooler and heat exchanger tubing.

Plates and forgings shall be vacuum degassed. Calcium treating (for inclusion shape control) is recommended.

All carbon steels for pressure containing parts shall be fully killed steels made to fine grain practice e.g. SA516

Base material hardness shall be tested for maximum 200HBN

Steels shall be Normalized or Normalized and Tempered. The normalizing heat treatment shall be carried out as a separate heat treatment at 900º±25ºC

Additional requirement for plates:

Deliberate additions of microalloying elements is not permitted. Limits are:

- Nb(Cb) <= 0.010 wt%
- V <= 0.008 wt%

- Nb(Cb)+V <= 0.015 wt%
- Ti <= 0.020 wt%
- B <=0.0005 wt%
- P <= 0.007 wt%
- S <= 0.002 wt% (<= 0.01 for SMLS pipe and <= 0.025 for forgings)

- The steel shall be made by electric arc furnace or in the basic oxygen furnace process.
- The steel shall be made by vacuum degassing process and produced to a fine grain practice, with low sulphur and phosphorus process. Grain size shall be 7 or finer as defined by ASTM E112.
- The oxygen content of the steel to be < 0.0025%.
- Sulphur content up to 0.007% may be allowed if the steel is inclusion shape control treated by Calcium addition. This option should be left at steel manufacturer's option. Alternative methods of inclusion shape control shall be subject to the acceptance by Contractor Engineering Department.

Calcium treatment, if any shall be at a Ca/S ratio >1.2 and shall not exceed 3 times the sulphur content.

- HIC test for plates and pipe and fittings from plate, each heat and thickness is to be tested as per NACE TM0284 requirements, using the low pH Solution A. Acceptance criteria are:
  - CLR ≤ 5.0% (Crack Length Ratio)
  - CTR ≤ 1.5% (Crack Thickness Ratio)
  - CSR ≤ 0.5% (Crack Sensitivity Ratio)
    The criteria should be based on average values for each bar with single values reported for information only.
  - Should any of initial test coupons failed to meet the acceptance criteria, the tested pipe shall be rejected. Two retest coupons shall be taken from another pipe with the same wall thickness and from the same heat. If both the coupons pass the test, then rest of the pipes with the same wall thickness and from the same heat will be accepted.
  - If any of these two coupons fails, then one test coupon from another pipe with the same wall thickness and from the same heat shall be tested with the following acceptance conditions:
    a) If this coupon passes the test, the rest of the pipes (including the pipe which two test coupons were taken from) with the same wall thickness and from the same heat shall be accepted.
    b) b) If this coupon fails in the test, then all pipes with the same wall thickness and from the same heat shall be rejected.
  - For any test coupon failures, the material manufacturer shall investigate the cause of failure and submit a report (including the cause of failure) to Contractor Engineering Department for review and comment. This report shall include the proposed means by material manufacturer to prevent the similar failure for other heats.

  HIC Report shall include the following information: -
  - Full chemical analysis and mechanical property results of material tested.
  - Results of cracking evaluation indicating individual and average CLR, CTR and CSR for each section.

- Photomicrographs of the specimens showing cracking, together with following photomicrographs of adjacent material structures:
    a) Unetched, showing the type of inclusions in the steel (magnification 200X)
    b) Etched, showing the parent material microstructure (magnification 200X)
- pH of H2S saturated solution at the beginning and at the end of the test and type of solution.
- Photographs of specimens showing blister
- Location and dimensions of specimens

The Manufacturer shall submit the following information in their quotation and provide:

- Steel making route, deoxidisation and desulphurisation practice, inclusion shape control method, and use of vacuum degassing.
- Casting route, ingot or continuous casting, segregation controls procedures, rolling reduction.
- Methods, standards for preventing Centre Line Segregation.
- HIC test results on previous similar material. The Mill test report shall include the value for the Crack Length Ratio (CLR), Crack Sensitivity Ratio (CSR) and Crack Thickness Ratio (CTR) as defined in NACE standard TM0284.
- Heat treatment

For SA-266 forgings, supplementary requirement S4 is required: MT testing of finished forging. Any linear indication is unacceptable.

SA-179 tubes shall be subjected to a non-destructive electric test in addition to a hydrotest. Referred tests mentioned in SA-179 para 11.5.

For header box plates of air cooled heat exchangers, SA-516 grade 65 or 70 is allowed only for expanded tube to tube-sheet connections (not welded). In case of welded tube sheet joint the steel grade is limited to max Gr. 60

Welded pipe intended for plant service shall have the longitudinal seam stress relieved

Plates and forgings shall be (both):

a. Ultrasonically examined with 100% scanning in accordance with the following:
    - Plates shall be ordered with optional UT in accordance with ASTM/ASME A/SA 578, S1 with Level C acceptance standards.
    - Forgings shall be examined in accordance with ASME A/SA-388 and ASME BPVC Section VIIII, Division2, paragraph 3.3.4.

b. Examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:
    - The entire surface of all forgings, after finish machining. Forgings shall be examined in accordance with ASME Section VIIII, Division2, paragraph 7.5.7.
    - Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 50mm of neighbouring surfaces.
    - Formed plate surfaces where weld overlay will be applied.
    - Any indication is unacceptable.

Roles and Responsibilities

The Project CoE Lead Engineering have the responsibility to approve this document.

The Project CoE Mechanical Team Lead will be responsible to ensure this document is updated and rolled-out.

The Project CoE Mechanical Technical Authority will be responsible to sign any deviation to this specification.

Appendix 1 - USER FEEDBACK PAGE

Document title Document number and the revision					
	User to use this Feedback Form to identify any inaccuracy, error or ambiguity to notify the Document Authority so that appropriate action can be taken. The user is requested to return this page fully completed, indicating precisely the proposed improvement and justification.				
Name:		**Email:**		**Date:**	
Page Ref:	**Observation**	**Proposed Improvement & Justification**			

DOCUMENT INFORMATION

Title	Metallic Materials Specification
Document Code	03.01.158-Metallic_Materials-Specification
Purpose	To define the minimum technical requirements of Metallic Materials for any OQ Project.
Audience	Project team, Contractors and Vendors
Category	Governance;
Subcategory	Projects/ CoE
Effective Date	15/03/2022
Review Date	14/03/2024
Document Advisor	Projects COE Mechanical Team Lead
Approving Authority	Projects COE Leader

RELATED AND SUPPORTING DOCUMENTS

Policy	N/A
Policy Manual	N/A
Process	N/A
Procedures	N/A
Related Documents and Forms	03.01.124-Mechanical_ Basis_of_Design-Specification

DOCUMENT APPROVALS		
Authorized Approver	**Date**	**Signature(s)**
VP, Project CoE	29/03/2022