



Standard Specification for Wrought High-Strength Low-Alloy Steel Butt-Welding Fittings¹

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1. Scope

1.1 This specification covers wrought high-strength low-alloy steel butt-welding fittings of seamless and electric fusion-welded construction covered by the latest revisions of ANSI B16.9, ANSI 16.28, and MSS-SP-75. Butt-welding fittings differing from these ANSI and MSS standards shall be furnished in accordance with Supplementary Requirement S9. These fittings are for use in high-pressure gas and oil transmission and distribution systems.

1.2 Optional supplementary requirements are provided for fittings when a greater degree of examination is desired. One or more of the supplementary requirements may be specified in the order.

1.3 This specification does not cover cast-welding fittings or fittings machined from castings.

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 the other. Combining values from the two systems may result in nonconformance with this specification. Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products²
- A 530/A 530 M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe²
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products²
- E 165 Test Method for Liquid Penetrant Examination³
- E 709 Practice for Magnetic Particle Examination³

2.2 ANSI Standards:

B16.9 Steel Butt-Welding Fittings⁴

B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns⁴

2.3 AWS Standard:

AWS 5.18 Specification for Carbon Steel Metals for Gas Shielded Arc Welding⁵

2.4 ASME Boiler and Pressure Vessel Code:⁶

Section V, Nondestructive Examination

Section VIII, Division 1, Pressure Vessels

Section IX, Welding Qualifications

2.5 MSS Standards:

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions⁷

MSS-SP-75 Specification for High Test Wrought Butt-Welding Fittings⁷

2.6 ASNT Standard:

SNT-TC-1A(1984) Recommended Practice for Non-destructive Testing Personnel Qualification and Certification⁸

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

- 3.1.1 Quantity, number of fittings of each kind,
- 3.1.2 Description of fitting and nominal dimensions (standard or special),
- 3.1.3 Grade Symbol,
- 3.1.4 Construction, seamless or welded (unless seamless or welded construction is specified by the purchaser either may be furnished at the option of the supplier),
- 3.1.5 Supplementary requirements, if any,
- 3.1.6 Specification designation and year of issue,
- 3.1.7 Additional requirements, if any (see 17.6), and
- 3.1.8 Requirements for certification of test report.

⁴ Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

⁵ Available from American Welding Society, 550 N. W. Lajeune Rd., Miami, FL 33135.

⁶ Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

⁷ Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Meyer Drive, Arlington, VA 22209.

⁸ Available from American Society for Nondestructive Testing, 4153 Arlinggate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

¹ This specification is under the jurisdiction of ASTM Committee A-1 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.

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² Annual Book of ASTM Standards, Vol 01.01.

³ Annual Book of ASTM Standards, Vol 03.03.

4. Materials and Manufacture

4.1 The material for fittings shall be fully killed fine-grain material made by a melting process that is intended to produce rounded, well dispersed, fine sulphide inclusions, that promote good notch toughness, assists in the resistance to hydrogen induced cracking, and for weldability suitable for field welding.

4.2 Starting materials shall consist of plate, sheet, forgings, forging quality bar, and seamless or fusion-welded tubular products with filler metal added. The chemical composition shall conform to Table 1.

4.3 A starting material that specifically requires the addition of any element beyond those listed in Table 1 is not permitted. This does not preclude the use of deoxidizers.

4.4 Starting material shall not require a preheat for field welding provided that the restrictions of ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-30 are complied with.

4.5 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion, welding, machining, or by a combination of these operations. Fittings machined from bar shall be restricted to NPS-4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.6 All welds including welds in tubular products from which the fittings are made shall be:

4.6.1 Made by welders, welding operators, and welding procedures qualified under the provisions of ASME Boiler and Pressure Vessel Code, Section IX,

4.6.2 Heat treated in accordance with Section 5 of this specification, and

4.6.3 Radiographically examined throughout the entire length of each weld in accordance with Articles 1 and 2 of ASME Boiler and Pressure Vessel Code, Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Boiler and Pressure Vessel Code, Section VIII.

4.7 The welded joints of the fittings shall be furnished in accordance with the requirements of Paragraph UW-35(a) of ASME Boiler and Pressure Vessel Code, Section VIII.

4.8 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirements S3 or S4. This examination shall be performed in accordance with a written procedure and shall be performed after final heat treatment. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 11.1 on finish. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance. NDE personnel shall be qualified in accordance with SNT-TC-1A.

4.9 All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with Supplementary Requirements S3 or S4, and with personnel qualifications, acceptance criteria, and marking as in 4.8.

5. Heat Treatment

5.1 All fittings shall be furnished in the heat-treated condition. Fittings formed above the transformation temperature or upon which welding is performed, shall be cooled to below the lower critical temperature prior to heat treatment. Fittings shall subsequently be heat treated by one or more of the following procedures:

5.1.1 *Normalizing*—Fittings shall be uniformly heated to a selected temperature above the transformation range and held at that temperature for a minimum of 30 min. Each fitting shall be uniformly cooled in air.

5.1.2 *Quenching and Tempering*:

5.1.2.1 *Quenching*—Fittings shall be uniformly heated to a selected temperature above the transformation range for at least 30 min and subsequently quenched in a liquid medium to a temperature below 300°F [150°C]. Quench facilities shall be equipped with suitable agitation systems such as mechanical agitation, recirculation pumps, sprays, or controlled overflow, or a combination thereof. The temperature of the water quenchants shall be restricted to a maximum of 120°F [49°C] at the end of the quench. The temperature of oil quenchants shall be maintained between 120 and 160°F [49 and 71°C] using the maximum temperature suggested by the manufacturer. Polymer quenchants shall be controlled to a maximum temperature recommended by the quenchant manufacturer. Baths shall be of adequate type and size to rapidly absorb the heat rejected by the most massive part to be quenched. Quenched fittings shall subsequently be tempered.

5.1.2.2 *Tempering*—Fittings to be tempered shall be heated to the selected temperature between 1150°F [620°C] and the lower critical temperature and held there for the greater of ½h or 1 h/in. [2.4 min/mm] of the thickness at the thickest section and subsequently cooled at any convenient rate.

5.1.3 *Stress Relieving*—The fittings shall be heated to selected temperature below the transformation range, but not

TABLE 1 Chemical Requirements

	Composition %		
	Heat Analysis	Product Analysis	
Carbon	0.20 ^A	0.22	
Manganese	1.00–1.45	1.50	All values are maximum unless a range is stated
Phosphorus	0.030	0.030	
Sulfur	0.010	0.010	
Silicon	0.15–0.40 ^B	0.10–0.40	
Nickel	0.50 ^C	0.60	
Chromium	0.30 ^C	0.30	
Molybdenum	0.25 ^C	0.25	
Copper	0.35 ^C	0.35	
Titanium	0.05	0.05	
Vanadium	0.10	0.10	
Columbium	0.04	0.04	
Vanadium plus Columbium	0.12	0.12	
Aluminum	0.06	0.06	

^A The carbon equivalent, as calculated by the following formula, shall not exceed 0.42 %:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

^B If vacuum carbon deoxidation is used, silicon shall not exceed 0.10 % by heat analysis and 0.12 % by product analysis.

^C The sum of Ni + Cr + Mo + Cu shall not exceed 1.0 %.

less than 1150°F [620°C], held at temperature for at least 1 h and subsequently cooled at any convenient rate.

6. Chemical Composition

6.1 The chemical composition of the steel shall conform to the requirements prescribed in Table 1.

6.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

6.3 Analysis of each heat of steel shall be made from a sample taken preferably during the pouring of the heat. The results shall conform to Table 1 for either heat or product analysis limits as applicable.

6.4 The fittings manufacturer shall make a product analysis per heat from either the starting material or from a fitting. The chemical composition thus determined shall conform to Table 1. The product analysis shall be the basis for rejection. For referee purposes, Methods, Practices, and Terminology A 751 shall apply.

6.5 The carbon equivalent of the base metal, as determined by the following formula, shall not exceed 0.42 % for the product analysis:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

6.6 Weld metal used in the construction of the fittings shall conform to the tensile and impact requirements of 8.4 and 7.1 after heat treatment in accordance with Section 5. A chemical analysis shall be performed on deposited weld metal for each heat of filler metal or, for submerged arc welding, each heat of

filler metal and batch of flux. The weld metal shall be deposited in accordance with the qualified weld procedure.

6.7 Only the carbon content of the deposited weld-metal composition need comply with the requirements of Table 1. The nickel content of the deposited weld metal shall not exceed 1.0 %.

7. Notch Toughness Properties

7.1 The notch toughness properties of the fittings shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Test Methods and Definitions A 370. Full size Charpy, V-notch specimens shall be used whenever possible. Small size specimens shall be used only when the material thickness does not permit full size specimens. The impact specimens shall not be flattened after heat treatment. All base metal specimens shall be removed with the axis of the specimens longitudinal to the direction of primary metal flow. Weld-metal specimens shall be specimens with the axis transverse to the weld seam.

7.2 One set of impact tests (three specimens) shall be made to represent the base metal and one set (three specimens) to represent the weld metal on the same frequency as the tension tests.

7.3 The test temperature shall be -50°F [-46°C].

8. Tensile Requirements

8.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Test Methods and Definitions A 370.

8.2 Tension test specimens shall be taken from a fitting after

TABLE 2 Mechanical Requirements

Property	Grade					
	WPHY 42	WPHY 46	WPHY 52	WPHY 60	WPHY 65	WPHY 70
Yield strength, min ^A 0.2 % offset, ksi [MPa]	42 [290]	46 [315]	52 [360]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60 [415]	63 [435]	66 [455]	75 [515]	77 [530]	80 [550]
	-85 [585]	- 88 [605]	- 91 [625]	- 100 [690]	- 102 [705]	- 105 [725]
<i>Elongation:</i>						
Standard round specimen, or small-size proportional specimen, min, % in 4D	25	25	25	20	20	20
Rectangular specimen, for section thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min, % in 2 in. [50 mm].	32	32	32	28	28	28
Rectangular specimen for thickness less than $\frac{5}{16}$ in. [7.94 mm]; min, % 2 in. [50 mm]. Width of specimen $1\frac{1}{2}$ in. [40 mm].	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>
<i>Toughness:</i>						
<i>C_v</i> energy absorption ^C ; measured at -50°F [-46°C].						
Size, mm	Average/min, ft·lbs[J]			Lateral Expansion min, MLS[mm]		
10 × 10	30/25 [40/34]			25 [0.64]		
10 × 7.5	25/21 [34/28]			21 [0.53]		
10 × 5	20/17 [27/23]			13 [0.33]		

^AActual yield strength shall not exceed specified minimum by more than 15 ksi [105 MPa].

^B For each $\frac{1}{32}$ -in. [0.79 mm] decrease in section thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5 % from the elongation value of specimens above $\frac{5}{16}$ in. [7.94 mm] is permitted. When the section thickness lies between two values defined above, the minimum elongation value is determined by the following equation:

$$E = 48t + 15.00$$

where:

E = elongation % in 2 in. [50 mm], and

t = actual thickness of specimen.

^C These requirements are intended to minimize fracture initiation. The requirements are not intended to give assurance against fracture propagation.

final heat treatment or from a test piece of the same heat and nominal thickness that was heat treated in a furnace charge with the fittings they represent.

8.3 One tensile test is required for each heat of fittings of the same section thickness, and heat treated in either a continuous or batch-type furnace, controlled within a range of 50°F [28°C] and equipped with recording pyrometers.

8.4 In addition, fittings containing welds shall have one center-weld tension test made with the axis transverse to the weld seam for each heat of filler metal, or each heat of filler metal and batch of flux for submerged arc welds, for fittings of the same section thickness and heat treated in either a continuous or batch-type furnace controlled within a range of 50°F [28°C] and equipped with recording pyrometers. Only the ultimate tensile strength need meet the minimum requirement of Table 2.

9. Hardness Requirements

9.1 Fittings shall have a maximum hardness of 22 HRC (235 HB).

10. Dimensions

10.1 Dimensional requirements for NPS 14 and smaller butt-welding fittings are provided in ANSI B16.9 and B16.28.

10.2 Dimensional requirements for butt-welding fittings larger than NPS 14 through NPS 48 are provided by MSS-SP-75.

10.3 Fittings of a size or shape differing from the standards in 10.1 and 10.2, but meeting all the other requirements of this specification, may be furnished in accordance with Supplementary Requirement S9.

10.4 Fittings that do not have a thickness or yield strength, or both, that are equal to the mating pipe, are acceptable provided the welding end preparations comply with MSS-SP-75, Figs. 3(a), (b), and (c) and the fitting welding-end thickness is at least equal to the pipe wall thickness times the ratio of the specified minimum yield strength of the pipe and the minimum tested yield strength of the fitting.

11. Workmanship, Finish and Appearance

11.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free of surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, and shall have a workmanlike finish.

11.2 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 93½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

11.3 Surface checks (fish scale) deeper than ¼in. [0.4 mm] shall be removed.

11.4 Mechanical marks deeper than ¼in. [1.6 mm] shall be removed.

11.5 When the removal of a surface discontinuity reduces the wall thickness below 93½ % of the specified nominal wall

thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 12.

12. Repair by Welding (Base Metal)

12.1 Repair welding by the manufacturer is permissible.

12.1.1 The welding procedure and the welder shall be qualified in accordance with Section IX of the Boiler and Pressure Vessel Code.

12.1.2 The deposited weld metal shall conform to the requirements of 6.4 and 6.5. Electrodes for the shielded metal-arc process shall be of the low-hydrogen type.

12.1.3 Surface discontinuities shall be completely removed by chipping or grinding to sound metal as verified by magnetic-particle or liquid-penetrant inspection.

12.1.4 After repair welding, the area welded shall be ground smooth to the original contour and shall be completely free of surface discontinuities as verified by magnetic-particle or liquid-penetrant inspection. Sections thicker than 1 in. [25 mm] shall also be radiographed in accordance with 4.6.

12.1.5 All fittings repaired by welding shall be thermally treated after repair by either complete reheat treatment or post-weld heat treatment at least 50°F [28°C] below the tempering temperature if tempering has been performed.

12.1.6 Repair by welding shall not exceed 10 % of the surface area of the fitting nor 33⅓ % of the nominal wall thickness.

12.1.7 Indications discovered by nondestructive examination shall, after reheat treatment, be again examined by the same NDE method as used in the original determination.

12.1.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

13. Hydrostatic Test

13.1 Hydrostatic testing is not required by this specification.

13.2 All fittings shall be capable of withstanding, after installation, without failure, leakage, or impairment of serviceability, a hydrostatic test pressure of 100 % based on minimum yield strength of the material grade, wall thickness, and outside diameter ordered in Section 3. The hydrostatic pressure shall be calculated in accordance with Barlow's equation:

$$P = 2S \frac{t}{D}$$

where:

P = hydrostatic pressure,

S = specific yield strength, min,

t = nominal wall thickness, and

D = outside diameter.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

15. Rejection and Reheating

15.1 Material that fails to conform to the requirements of

this specification may be rejected. Rejection shall be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a reheating.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following, when applicable:

16.1.1 Chemical analysis results, when (Section 6 and Table 1), base metal only, and

16.1.2 Tensile property results, (Section 8 and Table 2), the yield strength and ultimate strength in ksi, and elongation in percent for the base metal. Transverse-weld tensile strength shall be reported in ksi.

16.1.3 Impact test results, (Section 7 and Table 2), base metal and weld metal, specimen size, and test temperature,

16.1.4 Type heat treatment, (Section 5),

16.1.5 Radiographic examination results, and

16.1.6 Any supplemental testing required by the purchase order.

17. Product Marking

17.1 Identification marking shall consist of the Manufacturer’s symbol or name (Note Note 1), specification number (year date not needed), grade symbol, size and nominal wall thickness or schedule, and heat code identification. In addition, quench and tempered fittings shall be marked with the symbol QT, and cold-formed tees shall be marked as prescribed in 4.8.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

17.2 Fittings that have been repaired by welding shall be

marked with the letter W following the designation number.

17.3 Marking shall be by low-stress die stamps or interrupted dot stamps and shall be in accordance with MSS-SP-25.

17.4 If the impact test temperature is other than –50°F [–46°C], it shall be marked on the fitting.

17.5 If extra yield strength or wall thickness is used in a compensatory manner as described in 10.4 of this specification, the fitting shall be marked with both the minimum wall measured at the welding ends of the fitting and the actual yield and specified yield as illustrated in the following:

Manufacturer	Designation	$\frac{\text{Actual YS}}{\text{Specified YS}}$	Diameter
		$\frac{Z}{Y}$	
MNFR	AXXX		16
Specified wall	Actual wall	Heat code	Heat treatment
0.95	0.98	QQR	QT

where:

Z = actual yield strength, and

Y = specified minimum yield strength.

17.6 *Bar Coding*—In addition to the requirements in 17.1, 17.2, 17.3, 17.4, and 17.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 high-strength low-alloy steel; pipe fittings; steel; piping applications; pressure-containing parts

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser’s expense. The test specified shall be witnessed by the purchaser’s inspector before shipment of material, if so specified in the order.

S1. Repair Welding

S1.1 No repair welding shall be permitted without the prior approval of the purchaser.

S2. Special Notch Toughness

S2.1 The impact test temperature or acceptance values, or both, shall be as agreed upon, but only with respect to the lower temperatures or higher energy values.

S3. Liquid-Penetrant Examination

S3.1 All surfaces shall be liquid-penetrant examined in accordance with Practice E 165. Acceptance limits shall be specified by the purchaser. Personnel performing NDE

examinations shall be qualified in accordance with SNT-TC-1A.

S4. Magnetic-Particle Examination

S4.1 All acceptance surfaces shall be magnetic-particle examined in accordance with Practice E 709. Acceptance limits shall be specified by the purchaser. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

S5. Hydrostatic Test

S5.1 Fittings shall be hydrostatically tested as agreed upon between the purchaser and the manufacturer.

S6. Bar Stock Fittings

S6.1 Bar stock fittings shall not be permitted.

S7. Special Heat Treatment

S7.1 A special heat treatment shall be applied as agreed upon between the manufacturer and the purchaser (Section 5).

S8. Hardness Test

S8.1 If actual hardness testing of the individual fittings is required, the frequency and the method used shall be as agreed upon between the manufacturer and the purchaser.

S9. Special Fittings

S9.1 Partial compliance fittings of size or shape not conforming to the dimensional requirements of ANSI B16.9, B16.28, or MSS-SP-75 shall meet all other requirements of this

specification. In addition to the marking required by Section 18, the grade designation symbol shall be followed by the symbol S9.

S10. Ultrasonic Examination

S10.1 Each fitting shall be ultrasonically examined as agreed upon between the purchaser and the manufacturer.

S10.2 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

S11. Weld Metal Analysis

S11.1 Analysis of weld metal shall be reported.

S12. Welding Procedure Test Record

S12.1 The welding procedure test record shall be furnished.

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