Designation: A989/A989M – 23

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

This standard is issued under the fixed designation A989/A989M; 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, alloy 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 alloy 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 are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 The following safety hazards caveat pertains only to test methods portions, 8.1, 8.2, and 9.5 – 9.7 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, health, and environmental practices and to 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]

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A751 Test Methods and Practices for Chemical Analysis of Steel Products

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

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

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 Section IX Welding Qualifications:*

SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes[4]

[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 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved May 1, 2023. Published June 2023. Originally approved in 1998. Last previous edition approved in 2018 as A989/A989M – 18. DOI: 10.1520/A0989_A0989M-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.

[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.

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

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 that is removed partially or fully from the final part.

3.2.2 *compact, n*—the consolidated powder from one can that 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 that 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 produced from a single powder blend following the same manufacturing conditions.

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.

3.2.9 *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).

4.1.5 Microstructure examination, if required (5.1.5).

4.1.6 Inspection (14.1).

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 7.2.1 and 16.1).

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 9.3.1).

5. Materials and Manufacture

5.1 *Manufacturing Practice:*

5.1.1 Powder should be protected during storage to prevent the detrimental pick-up of oxygen and other contaminants.

5.1.2 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 8.1.2.1. One or more parts shall be machined from a single compact.

5.1.3 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.

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

5.1.5 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections and shall meet the requirements of 8.1.3. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.6 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 A751 shall apply.

6.1.1 A representative sample of each blend of powder shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. The blend shall conform to the chemical composition requirements prescribed in Table 1.

6.1.2 When required by the purchaser, the chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical composition requirements prescribed in Table 1.

6.2 Addition of lead, selenium, or other unspecified elements for the purpose of improving the machinability of the compact shall not be permitted.

6.3 The steel shall not contain an unspecified element, for the ordered grade, to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7. Heat Treatment

7.1 After hot isostatic-pressing, the compacts shall be annealed prior to heat treating in accordance with the requirements of Table 2. At the option of the producer, this anneal shall be a separate operation following powder consolidation or shall be a part of the consolidation process.

7.2 The alloy steels shall be heat treated in accordance with the requirements of 7.1 and Table 2.

TABLE 1 Chemical Requirements

UNS Designation	Grade	Composition, %[A]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Niobium[B]	Other Elements
						Alloy Steels					
K90941	9 % chromium	0.15	0.30–0.60	0.030	0.030	0.50–1.00	. . .	8.0–10.0	0.90–1.10	. . .	. . .
K90901	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus niobium[B] and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.06–0.10	N 0.03–0.07 Al 0.04 V 0.18–0.25
K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	. . .	2.7–3.3	0.80–1.06	. . .	. . .
K21590 Class 1	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	. . .	2.00–2.50	0.87–1.13	. . .	. . .
K21590 Class 3	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	. . .	2.00–2.50	0.87–1.13	. . .	. . .

[A] Maximum, unless otherwise specified.
[B] Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.

TABLE 2 Heat Treating Requirements

UNS No.	Heat Treat Type	Austenitizing/Solutioning Temperature, °F [°C][A]	Cooling Media	Quenching, Cool to Below °F [°C]	Tempering Temperature, min °F [°C]
		Alloy Steels			
K90941	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
K90901	normalize and temper	1900–2000 [1040–1095]	air cool	[B]	1350 [730]
K31545	anneal	1750 [955]	furnace cool	[B]	[B]
K21590 Class 1, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1250 [675]

[A] Minimum unless temperature range is listed.
[B] Not applicable.

7.2.1 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 2 for each grade are utilized.

7.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT".

7.3 See Supplementary Requirement S12 if a particular heat treatment method is specified by the purchaser in the purchase order.

7.4 *Time of Heat Treatment*—Heat treatment of the hot isostatically-pressed parts shall be performed before or after machining at the option of the manufacturer.

8. Structural Integrity Requirements

8.1 *Microporosity:*

8.1.1 The parts shall be free of microporosity as demonstrated by measurement of density as provided in 8.1.2 or by microstructural examination as provided in 8.1.3.

8.1.2 *Density Measurement:*

8.1.2.1 The density measurement shall be used for acceptance of material but not for rejection of material. The measured density for each production lot shall exceed 99 % of the density typical of that grade when wrought and in the same heat treated condition as the sample. A production lot that fails to meet this acceptance criterion is permitted, at the option of the producer, to be tested for microporosity in accordance with the microstructural examination as provided in 8.1.3.

8.1.2.2 Density shall be determined for one sample from each production lot by measuring the difference in weight of the sample when weighed in air and when weighed in water and multiplying this difference by the density of water (Archimede's principle). The equipment used shall be capable of determining density within ±0.004 lb/in.^{3} [0.10 g/cm^3]. Alternatively, at the option of the producer, it is permitted to use Test Method B311 to determine the density.

8.1.2.3 At the option of the producer, the density shall be compared to the room temperature density typical of wrought alloy steels or to the density of a wrought reference sample of the same grade heat treated in accordance with the requirements of Table 2 (see Note 2). The typical density for alloy steel in the annealed condition at room temperature is 0.28 lb/in.^{3} [7.8 g/cm^3].

NOTE 2—The actual density of alloy steel varies slightly with composition and heat treatment. For this reason, small differences in the measured density from the typical density for a given grade of steel may be the result of differences in alloy content, heat treatment, or microporosity. When density values are measured that are less than the density typical of a given grade of steel, it is appropriate to examine the sample for microporosity by the more specific metallographic examination procedures.

8.1.3 *Microstructural Examination:*

8.1.3.1 The microstructure shall be examined at 20-50×, 100-200×, and 1000-2000× and shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity.

8.1.3.2 One sample from each production lot shall be examined. The sample shall be taken from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press using the same pressure, temperature, and time parameters and heat-treated in the same final heat treatment charge, after hot isostatic-pressing or after final heat treatment. The microstructure shall meet the requirements of 8.1.3.1.

8.1.3.3 If the sample fails to meet the requirements for acceptance, it is permitted to retest each part in the lot. Each part that passes the requirements of 8.1.3.1 shall be accepted.

8.2 *Hydrostatic Tests*—After they have been machined, pressure-containing parts shall be tested to the hydrostatic shell test pressures prescribed in ASME B16.5 for the applicable steel rating for which the part is designed, and shall show no leaks. Parts ordered under these specifications for working pressures other than those listed in the ASME B16.5 ratings shall be tested to such pressures as may be agreed upon between the manufacturer and purchaser.

8.2.1 No hydrostatic test is required for welding neck or other flanges.

8.2.2 The compact manufacturer is not required to perform pressure tests on rough parts that are to be finish machined by others. The fabricator of the finished part is not required to pressure test parts that are designed to be pressure-containing only after assembly by welding into a larger structure. The manufacturer of the compacts, however, shall be responsible as required in 15.1 for the satisfactory performance of the parts under the final test required in 8.2.

9. Mechanical Properties

9.1 The material shall conform to the requirements for mechanical properties prescribed in Table 3 at room temperature.

9.2 Mechanical test samples shall be obtained from the component stem, protrusion, or test part made from a single powder blend consolidated in the same hot-isostatic press using the same pressure, temperature, and time parameter and heat-treated in the same final heat-treatment charge. If repair welding is required (see Section 15), the test specimens prior to testing shall accompany the repaired parts if a post weld heat treatment is done.

9.3 For normalized and tempered parts, or quenched and tempered parts, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat treated thickness of the represented part. In addition, for quenched and tempered parts, the midlength of the test specimen shall be at least *T* from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.3.1 Alternatively, with prior approval of the purchaser, it is permitted to take the test specimen for the steel parts at a depth (*t*) corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance (2*t*) from any second surface. The test depth, however, shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to complex parts, or parts with thick cross-sectional areas where ¼ *T* and *T* testing (see 9.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

9.4 For annealed alloy steels the test specimen may be taken from any convenient location.

9.5 *Tension Test:*

9.5.1 One tension test shall be made for each production lot in each heat treatment charge.

9.5.1.1 When the heat treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each production lot of each type of part, and section size is required instead of one test from each production lot in each heat-treatment charge. The term "type," as used here, designates a characteristic shape of a part, such as flange, elbow, tee, and so forth.

9.5.1.2 The tension test specimen shall be made from material accompanying the parts in final heat treatment.

9.5.2 Testing shall be performed as specified in Specification A961/A961M using the largest feasible of the round specimens.

9.6 *Hardness Tests:*

9.6.1 When two or more parts are produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
		Alloy Steels			
K90941	85 [585]	55 [380]	20.0	40.0	179–217
K90901	85 [585]	60 [415]	20.0	40.0	248 max
K31545	75 [515]	45 [310]	20.0	30.0	156–207
K21590 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
K21590 Class 3	75 [515]	45 [310]	20.0	30.0	156–207

[A] Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method also may be used.

be hardness tested as specified in Specification A961/A961M to ensure that the parts are within the hardness limits given for each grade in Table 3. When only one part is produced, it shall be hardness tested as required. The purchaser is permitted to verify that the requirement has been met by testing at any location on any part, provided such testing does not render the part useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1.1 is applied, additional hardness tests shall be made on parts or samples as defined in 9.2 distributed throughout the charge. At least eight samples shall be checked from each batch load and a least one check/h shall be made from a continuous run. When the furnace batch charge is less than eight parts, each part shall be checked. If any hardness test result falls outside the prescribed limits, the entire lot of parts shall be reheat treated and the requirements of 9.5.1 shall apply.

9.7 *Fatigue Tests*—When specified in the order, the fatigue strength of alloy steel, except UNS K90901, components intended for service above 800 °F [425 °C] and for UNS K90901 components intended for service above 1000 °F [540 °C] shall be tested in accordance with the requirements of Supplementary Requirement S13.

10. Product Analysis

10.1 The purchaser is permitted to make a product analysis on parts supplied to this specification. The chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. Samples for analysis shall be taken from midway between the center and surface of solid parts, midway between the inner and outer surfaces of hollow parts, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 with the tolerances as stated in Table 4 or Table 5.

11. Reheat Treatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer is permitted to reheat treat the parts and repeat the tests specified in Section 9, but not more than twice.

12. Surface Finish, Appearance, and Corrosion Protection

12.1 The requirements of Specification A961/A961M apply to hot isostatically pressed finished parts.

12.2 In addition to the requirements of Specification A961/A961M, the following requirements apply:

12.2.1 The parts shall be free of machining burrs and machined surfaces, other than surfaces having special requirements, shall have a surface finish not to exceed R_a 250 microinch [6.3 micrometer] (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9) only with prior approval of the purchaser and with the following limitations and requirements:

TABLE 4 Product Analysis Tolerances for Alloy Steels with a Maximum Chromium Limit 4 % or More[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
Titanium	all ranges	0.05
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
Niobium[C]	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	–0.005
		+0.01
Tungsten	to 1.00, incl	0.04
Copper	to 1.00, incl	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.
[C] Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 6. The electrodes shall be purchased in accordance with ASME Specification SFA-5.5. The submerged arc process with neutral flux, the gas metal-arc welding and gas tungsten-arc welding processes are permitted.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A275/A275M for the alloy steels in this specification, or by liquid penetrant inspection in accordance with Test Method E165/E165M for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment, requirements given in Table 6 shall be met.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the part. Repair by welding shall not exceed 33⅓ % of the wall thickness of the finished part or ⅜ in. [9.5 mm], whichever is less.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the purchase