Designation: ~~A988/A988M – 17~~ A988/A988M – 23

Standard Specification for Hot Isostatically-Pressed Stainless Steel Flanges, Fittings, Valves, and Parts for High Temperature Service[1]

This standard is issued under the fixed designation A988/A988M; 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.

1. Scope*

1.1 This specification covers hot isostatically-pressed, powder metallurgy, stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts made to specified dimensions or to dimensional standards, such as in ASME specification B16.5.

1.2 Several grades of martensitic, austenitic, age hardening, and austenitic-ferritic stainless steels are included in this specification.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. Unless the order specifies the applicable "M" specification designation (SI units), however, the material shall be furnished to inch-pound units.

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

1.6 The following safety hazards caveat pertains only to test methods portions 8.1, 8.2, 9.5 – 9.7, and Section 10 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety and health~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A745/A745M Practice for Ultrasonic Examination of Austenitic Steel Forgings

[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 A01.22 onSteel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved ~~May 1, 2017~~May 1, 2023. Published ~~May 2017~~May 2023. Originally approved in 1998. Last previous edition approved in ~~2016~~2017 as ~~A988/A988M – 16.~~A988/A988M – 17. DOI: ~~10.1520/A0988_A0988M-17.~~10.1520/A0988_A0988M-23.

[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.

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

A751 Test Methods and Practices for Chemical Analysis of Steel Products
A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications
B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity
E112 Test Methods for Determining Average Grain Size
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E340 Practice for Macroetching Metals and Alloys
E606/E606M Test Method for Strain-Controlled Fatigue Testing
G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

2.2 *MSS Standard:*
SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions[3]

2.3 *ASME Specifications and Boiler and Pressure Vessel Codes:*
B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings [4]

2.4 *ASME Specification IX Welding Qualifications:*
SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes[4]
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes[4]
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes[4]
SFA-5.14 Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods[4]

2.5 *AWS Standard:*[5]
A5.11 Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.14 Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *can, n*—the container used to encapsulate the powder during the pressure consolidation process; it is partially or fully removed from the final part.

3.2.2 *compact, n*—the consolidated powder from one can. It may be used to make one or more parts.

3.2.3 *consolidation, n*—the bonding of adjacent powder particles in a compact under pressure by heating to a temperature below the melting point of the powder.

3.2.4 *fill stem, n*—the part of the compact used to fill the can. It is not usually integral to the part produced.

3.2.5 *hot isostatic-pressing, n*—a process for simultaneously heating and forming a compact in which the powder is contained in a sealed formable enclosure usually made from metal and the so-contained powder is subjected to equal pressure from all directions at a temperature high enough to permit plastic deformation and consolidation of the powder particles to take place.

3.2.6 *lot, n*—a number of parts made from a single powder blend following the same manufacturing practice.

3.2.7 *part, n*—a single item coming from a compact, either prior to or after machining.

3.2.8 *powder blend, n*—a homogeneous mixture of powder from one or more heats of the same grade.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from American Welding Society (AWS), 8669 NW 36 St., #130, Miami, FL 33166-6672, http://www.aws.org.

3.2.9 *rough part, n*—the part prior to final machining.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify in the purchase order all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of parts),

4.1.2 Name of material or UNS number,

4.1.3 ASTM designation and year of issue,

4.1.4 Dimensions (tolerances and surface finishes should be included),

4.1.5 Microstructure examination if required (5.1.4),

4.1.6 Inspection (15.1),

4.1.7 Whether rough part or finished machined part (8.2.2),

4.1.8 Supplementary requirements, if any,

4.1.9 Additional requirements (See 7.2 and 17.1), and

4.1.10 Requirement, if any, that the manufacturer shall submit drawings for approval showing the shape of the rough part before machining and the exact location of test specimen material (See 9.3).

5. Materials and Manufacture

5.1 *Manufacturing Practice:*

5.1.1 Compacts shall be manufactured by placing a single powder blend into a can, evacuating the can, and sealing it. The can material shall be selected to ensure that it has no deleterious effect on the final product. The entire assembly shall be heated and placed under sufficient pressure for a sufficient period of time to ensure that the final consolidated part meets the density requirements of 8.1.1.1. One or more parts shall be machined from a single compact.

5.1.2 The powder shall be prealloyed and made by a melting method capable of producing the specified chemical composition, such as but not limited to, air or vacuum induction melting, followed by gas atomization.

5.1.3 When powder from more than one heat of the same grade is used to make a blend, the heats shall be mixed thoroughly to ensure homogeneity.

5.1.4 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections. It shall meet the requirements of 8.1.2. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.5 Unless otherwise specified in the purchase order, the manufacturer shall remove the can material from the surfaces of the consolidated compacts by chemical or mechanical methods such as by pickling or machining. This removal shall be done before or after heat treatment at the option of the manufacturer (See Note 1).

NOTE 1—Often, it is advantageous to leave the can material in place until after heat treatment or further thermal processing of the consolidated compact.

6. Chemical Composition

6.1 The steel, both as a blend and as a part, shall conform to the requirements for chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology of A751 shall apply.

TABLE 1 Chemical Requirements

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[ED]	Nitrogen	Other Elements
					Martensitic Stainless Steels								
S41000	13 chromium	0.15	1.00	0.040	0.030	1.00	. . .	11.5–13.5	. . .	. . .	. . .	. . .	
S41026	13 chromium 0.5 molybdenum	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60	0.50	. . .	. . .	
S41500	13 chromium, 4 nickel	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	. . .	. . .	. . .	
S42390	12 chromium, 1.0 molybdenum, modified with vanadium	0.18–0.25	1.00	0.030	0.030	1.00	0.30–0.80	11.5–12.5	0.80–1.20	. . .	0.08–0.15	0.03–0.08	V 0.25–0.35
					Austenitic Stainless Steels								
N08028	32 nickel, 27 chromium, 3.5 molybdenum	0.030	2.50	0.030	0.030	1.0	30.0–34.0	26.0–28.0	3.0–4.0	0.60–1.4	. . .	. . .	
~~N08029~~	~~32 nickel, 27 chormium, 4.5 molybdenum~~	~~0.020~~	~~2.0~~	~~0.025~~	~~0.015~~	~~0.6~~	~~30.0–34.0~~	~~26.0–28.0~~	~~4.0–5.0~~	~~0.60–1.4~~	~~. . .~~	~~. . .~~	
N08029	32 nickel, 27 chromium, 4.5 molybdenum	0.020	2.0	0.025	0.015	0.6	30.0–34.0	26.0–28.0	4.0–5.0	0.60–1.4	. . .	. . .	
~~S30400[B]~~	~~18 chromium, 8 nickel~~	~~0.08~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~8.0–11.0~~	~~18.0–20.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	
S30400	18 chromium, 8 nickel	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	0.10	
~~S30403[B]~~	~~18 chromium, 8 nickel, low carbon~~	~~0.035~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~8.0–13.0~~	~~18.0–20.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	
S30403	18 chromium, 8 nickel, low carbon	0.035	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0	. . .	. . .	. . .	0.10	
~~S30451[C]~~	~~18 chromium, 8 nickel, modified with nitrogen~~	~~0.08~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~8.0–11.0~~	~~18.0–20.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	
S30451	18 chromium, 8 nickel, modified with nitrogen	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	0.10–0.16	
~~S30453~~	~~18 chromium, 8 nickel, modified with nitrogen~~	~~0.030~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~8.0–11.0~~	~~18.0–20.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	
S30453	18 chromium, 8 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	0.10–0.16	
~~S31600[B]~~	~~18 chromium, 8 nickel, modified with molybdenum~~	~~0.08~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~10.0–14.0~~	~~16.0–18.0~~	~~2.00–3.00~~	~~. . .~~	~~. . .~~	~~. . .~~	
S31600	18 chromium, 8 nickel, modified with molybdenum	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	0.10	

TABLE 1 *Continued*

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[E,D]	Nitrogen	Other Elements
~~S31603~~[B]	~~18 chromium, 8 nickel, modified with molybdenum, low carbon~~	~~0.030~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~10.0–14.0~~	~~16.0–18.0~~	~~2.00–3.00~~	~~. . .~~	~~. . .~~	~~. . .~~	
S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.030	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	0.10	
~~S31651~~[C]	~~18 chromium, 8 nickel, modified with molybdenum and nitrogen~~	~~0.08~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~10.0–13.0~~	~~16.0–18.0~~	~~2.00–3.00~~	~~. . .~~	~~. . .~~	~~. . .~~	
S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	0.10–0.16	
~~S31653~~[C]	~~18 chromium, 8 nickel, modified with molybdenum and nitrogen~~	~~0.030~~	~~2.00~~	~~0.045~~	~~0.030~~	~~1.00~~	~~10.0–13.0~~	~~16.0–18.0~~	~~2.00–3.00~~	~~. . .~~	~~. . .~~	~~. . .~~	
S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	0.10–0.16	
S31700	19 chromium, 13 nickel 3.5 molybdenum	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	
S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	
S21904	20 chromium, 6 nickel, 9 manganese	0.04	8.0–10.0	0.045	0.030	1.00	5.5–7.5	19.0–21.5	. . .	. . .	. . .	0.15–0.40	
S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	0.50–1.00	. . .	0.18–0.22	
S31725	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	0.20	
S31726	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	14.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	0.10–0.20	
N08367	22 chromium, 25 nickel, 6.5 molybdenum, low carbon	0.030	2.00	0.040	0.030	1.00	23.50–25.50	20.0–22.0	6.0–7.0	0.75	. . .	0.18–0.25	

TABLE 1 *Continued*

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[ED]	Nitrogen	Other Elements
S32654	25 chromium, 22 nickel, 7 molybdenum, low carbon	0.020	2.0–4.0	0.030	0.005	0.50	21.0–23.0	24.0–25.0	7.0–8.0	0.30–0.60	. . .	0.45–0.55	
						Age-Hardening Stainless Steels							
S17400	17 chromium, 4 nickel, 3 copper	0.07	1.00	0.040	0.030	1.00	3.0–5.0	15.0–17.5	. . .	3.0–5.0	0.15–0.45	. . .	
						Austenitic-Ferritic Stainless Steels							
S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	. . .	. . .	0.08–0.20	
S32205	22 chromium, 5.5 nickel, modified with high nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.75	. . .	0.14–0.20	
S32906	29 chromium, 6.5 nickel, 2.0 molybdenum, modified with high nitrogen	0.030	0.80–1.50	0.030	0.030	0.50	5.8–7.5	28.0–30.0	1.50–2.60	0.80	. . .	0.30–0.40	
S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	. . .	. . .	0.15–0.35	
S32750[B]	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0-5.0	0.50	. . .	0.24–0.32	
S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.0	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.20–0.80	. . .	0.24–0.32	W 1.50–2.50
~~S32760[D]~~	~~25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten~~	~~0.030~~	~~1.00~~	~~0.030~~	~~0.010~~	~~1.00~~	~~6.0–8.0~~	~~24.0–26.0~~	~~3.0–4.0~~	~~0.50–1.00~~	~~. . .~~	~~0.20–0.30~~	~~W 0.50–1.00~~
S32760[C]	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.50–1.00	. . .	0.20–0.30	W 0.50–1.00
S39277	25 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	1.20–2.00	. . .	0.23–0.33	W 0.80–1.20
S32505	27 chromium, 7 nickel, 3 molybdenum, modified with nitrogen and copper	0.030	1.50	0.030	0.020	1.00	4.5–7.0	24.0–27.0	2.9–3.9	1.50–2.50	. . .	0.25–0.30	

[A] Maximum, unless otherwise specified. Where ellipses (. . .) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.
[B] ~~S30400, S30403, S31600, and S31603 shall have a maximum nitrogen content of 0.10 %.~~

[C] ~~S30451, S31651, S30453, S31653 shall have a nitrogen content of 0.10 to 0.16 %.~~
[B] % Cr + 3.3 × % Mo + 16 × % N ~~> 40 min.~~ ≥ 41.
[C] % Cr + 3.3 × (% Mo + 1/2 %W) + 16 × % N ≥ 41.
[D] ~~The~~ The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.