

# ASTM - A688/A688M

## Standard Specification for

### Seamless and Welded Austenitic Stainless Steel Feedwater Heater Tubes

This specification covers seamless and welded austenitic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feed-water heaters.

The tubing sizes covered shall be 5/8 to 1 in. [15.9 to 25.4 mm] inclusive outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

#### A. Materials and Manufacture :-

1. The tube shall be manufactured by either the seamless or welded and cold worked process.

#### B. Heat Treatment :-

1. All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition.
2. The annealing procedure, except for N08367, S31254, S32654, N08810, N08811, and N08926, shall consist of heating the material to a minimum temperature of 1900 °F [1040 °C] followed by a rapid cooling to below 700 °F [370 °C].
3. UNS N08367 shall be solution annealed at 2025 °F [1107 °C] minimum followed by rapid quenching.
4. N08926 shall be heat-treated at a minimum temperature of 2010 °F [1100 °C] followed by quenching in water or rapidly cooling by other means.
5. S31254, S32654, and N08811 shall be solution annealed at 2100 °F [1150 °C] minimum followed by rapid quenching.
6. N08810 shall be heat-treated to a minimum temperature of 2050 °F [1120 °C] minimum followed by rapid quenching.

#### C. Chemical Composition :-

The chemical composition shall conform to the requirements shown in Table 1.

**Table 1**

Grade	UNS Designation <sup>A</sup>	C, max	Mn, max <sup>B</sup>	P, max	S, max	Si, max	Ni	Cr	Mo	N <sup>C</sup>	Cu	Ti	Al	Others
TP 304	S30400	0.08	2	0.04	0.03	0.75	8.0–11	18–20	...	...	...	...	...	...
TP 304L	S30403	0.035	2	0.04	0.03	0.75	8.0–13	18–20	...	...	...	...	...	...
TP 304LN	S30453	0.035	2	0.04	0.03	0.75	8.0–13	18–20	...	0.10–0.16	...	...	...	...
TP 316	S31600	0.08	2	0.04	0.03	0.75	10–14	16–18	2–3	...	...	...	...	...

TP 316L	S31603	0.035	2	0.04	0.03	0.75	10–15	16–18	2–3	...	...	...	...	...
TP 316LN	S31653	0.035	2	0.04	0.03	0.75	10–15	16–18	2–3	0.10–0.16	...	...	...	...
TP XM29	S24000	0.06	11.5–14.5	0.06	0.03	1	2.25–3.75	17–19	...	0.2–0.4	...	...	...	...
TP 304N	S30451	0.08	2	0.04	0.03	0.75	8.0–11	18–20	...	0.10–0.16	...	...	...	...
TP 316N	S31651	0.08	2	0.04	0.03	0.75	10–14	16–18	2–3	0.10–0.16	...	...	...	...
...	N08367	0.03	2	0.04	0.03	1	23.50–25.5	20–22	6–7	0.18–0.25	0.75 max	...	...	...
800	N08800	0.1	1.5	0.045	0.015	1	30.0–35	19–23	...	...	0.75	0.15–0.6	0.15–0.6	Fe 39.5 min. <sup>E</sup>
800H	N08810	0.05–0.1	1.5	0.045	0.015	1	30.0–35	19–23	...	...	0.75	0.15–0.6	0.15–0.6	Fe 39.5 min. <sup>E</sup>
...	N08811	0.06–0.1	1.5	0.045	0.015	1	30.0–35	19–23	...	...	0.75	0.25–0.60 <sup>D</sup>	0.25–0.60 <sup>D</sup>	Fe 39.5 min. <sup>E</sup>
...	N08926	0.02	2	0.03	0.01	0.5	24.00–26	19–21	6–7	0.15–0.25	0.5–1.5	...	...	...
...	S31254	0.02	1	0.03	0.01	0.8	17.5–18.5	19.5–20.5	6-6.5	0.18–0.22	0.5–1.0	...	...	...
...	S32654	0.02	2.0–4.0	0.03	0.005	0.5	21–23	24–25	7–8	0.45–0.55	0.3–0.6	...	...	...

<sup>A</sup> New designation established in accordance with Practice E527 and SAE J1086.

<sup>B</sup> Maximum, unless otherwise noted.

<sup>C</sup> The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

<sup>D</sup> (Al + Ti) = 0.85 – 1.20.

<sup>E</sup> Fe shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

#### D. Mechanical Requirements :- 1. Tensile Properties:

i. The material shall conform to the tensile properties shown in Table 2.

#### 2. Hardness:

i. Grade TP XM-29 and N08367 tubes shall have a hardness number not exceeding 100 HRB or its equivalent.

ii. Tubes of all other grades shall have a hardness number not exceeding 90 HRB or its equivalent.

iii. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

#### 3. Reverse Bend Test (Welded Product).

#### 4. Flattening Test (Seamless and Welded Products).

#### 5. Flange Test (Welded Product).

6. Flaring Test (Seamless Product).
7. Pressure Test:
  - i. Hydrostatic Test— Each tube shall be given an internal hydrostatic test in accordance with Specification A1016/A1016M, except that the test pressure and hold time, when other than that stated in Specification A1016/A1016M, shall be agreed upon between purchaser and manufacturer.
  - ii. Pneumatic Test— Each tube shall be examined by a pneumatic test (either air underwater or pneumatic leak test) in accordance with Specification A1016/A1016M.

**E. Grain Size :-**

1. The grain size of grades N08810 and N08811, as determined in accordance with Test Methods E1 12, shall be No. 5 or coarser.

**F. Non-destructive Test (Electric Test) :-**

1. Each straight tube shall be tested after the finish heat treatment by passing it through a non-destructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A1016/A1016M.

**Table 2**

Grade	UNS Designation	Tensile strength, min ksi [MPa]	Yield strength, min ksi [MPa]	Elongation in 2 in. or 50 mm, min, %
304, 316	S30400, S31600	75 [515]	30 [205]	35
304L, 316L	S30403, S31603	70 [485]	25 [175]	35
XM-29	S24000	100 [690]	55 [380]	35
304N, 316N	S30451, S31651	80 [550]	35 [240]	35
304LN, 316LN	S30453, S31653	75 [515]	30 [205]	35
...	N08367 t ≤ 0.187	100 [690]	45 [310]	30
...	N08367 t > 0.187	95 [655]	45 [310]	30
800	N08800	75 [520]	30 [205]	30
800H	N08810	65 [450]	25 [170]	30
...	N08811	65 [450]	25 [170]	30
...	N08926	94 [650]	43 [295]	35
...	S31254 t ≤ 0.187	100 [690]	45 [310]	35

...	S31254 t > 0.187	95 [655]	45 [310]	35
...	S32654	120 [825]	65 [450]	40

**G. Permissible Variations in Dimensions (Fig. 1):-**

1. Permissible variations from the specified outside diameter shall be in accordance with Specification A1016/A1016M. At the bent portion of a U-tube for  $R = 2 \times D$  or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %. If less than  $2 \times D$  is specified, tolerances could be greater.
2. Permissible Variations from the Specified Wall Thickness:
  - i. Permissible variations from the specified minimum wall thickness shall not exceed +20 %, - 0.
  - ii. Permissible variations from the specified average wall thickness are 610 % of the nominal wall thickness.
  - iii. The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:  $t_f = (4RT) / (4R+D)$   
where:  $t_f$  = wall thickness after bending, in. [mm],  
 $T$  = minimum wall thickness of G.2.i or G.2.ii, in. [mm],  
 $R$  = center line bend radius, in. [mm], and  
 $D$  = nominal outside tube diameter, in. [mm].
3. Permissible Variations from the Specified Length:
  - i. Straight Lengths—The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +1/8 in. [3 mm], -0; for lengths longer than 24 ft [7.3 mm], an additional over tolerance of +1/8 in. [3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +1/2 in. [13 mm].
  - ii. U-Bends—In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 3.
4. The end of any tube may depart from square by not more than the amount given in Table 4.

**Table 3: Tube Leg Length Tolerance**

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]

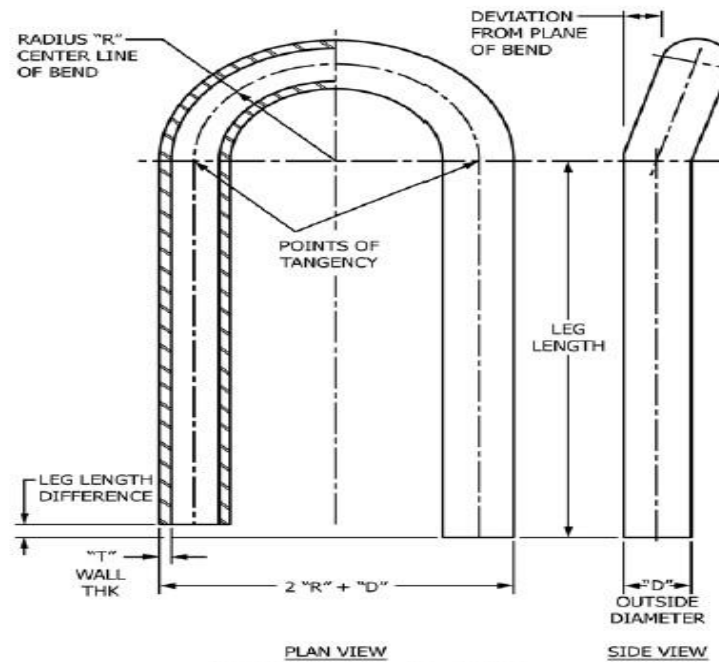
Over 30 to 40 [9 to 12.2], incl	3/16 [4.8]
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**Table: 4 Squareness of Ends Tolerance**

Tube OD, in. [mm]	Tolerance, in. [mm]
5/8 [15.9], incl	0.010 [0.25]
Over 5/8 to 1 in. [15.9 to 25.4], incl	0.016 [0.4]

**H. Supplementary Test :-**

1. Non-destructive Eddy-Current Test.
2. Intergranular Corrosion Tests.



**FIG. 1 Plane Bend for U-Tube**

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