



Materials System Specification

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Stainless Steel and Nickel Alloy Tubes

Document Responsibility: Materials and Corrosion Control Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This Specification covers seamless and welded tubes manufactured by an automatic welding process without addition of filler metal. This specification is applicable to Austenitic, Ferritic, Ferritic/Austenitic (Duplex) Stainless Steel and Nickel alloys (UNS N08800, N08825 and N06625 only) tubes for heat exchangers, heaters, air coolers and boilers in accordance with applicable ASTM standards. The requirements stated in this specification are supplementary to the applicable ASTM standard.

2 Conflicts and Deviations

- 2.1 Any conflicts between this specification and other applicable Saudi Aramco Materials System Specifications (SAMSSs), Engineering Standards (SAESs), or industry standards, codes, and forms shall be resolved in writing by the Company or Purchaser Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this specification in writing to the Company or Purchaser Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The manufacture and purchase of material covered by this specification shall comply with the latest edition (as per the purchase order date) of the references listed below, as noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

[SAEP-302](#)

Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement

Form [175-014301](#)

Stainless Steel and Nickel Alloy Tubes

3.2 Industry Codes and Standards

American Society for Nondestructive Testing

[ASNT SNT-TC-1A](#)

Recommended Practice for Personnel Qualification and Certification

[ASNT CP-189](#)

Standard for Qualification and Certification of Nondestructive Testing Personnel

American Society for Testing and Materials

<u>ASTM G28</u>	<i>Standard Test Methods for Determining Susceptibility to Intergranular Corrosion In Wrought, Nickel-Rich, Chromium Bearing Alloys</i>
<u>ASTM A213</u>	<i>Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes</i>
<u>ASTM A249</u>	<i>Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes</i>
<u>ASTM A262</u>	<i>Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels</i>
<u>ASTM A268</u>	<i>Standard Practices for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service</i>
<u>ASTM A269</u>	<i>Standard Specification for Welded Austenitic Stainless Steel Tubing for General Service</i>
<u>ASTM A380</u>	<i>Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems</i>
<u>ASTM A688</u>	<i>Standard Specification for Welded Stainless Steel Feedwater Heater Tubes</i>
<u>ASTM A763</u>	<i>Standard Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels</i>
<u>ASTM A789</u>	<i>Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service</i>
<u>ASTM A803</u>	<i>Standard Practices for Welded Ferritic Stainless Steel Feedwater Heater Tubes</i>
<u>ASTM A923</u>	<i>Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels</i>
<u>ASTM A1016</u>	<i>Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes</i>
<u>ASTM B163</u>	<i>Standard Specification for Seamless Nickel and</i>

	<i>Nickel Alloy Condenser and Heat-Exchanger Tubes</i>
<u>ASTM B444</u>	<i>Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625 and UNS N06219) Pipe and Tube</i>
<u>ASTM B515</u>	<i>Standard Specification for Welded UNS N08120, UNS N08800, UNS N08810, and UNS N 08811 Alloy Tubes</i>
<u>ASTM B704</u>	<i>Standard Specification for Welded UNS N06625, UNS N06219 and UNS N08825 Alloy Tubes</i>
<u>ASTM B751</u>	<i>Standard Specification for General Requirements for Nickel and Nickel Alloy Welded Tube</i>
<u>ASTM B829</u>	<i>Standard Practice for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube</i>
<u>ASTM E165</u>	<i>Practice for Liquid Penetrant Examination for General Industry</i>
<u>ASTM E213</u>	<i>Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing</i>
<u>ASTM E309</u>	<i>Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation</i>
<u>ASTM E426</u>	<i>Standard Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys</i>
<u>ASTM E562</u>	<i>Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count</i>
<u>ASTM E571</u>	<i>Standard Practice for Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products</i>
<u>ASTM G48</u>	<i>Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution</i>

International Standardization Organization

[NACE MR 0175/ISO 15156](#) *Petroleum and Natural Gas Industries-
Materials for use in H₂S-containing*

Environments in Oil and Gas Production

American Society of Mechanical Engineers

[ASME SEC VIII D1](#)*Rules for Construction of Pressure Vessels*

NACE International

[NACE MR0103](#)*Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

European Standard

[EN 473](#)*Non-Destructive Testing - Qualification and Certification of NDT Personnel - General Principles***4 Definitions**

Lot: For the purpose of corrosion tests and micrographic examination, the term “lot” applies to all tubes, prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at temperature, and furnace speed. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heats which are heat treated in the same furnace charge. The size of the lot shall not exceed the tonnage restriction, if any, specified in applicable ASTM (e.g., ASTM B829).

5 Information to be Supplied by the Purchaser

- 5.1 If the tubes are intended for sour service, [NACE MR 0175/ISO 15156](#) must be specified in the purchase order.
- 5.2 Tubes against ASTM B704 and B444 UNS N06625 shall be Grade 2 unless stated otherwise in the purchase order.

6 Manufacture

- 6.1 Gas tungsten arc welding, plasma arc welding and laser welding are acceptable welding processes.
 - 6.2 High frequency welding (HFI or ERW) is not an acceptable welding process.
 - 6.3 All welded tubes shall be subjected to bead rolling. Polishing is not an acceptable alternative to bead rolling. OD reduction without reduction in wall thickness as an alternative to bead rolling is not acceptable.
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- 6.4 For all welded tubes, effectiveness of purging shall be checked periodically by splitting the tube sample and inspecting the ID surface of the weld visually. The frequency of inspection shall be not be less than four times in an 8 hour shift.
- 6.5 Welding qualification requirements (Procedure Qualification Record and Welding Procedure Specification) for Duplex Stainless Steels shall be as specified in [NACE MR0103](#) shall apply for UNS S31803, S32205 and S32750.
- 6.6 Repairs on tubes by welding or grinding are not permitted. Surface polishing to remove superficial surface imperfections without breaching the minimum thickness required is acceptable.
- 6.7 The finished tube shall not include welds used for joining together lengths of the hot rolled or cold rolled strip prior to forming.
- 6.8 Hot extruded mother pipe must be used for manufacture of seamless tubes. It is not acceptable to use hot pierced mother pipes.

7 Heat Treatment

- 7.1 All tubes shall be supplied in solution annealed condition except as stated in 7.3 below.
- 7.2 Tubes manufactured to [ASTM A789](#) shall be rapidly cooled by water quenching, or air or inert gas cooling to below 315°C immediately after annealing.
- 7.3 All stainless steel stabilized grades shall be given a stabilization heat treatment subsequent to solution annealing. Stabilization heat treatment shall be carried out at 900±15°C for a minimum period of 2 hours. If stabilization heat treatment is being carried out in a continuous furnace, a lower soaking time can be considered for tubes with wall thickness less than 3.2 mm.
- 7.4 Batch-type furnaces shall be equipped with recording pyrometers and automatically controlled within a 10°C or lesser range.

8 Chemical Composition

- 8.1 Product analysis shall be reported in the mill test certificate.
 - 8.2 UNS S31803 tubes dual certified as S31803/S32205 are acceptable. Dual certified 304/304L and 316/316L tubes are acceptable if the design temperature is less than 538°C. Dual certification for all other grades (e.g., 304/304H or 316/316H) is not acceptable.
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- 8.3 All non 'L' austenitic stainless steel grades (e.g., 304, 316) shall have a minimum carbon content of 0.04% if the design temperature is more than 538°C.
- 8.4 Pitting Resistance Equivalent (PRE) (%Cr+3.3%Mo+16%N) for the base material for the grades listed below must be greater than or equal to that shown in Table 1 below.

Table 1

Grade	PRE
316/316L	25.5
317/317L	29
N08904	34
S31254 ⁽¹⁾ N08367 N08926	42
S31803	35
S32205	35
S32750	42
N08825	32
N06625	45

(1) UNS N08367 and N08926 are acceptable substitutes to UNS S31254. It is acceptable to offer UNS N08367 or N08926 in lieu of UNS S31254.

- 8.5 Restrictions on minimum molybdenum and nitrogen content in the base metal shall be as stated in Table 2 below.

Table 2

Grade	%Mo	%N
316/316L	2.5	-
317/317L	3.5	-
N08904	4.2	-
S31803	-	0.15

9 Mechanical Tests

- 9.1 Hardness testing shall be carried out on all grades for each lot. The mechanical testing lot definition as stated in applicable ASTM standard shall apply.
- 9.2 A minimum of three indentations shall be taken on the inside and outside surface.

- 9.3 Acceptance criteria shall be as specified in the Table 3 below or applicable ASTM standard, whichever is more restrictive.

Table 3

UNS No.	Hardness (maximum)
S31803	28 HRC
S32205	28 HRC
S32750	32 HRC
S31254	31 HRC
N08800	28 HRC
N08825	25 HRC
N06625	35 HRC

- 9.4 Acceptance criteria for all other grades not specified in the Table 3 above shall be as per the applicable ASTM standard. In no case shall the hardness exceed 22 HRC.

10 Corrosion Tests

- 10.1 All austenitic stainless steel grades except those specified in Table 4 shall be subjected to intergranular corrosion test as per [ASTM A262](#) Practice E. Requirement for sensitization of samples shall be as specified in [ASTM A262](#) except that sensitization heat treatment is not required for grades having more than 3% Mo.
- 10.2 Intergranular Corrosion test specified in paragraph 10.1 is not required for heats having less than 0.020% carbon as shown in product analysis.
- 10.3 All ferritic stainless steel grades shall be subjected to intergranular corrosion test as per [ASTM A763](#) Practice Z.
- 10.4 Following grades shall be subjected to corrosion test as specified in Table 4 below.

Table 4

Steel Grade	Corrosion Test	Test Conditions	Acceptance Criteria
UNS N08904 (904L)	ASTM G48 Method A	Test temperature: 25°C Test duration : 24 hours	No pitting at 20X magnification. Weight loss shall be less

Steel Grade	Corrosion Test	Test Conditions	Acceptance Criteria
			than 4.0 g/m ² .
UNS S31254 UNS N08367 UNS N08926	ASTM G48 Method A	Test temperature: 50°C Test duration : 48 hours	No pitting at 20X magnification Weight loss shall be less than 4.0 g/m ² .
UNS S31803	ASTM A923 Test Method C	As per ASTM A923	As per ASTM A923
UNS S32205	ASTM A923 Test Method C	As per ASTM A923	As per ASTM A923
UNS S32750	ASTM A923 Test Method C	As per ASTM A923	As per ASTM A923
UNS N08800	ASTM G28 Test Method A	As per ASTM G28	48 mills/year maximum
UNS N08825	ASTM G48 Method A	Test temperature: 22°C Test duration : 72 hours	No pitting at 20X magnification Weight loss shall be less than 4.0 g/m ² .
UNS N06625	ASTM G48 Method A	Test temperature: 50°C Test duration : 72 hours	No pitting at 20X magnification Weight loss shall be less than 4.0 g/m ² .

Notes:

- a. The internal and external surfaces of the specimens shall be in the as delivered condition (pickling or bright annealed) unless stated otherwise in the applicable standard.
- b. Cut edges shall be prepared according to [ASTM G48](#), and the whole specimen shall be pickled if the tubes are to be delivered after pickling.
- c. For welded tubes the sample for corrosion test shall include the weld at the centre of the sample.
- d. Rapid screening test ([ASTM A923](#) Test Method A) shall not be used as an acceptance test.

10.5 The applicable corrosion test shall be conducted on each lot. The definition of lot shall be as stated in paragraph 4 of this specification.

11 Metallographic Examination

11.1 Ferrite content for UNS S31803, S32205 and UNS S32750, as determined in accordance with [ASTM E562](#), shall be between 35 to 65%. Examination for welded tubes must include the weldmetal and the heat affected zone in addition to the base metal for each lot as defined in paragraph 4 of this specification.

- 11.2 The microstructure for UNS N08904, S31254, N08367, N08926, S31803, S32205 and S32750 shall be examined at a minimum magnification of 400X on a suitably etched specimen after the final heat treatment. The microstructure amount of detrimental precipitates and intermetallic phases shall be less than 0.05%. This examination shall be carried out for each lot as defined in paragraph 4 of this specification.

12 Additional Requirements for U-Tubes

- 12.1 U-bends including 300 mm (150 mm for radius greater than 1000 mm) of straight portion measured from the tangent line shall be solution annealed at the temperature and time range as specified in the product specification. This requirement does not apply to duplex and super duplex stainless steel tubes.
- 12.2 Heat treatment shall be carried out using resistance heating. The bends must be subjected to force cooling to prevent sensitization.
- 12.3 Temperature control shall be accomplished through use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.
- 12.4 The location where the electrodes are clamped shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.
- 12.5 Tubes must be purged with a protective or inert gas during the process of heat treatment during heating and cooling to below 370°C.
- 12.6 Mock ups must be made for austenitic stainless steels for three innermost tubes and tested for [ASTM A262](#) Practice A ([ASTM A763](#) Practice W for ferritic stainless steel) at the transition zone. The heat treated portion of the tubes must also be cut open to visually inspect for oxidation in the ID surface.
- 12.7 Hardness test shall be carried out in the bent portion of the innermost mock up tube as per Section 9.
- 12.8 Visual inspection of the bent portion must be carried out to ensure that the outside surface is free from waviness.
- 12.9 Bend portion must be checked with dye penetrant testing to ensure that there are no cracks. Test shall be carried out in accordance to ASTM E165 method A and acceptance criteria shall be as per ASME SEC VIII D1 Appendix 8.
- 12.10 ID cleanliness shall be checked by cotton ball or felt plug test. A light gray color is considered acceptable.
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- 12.11 Dimensional tolerances for the diameter and wall thickness shall be as specified in [ASTM A688](#).

13 Non-Destructive Testing

- 13.1 Each tube shall be subjected to non destructive electric test.
- 13.2 All NDT operators shall be qualified to [ASNT SNT-TC-1A](#), [ASNT CP-189](#) or EN473 level II or equivalent.
- 13.3 Eddy current testing shall be carried out as per [ASTM E426](#) ([ASTM E309](#) for ferromagnetic materials)/[E571](#), as applicable, with the acceptance criteria referenced in [ASTM A1016/B829/B751](#), as applicable.
- 13.4 As an alternative to eddy current testing, ultrasonic examination can be carried out in accordance with [ASTM E213](#). The acceptance criteria referenced in [ASTM A1016/B751/B829](#), as applicable, shall apply.
- 13.5 The ends of the tube that cannot be inspected by above test methods shall be removed and discarded. This requirement does not apply if a second non-destructive examination (NDE) is done after cutting, assuming full coverage during the first NDE.
- 13.6 All seamless and welded tubes shall be subjected to Air Underwater Pressure Test as per [ASTM A1016/B751](#), as applicable. In case of U-tubes, testing shall be carried out after bending and heat treatment, if applicable. Alternatively, seamless tubes can be hydrotested in accordance to [ASTM A1016/B751](#), Chloride content of water shall not exceed 50 ppm. The tubes should be cleaned and dried after the test.

14 Pickling and Passivation

- 14.1 All tubes that are not bright annealed must be subjected to pickling and passivation in accordance with ASTM A380. Pickling of U-tubes shall be carried out after bending and heat treatment, if applicable.
- 14.2 Passivation is mandatory for all tubes including bright annealed tubes. Passivation can be waived for bright annealed tubes if the mill does not have the facility for passivation and provided the ID of the tubes are cleaned by passing a clean dry cotton or felt plug using clean, dry, oil free compressed air.

15 Inspection

Tubes purchased in accordance with this specification are subject to the requirements of Saudi Aramco Inspection Form [175-014301](#).

16 Marking

- 16.1 The marking shall ensure full traceability to melt and heat treatment lot.
- 16.2 Marking materials shall be suitable for stainless steels and contain less than 200 ppm halogens and 200 ppm sulfur. When requested, composition certificates of marking materials shall be provided.

17 Positive Material Identification (PMI)

- 17.1 PMI shall be conducted randomly on finished tubes on each lot before dispatch. A minimum of 5% of tubes in each heat must be tested. Internal company procedure can be followed for conducting PMI.

Commentary:

The intent of PMI is to ensure that there is no mix up of material. Quantitative determination to ascertain that the material is meeting the entire chemistry of the applicable ASTM standard is not the intent of PMI.

- 17.2 Saudi Aramco representative may select the tubes for testing.

18 Handling, Packing and Transportation

- 18.1 Stainless steel and nickel alloy tubes shall not be manufactured in the same shop or facility where carbon steel products are being produced.
- 18.2 Iron contamination after heat treatment and pickling/passivation shall be prevented. On suspicion of iron contamination, Saudi Aramco representative can request for Ferroxyl Test for Free Iron as per [ASTM A380](#).
- 18.3 Tube ends shall be protected by end caps.
- 18.4 Tube bundles shall be wrapped in plastic and packed in fully covered wooden boxes. Alternative packing can be accepted upon approval by Saudi Aramco Standards Chairman.

19 Certification

- 19.1 The tube manufacturer shall furnish the mill test certificate as per [ASTM A1016/B751/B829](#), as applicable. All test results shall be reported in the mill test certificate.
 - 19.2 Solution annealing temperature, soaking time and cooling media shall be reported in the mill test certificate. In case of stabilized grades, the above details for stabilization heat treatment shall also be reported.
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- 19.3 Corrosion tests, including weight loss (where applicable) shall be reported in the mill test certificate.
- 19.4 Micrographs as referenced on paragraphs 11.1 and 11.2 shall be included in the mill test certificate.
- 19.5 It shall be certified that the radioactivity level of the pipes is less than 0.5 μ Sv/hour (on the surface) or 100 beckerels/gram. Certification can be based on measurements conducted by the steel manufacturer and as reported in the mill test certificates of the raw material.

Revision Summary

13 December 2011 Major revision after value engineering session.