Designation: A 608/A 608M – 06

Standard Specification for Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures[1]

This standard is issued under the fixed designation A 608/A 608M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers iron-chromium-nickel, high-alloy tubes made by the centrifugal casting process intended for use under pressure at high temperatures.

1.2 The grades of high alloys detailed in Table 1 are intended for applications requiring strength and resistance to corrosion and scaling at high temperatures.

1.3 Optional Supplementary Requirements S1 to S11 are provided; these call for additional tests to be made if desired.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 342/A 342M Test Methods for Permeability of Feebly Magnetic Materials

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 8 Test Methods for Tension Testing of Metallic Materials

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E 94 Guide for Radiographic Examination

E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

E 142 Method for Controlling Quality of Radiographic Testing[3]

E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[3]

E 165 Test Method for Liquid Penetrant Examination

E 340 Test Method for Macroetching Metals and Alloys

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (centrifugally cast tubing),

3.1.3 Specification number and grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness, see Section 8).

3.1.5 Condition (see Section 9, as cast or as cast with machining on outside or inside surfaces, or machined; see 5.1, 8, and 9),

3.1.6 Length (specific or random), (Permissible Variations in Length Section of Specification A 999/A 999M),

3.1.7 End finish (Ends Section of Specification A 999/A 999M),

3.1.8 Optional requirements (see 8.2.3 regarding the manufacturer's wall thickness allowance for as cast tubing and Supplementary Requirements S1 to S11),

3.1.9 Test report required (see Section 13), and

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Chemical Requirements

Grade	Composition, %							
	Carbon	Manganese	Silicon	Chromium	Nickel	Phosphorus	Sulfur	Molybdenum
HC30	0.25–0.35	0.5–1.0	0.50–2.00	26–30	4.0 max	0.04 max	0.04 max	0.50 max
HD50	0.45–0.55	1.50 max	0.50–2.00	26–30	4–7	0.04 max	0.04 max	0.50 max
HE35	0.30–0.40	1.50 max	0.50–2.00	26–30	8–11	0.04 max	0.04 max	0.50 max
HF30	0.25–0.35	1.50 max	0.50–2.00	19–23	9–12	0.04 max	0.04 max	0.50 max
HH30	0.25–0.35	1.50 max	0.50–2.00	24–28	11–14	0.04 max	0.04 max	0.50 max
HH33[A]	0.28–0.38	1.50 max	0.50–2.00	24–26	12–14	0.04 max	0.04 max	0.50 max
HI35	0.30–0.40	1.50 max	0.50–2.00	26–30	14–18	0.04 max	0.04 max	0.50 max
HK30	0.25–0.35	1.50 max	0.50–2.00	23–27	19–22	0.04 max	0.04 max	0.50 max
HK40	0.35–0.45	1.50 max	0.50–2.00	23–27	19–22	0.04 max	0.04 max	0.50 max
HL30	0.25–0.35	1.50 max	0.50–2.00	28–32	18–22	0.04 max	0.04 max	0.50 max
HL40	0.35–0.45	1.50 max	0.50–2.00	28–32	18–22	0.04 max	0.04 max	0.50 max
HN40	0.35–0.45	1.50 max	0.50–2.00	19–23	23–27	0.04 max	0.04 max	0.50 max
HT50	0.40–0.60	1.50 max	0.50–2.00	15–19	33–37	0.04 max	0.04 max	0.50 max
HU50	0.40–0.60	1.50 max	0.50–2.00	17–21	37–41	0.04 max	0.04 max	0.50 max
HW50	0.40–0.60	1.50 max	0.50–2.00	10–14	58–62	0.04 max	0.04 max	0.50 max
HX50	0.40–0.60	1.50 max	0.50–2.00	15–19	64–68	0.04 max	0.04 max	0.50 max

[A] Manufacturing control should ensure that this composition contain a minimal amount of ferrite. See Supplementary Requirement S5.

3.1.10 Special requirements to be added to the specification.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 The tubing may be supplied in the as cast condition or as cast with machining on the outside or inside surfaces, or machined, as agreed upon between the manufacturer and the purchaser.

5.2 Heat treatment of the tubing shall not be required under this specification.

6. Chemical Requirements

6.1 The material shall conform to the requirements as to chemical composition as prescribed in Table 1.

7. Tensile Properties

7.1 Tension tests at room temperature are not recommended as acceptance criteria under this specification since the alloys are intended for elevated-temperature service, and room-temperature tests do not have a dependable relationship to elevated-temperature properties. (Where the design of the tubing is based on an assumption of certain minimum creep-rupture properties, one of the supplementary requirements of this specification may be stipulated on the order to ascertain the ability of the material to meet the design properties.)

8. Permissible Variation in Dimensions

8.1 *Machined Tubing (Tubing Machined on Inside and Outside)*:

8.1.1 The tolerances given in Specification A 999/A 999M shall govern, except that the wall thickness shall not vary over the specified minimum wall thickness by more than 10 % or 1/16 in. [1.6 mm], whichever is greater. There shall be no variation under the specified minimum wall thickness.

8.2 *As-Cast Tubing (No Machining or Machined on Inside or Outside)*:

8.2.1 *Outside Diameter (For Tubes Ordered to Outside Diameter)*:

8.2.1.1 Tubes machined on the outside shall meet the requirements of Specification A 999/A 999M.

8.2.1.2 Tubes not machined on the outside shall meet the permissible variations of Table 2.

8.2.2 *Inside Diameter (For Tubes Ordered to Inside Diameter)*:

8.2.2.1 Tubes machined on the inside shall meet the requirements of Specification A 999/A 999M.

8.2.2.2 Tubes not machined on the inside shall have permissible variations as agreed upon by the purchaser and the manufacturer.

8.2.3 *Wall Thickness*—The wall thickness shall not exceed the calculated minimum as cast wall thickness by more than the limits shown in Table 3. The calculated minimum wall thickness shall be equal to the specified minimum wall thickness plus the manufacturer's allowance for "inside surface feed metal" and outside surface roughness. Upon request, the manufacturer's allowance shall be furnished to the purchaser. There shall be no variation under the calculated minimum as cast wall thickness. For tubes over 24 up to and including 54 in. [600 to 1350 mm] in diameter the "permissible variations over specified minimum as cast wall thickness" shall be agreed upon by the manufacturer and the purchaser.

8.2.4 *Length*—If definite lengths are ordered, no length of tubing shall be under the length specified and not longer than the tolerance shown in Table 4.

TABLE 2 Permissible Variations in As-Cast Outside Diameter

Specified Outside Diameter of Tubing		Permissible Plus or Minus Variations from Specified Outside Diameter	
in.	mm	in.	mm
From 2 to 4	50 to 100	0.08	2.0
Over 4 to 12	100 to 300	0.10	2.5
Over 12 to 24	300 to 600	0.12	3.0
Over 24 to 36	600 to 900	0.16	4.1
Over 36 to 54	900 to 1350	0.25	6.4

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TABLE 3 Permissible Variations in As-Cast Wall Thickness

Specified Outside Diameter of Tubing		Permissible Variations over Calculated Minimum As-Cast Wall Thickness	
in.	mm	in.	mm
From 2 to 6	50 to 150	0.08	2.0
Over 6 to 12	150 to 300	0.10	2.5
Over 12 to 24	300 to 600	0.13	3.3

TABLE 4 Excess Length Tolerances for Centrifugally Cast Tubes

Outside Diameter of Tube		Permissible Excess Length	
in.	mm	in.	mm
From 2 to 12	50 to 300	¼	6.4
Over 12 to 24	300 to 600	½	13
Over 24 to 54	600 to 1350	1	25

9. Finish

9.1 *Machined Tubing*—All tubes shall be reasonably straight and free of rejectable indications. All visual irregularities shall be explored for depths. When the depth encroaches on the specified minimum wall thickness, such irregularities shall be considered rejectable indications.

9.2 *As-Cast Tubing*:

9.2.1 The outside surface shall be adequately cleaned (such as by shotblasting, sandblasting, wire brushing, grinding, or machining). The metal surface so revealed shall be visually inspected and shall be free of linear discontinuities or other imperfections that encroach on the specified minimum wall of the tube.

9.2.2 Various degrees of surface roughness occur on unmachined tubing. If a specific surface finish is required, it shall be a matter of agreement between the manufacturer and the purchaser.

9.3 *Surface Irregularities Not Classified as Rejectable*—Visual surface defects that have been explored and that do not encroach on the minimum sound wall thickness shall be blended either by machining or grinding the surface into the surrounding unaffected surface area of the tubing.

9.4 *Repair by Welding*—Repair of injurious defects by welding shall be permitted and major weld repairs shall be permitted only subject to the approval of the purchaser. Weld repairs shall be considered major if the depth of the cavity prepared for welding exceeds 20 % of the required minimum wall thickness or if the total surface area exceeds 10 in.^{2}[65 cm^2]. Defects shall be completely removed before welding. If defects are linear, complete removal shall be checked by liquid penetrant inspection (Practice E 165). Only qualified operators and procedures in accordance with Practice A 488/A 488M shall be used. All weld repairs shall be subjected to the same inspection standard as the tubing.

10. Pressure Test

10.1 All tubing shall be subjected to an internal air pressure of at least 75 psi [515 kPa] for at least 1 min either while submerged in clear water or with the entire outer surface coated with sulfur-free soap suds at the discretion of the manufacturer. In the usable portion of the tube, leaks are not permitted. If the Hydrostatic Test, Supplementary Requirement S6, is invoked, the exact details of the test and testing procedure shall be clearly defined and made a part of the Ordering Information (3.1.8).

10.2 Leaks may be repaired by welding only if such repair is approved by the purchaser.

11. Flattening Test

11.1 Flattening tests are not required since material covered by this specification is not intended to be bent, flanged, or otherwise formed.

12. Mechanical Tests Required

12.1 *Air Pressure Test*—Each length of tubing shall be subjected to the pressure test described in Section 10.

13. Certification

13.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the length, an additional symbol "S" if the tubing conforms to the supplementary requirements specified in Supplementary Requirements S1 to S11, and the heat number or manufacturer's number by which the tube can be identified, and, when as cast (see 8.2), the notation "AS CAST."

15. Keywords

15.1 alloy; centrifugal casting; high temperatures; pressure containing parts; steel tube; temperature service applications

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SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may become a part of the specification when specified on the inquiry or invitation to bid, and purchase order or contract.

S1. Product Analysis

S1.1 Product analysis may be made on any length of tubing. Individual lengths failing to conform to the chemical requirements shall be rejected. For product analysis the outside surface of the tube shall be ground clean before sampling and a sample taken from this area by drilling. If drillings are taken, the drill should penetrate at least to the mid point of the tube wall, but the inner ⅛ in. [3 mm] of the tube wall shall not be included in the sample unless the tube has been bored.

S2. Short-Time, High-Temperature Tension Test

S2.1 Short-time, high-temperature tension tests shall be made from a longitudinal or transverse section cut from the end of the tubing representing each heat or lot as agreed upon between the manufacturer and the purchaser.

S2.2 The test specimen shall conform to the dimensions shown in Fig. 7 or 9 of Test Methods E 8, or as described in Practice E 151. The specimen gage diameter shall not encroach on the zone of feed metal when cut from an as-cast tube.

S2.3 The specimen shall be subjected to a short-time tension test at a temperature of 1400 °F [760 °C], 1600 °F [870 °C], 1800 °F [980 °C], or 2000 °F [1095 °C], as selected by the purchaser. During the test the temperature range shall be maintained within ± 10 °F [5.5 °C] at the selected temperature. If the temperature is not specified by the purchaser, the test shall be conducted at 1600 °F [870 °C]. Processing by heat treatment to improve the hot tensile strength of the material or specimen shall not be permitted. However, the specimens may be aged for 24 h at test temperature before testing.

S2.4 The test shall be made in accordance with Practice E 21 except that the speed of the head of the testing machine shall be so adjusted that the cross-head speed shall not exceed 0.05 in. [1.3 mm]/in. [25 mm]/min.

S2.5 The test specimens shall conform to properties agreed upon between the manufacturer and the purchaser. The values shown in Table S2 may be used as a guide.

S3. Stress Rupture Test

S3.1 The stress rupture test shall be made from a longitudinal or transverse section cut from the end of the tubing representing each heat or lot as agreed upon between the manufacturer and the purchaser.

S3.2 The conditions of testing may be specified by the purchaser as either:

S3.2.1 1600 °F [870 °C] and an initial stress of 10 000 psi [69 000 kPa] or 8000 psi [55 000 kPa], or

S3.2.2 1800 °F [980 °C] and an initial stress of 6000 psi [41 000 kPa] or 4000 psi [28 000 kPa].

S3.2.3 If not specified, the test temperature shall be 1600 °F [870 °C] and the stress 10 000 psi [69 000 kPa]. During the test the temperature range shall be maintained within ± 10 °F [5.5 °C] of the selected temperature. The test specimen shall conform to the dimensions shown in Fig. 7 or 9 of Test Methods E 8 or as described in Practice E 139. The specimen gage diameter shall not encroach on the zone of feed metal when cut from an as-cast tube.

S3.3 The stress rupture test shall be made in accordance with Practice E 139. Measurements of creep rate shall not be required. The test shall be considered complete after the specimen has endured the specified stress for the minimum acceptable time. Processing by heat treatment to improve the creep resistance of the material or specimen shall not be permitted. However, the specimens may be aged for 24 h at test temperature before testing.

TABLE S2 Minimum Elevated Temperature Tensile Strength and Elongation Values for Centrifugal Cast Heat-Resistant Alloy Tubing

Grade	1400 °F [760 °C]		1600 °F [870 °C]		1800 °F [980 °C]		2000 °F [1095 °C]	
	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %
HC30	5300 [36000]	40	2960 [20400]	50	1600 [11000]	40		
HD50	7450 [51400]		2580 [17800]		910 [6200]			
HF30[A]	26000 [180000]	7.0	14500 [100000]	9.0	(not for use above 1600 °F)			
HH30			7650 [52700]	12.0	3510 [24200]	16.0		
HH33[A]			20000 [138000]	8.0	8200 [56000]	12.0	4000 [28000]	20.0
H135[A]			20000 [138000]	8.0	8200 [56000]	12.0		
HK30	26000 [180000]		14000 [97000]	9.0	7500 [52000]	18.0	3600 [25000]	24.0
HK40	29000 [200000]	7.0	16500 [114000]	6.0	8800 [61000]	15.0	4200 [29000]	22.0

[A] If these values are to be met, manufacturing control should ensure that these compositions contain a minimal amount of ferrite. See Supplementary Requirement S5.

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S3.4 The test specimens shall conform to properties agreed upon between the manufacturer and the purchaser. The values shown in Table S3 may be used as a guide.

S4. Room-Temperature Tension Test

S4.1 The manufacturer shall perform one tension test at room temperature on material from each heat. The properties to be met are a matter of agreement between the purchaser and the manufacturer.

S5. Control of Ferrite

S5.1 The amount of ferrite in the metal structure of Alloys HF30, HH33, and HI35 shall be controlled to limit the magnetic permeability to a maximum of 1.05.

S5.2 Test specimens for magnetic permeability measurements to determine delta ferrite content shall be in accordance with the applicable specimen requirements of Test Methods A 342/A 342M. Apparatus to perform the magnetic permeability measurements shall be in accordance with the requirements of Test Methods A 342/A 342M (Section 1, 2, or 3) whether individually constructed or obtained commercially. Prior to testing the test specimen material shall be heated in air to 2000 °F [1095 °C], held within ± 25 °F [15 °C] range of this temperature for 24 h, and then quenched in water. After quenching, all scale and superficial oxidized metal shall be removed from the specimen prior to testing.

S6. Hydrostatic Test

S6.1 Hydrostatic tests shall be performed in accordance with the Hydrostatic Test Requirements Section of Specification A 999/A 999M or as agreed upon between the manufacturer and the purchaser.

S7. Metal Structure and Etching Tests

S7.1 Etching tests (Note S1) shall be made on transverse or longitudinal sections from any tube, and shall show sound and reasonably uniform material within the specified sound wall area, free of injurious laminations and similar objectionable defects. If the specimen from either end of any length shows objectionable defects, one retest shall be permitted from that end. If this fails, the length shall be cut back until sound metal is obtained.

S7.2 The nature of these heat-resistant alloys produced by the centrifugal process may cause them to exhibit a difference in grain size from length to length and within an individual length. This difference in grain size shall not be cause for rejection.

NOTE S1—It is recommended that the macroetching test procedures described in Test Method E 340 be followed.

TABLE S3 Minimum Time to Rupture Values for Centrifugally Cast Heat-Resistant Alloy Tubing

Grade	Minimum Rupture Life, h			
	1600 °F [870 °C] 10 000 psi [69000 kPa]	1600 °F [870 °C] 8000 psi [55000 kPa]	1800 °F [980 °C] 6000 psi [41000 kPa][2]	1800 °F [980 °C] 4000 psi [28000 kPa]
HF30	6.0	18		
HH33[A]	5.0	17	3.0	20
HK30	7.0	24	4.0	34
HK40	25		11	
HK50	47		20	

[A] Manufacturing control should ensure that this composition contain a minimal amount of ferrite. See Supplementary Requirement S5.

S8. Photomicrographs

S8.1 The manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of tubing in the as-finished condition representing each heat. Such photomicrographs shall be suitably identified as to tubing size, wall thickness, and heat number. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S9. Such photomicrographs are for information only, to show the actual metal structure of the tubing as furnished.

S9. Photomicrographs for Individual Pieces

S9.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S8, photomicrographs shall be furnished from one or both ends of a length of tubing. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of tubing from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of tubing it represents.

S10. Radiographic Inspection

S10.1 The turned and bored tubing shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with the Practice E 94 or Method E 142 as agreed upon between the manufacturer and the purchaser. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. A specification which may be used as a basis for such agreement is Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components (Radiographic Inspection Method, SP-54) of the Manufacturer's Standardization Society of the Valve and Fittings Industry.

S11. Liquid Penetrant Inspection

S11.1 Liquid penetrant inspection shall be performed only on those areas of the tubing which have been suitably prepared for this type of inspection by grinding, machining, polishing, or other processing. The number of pieces, the areas to be inspected, the procedure to be used, and the standards of acceptability shall be agreed upon between the manufacturer and the purchaser.

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SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 608/A 608M – 02, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Replaced Specification A 530/A 530M with Specification A 999/A 999M throughout.

(*2*) Revised Note S1 to replace *Metals Handbook*, American Society for Metals, 1948 edition, p. 389 with Test Method E 340.

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