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Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A369/A369M; 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[2] covers heavy-wall carbon and alloy steel pipe (Note 1) made from turned and bored forgings and is intended for high-temperature service. Pipe ordered under this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics.

NOTE 1—The use of the word "pipe" throughout the several sections of this specification is used in the broad sense and intended to mean pipe headers, or leads.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. Supplementary requirements S1 to S5 call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required as applicable.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as 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. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.5 *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:*[3]

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E290 Test Methods for Bend Testing of Material for Ductility

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

2.2 *ASME Boiler and Pressure Vessel Code:*[4]

Section IX

2.3 *ASME Standard:*[4]

B 46.1 Surface Texture

2.4 *AWS Specifications:*[5]

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

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 (forged and bored pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (inside diameter and minimum wall thickness),

[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 A01.10 on Stainless and Alloy Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-369 in Section II of that Code.

[3] 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.

[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), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

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

TABLE 1 Chemical Requirements

Grade	Composition, %			
	FPA	FPB	FP1	FP2
Carbon	0.25 max	0.30 max	0.10–0.20	0.10–0.20
Manganese	0.27–0.93	0.29–1.06	0.30–0.80	0.30–0.61
Phosphorus, max	0.035	0.035	0.025	0.025
Sulfur, max	0.035	0.035	0.025	0.025
Silicon	0.10 min	0.10 min	0.10–0.50	0.10–0.30
Chromium	...	...	...	0.50–0.81
Molybdenum	...	...	0.44–0.65	0.44–0.65
Grade	FP5	FP9	FP11	FP12
Carbon	0.15 max	0.15 max	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.61
Phosphorus, max	0.025	0.030	0.025	0.025
Sulfur, max	0.025	0.030	0.025	0.025
Silicon	0.50 max	0.50–1.00	0.50–1.00	0.50 max
Chromium	4.00–6.00	8.00–10.00	1.00–1.50	0.80–1.25
Molybdenum	0.45–0.65	0.90–1.10	0.44–0.65	0.44–0.65
Grade	FP21	FP22	FP91	FP92
			Type 1 / Type 2	
Carbon				0.07–0.13
Heat	0.05–0.15	0.05–0.15	0.08–0.12 / 0.08–0.12	
Product	...	...	... / 0.07–0.13	
Manganese	0.30–0.60	0.30–0.60	0.30–0.60 / 0.30–0.50[A]	0.30–0.60
Phosphorus, max	0.025	0.025	0.025 / 0.020[A]	0.020
Sulfur, max	0.025	0.025	0.025 / 0.005[A]	0.010
Silicon	0.50 max	0.50 max	0.20–0.50 / 0.20–0.40[A]	0.50 max
Chromium	2.65–3.35	1.90–2.60	8.00–9.50 / 8.0–9.50[A]	8.50–9.50
Molybdenum				0.30–0.60
Heat	0.80–1.06	0.87–1.13	0.85–1.05 / 0.85–1.05	
Product	...	...	... / 0.80–1.05	
			Others:	W 1.50–2.00
			Ni 0.40 max / 0.20 max[A]	V 0.15–0.25
			V	Nb[C] 0.04–0.09
			Heat 0.18–0.25 / 0.18–0.25	
			Product ... / 0.16–0.27	
			Nb[C]	N 0.030–0.070
			Heat 0.06–0.10 / 0.06–0.10	
			Product ... / 0.05–0.11	
			N 0.03–0.07 / 0.035–0.070[A]	Ni 0.40 max
			Al 0.02 max / 0.020 max[A]	Al 0.02 max
			Ti 0.01 max / 0.01 max[A]	Ti 0.01 max
			Zr 0.01 max / 0.01 max[A]	Zr 0.01 max
			Sn ... / 0.010 max[A]	B 0.001–0.006
			Sb ... / 0.003 max[A]	
			B ... / 0.001 max[A]	
			Cu ... / 0.10 max[A]	
			W ... / 0.05 max[A]	
			As ... / 0.010 max[A]	
			N/Al ... / ≥ 4.0	

Grade	FP115 Heat	FP115 Product
Carbon	0.08–0.13	0.07–0.14
Manganese	0.20–0.50	0.20–0.50
Phosphorous, max	0.020 max	0.020 max
Sulfur, max	0.005 max	0.005 max
Silicon	0.15–0.45	0.15–0.45
Chromium	10.0–11.0	10.0–11.0
Molybdenum	0.40–0.60	0.37–0.63
	W 0.05 max	W 0.05 max
	V 0.18–0.25	V 0.16–0.27
	Nb[C] 0.02–0.06	Nb[C] 0.02–0.07
	N 0.030–0.070	N 0.030–0.070
	Ni 0.25 max	Ni 0.25 max
	Al 0.02 max	Al 0.02 max
	Ti 0.01 max	Ti 0.01 max
	Zr 0.01 max	Zr 0.01 max
	B 0.001 max	B 0.001 max
	Cu 0.10 max	Cu 0.10 max
	As 0.010 max	As 0.010 max
	Sn 0.010 max	Sn 0.010 max
	Sb 0.003 max	Sb 0.003 max
	N/Al ratio 4.0 min	
	CNB[B] 10.5 max	

[A] Applies to both heat and product analyses.
[B] Chromium-Nickel Balance is defined as CNB = (Cr + 6Si + 4Mo + 1.5W + 11V + 5Nb + 9Ti + 12Al) – (40C + 30N + 4Ni + 2Mn + 1Cu).
[C] The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

3.1.5 Length (Permissible Variations in Length Section of Specification A999/A999M),

3.1.6 Verification of tensile and hardness properties at mid-thickness for Grade FP91 Type 1 and Type 2 (9.2),

3.1.7 End finish (13),

3.1.8 Optional requirements (Sections 8, Supplementary Requirements S1 to S7; 13.2),

3.1.9 Test report required (Certification Section of Specification A999/A999M),

3.1.10 Specification designation, and

3.1.11 Special requirements or exceptions to this specification.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Discard:*

5.1.1 A sufficient discard shall be made from each ingot to secure freedom from injurious defects. The steel shall have a homogeneous structure.

5.2 *Manufacture:*

5.2.1 Material for forging shall consist of ingots or of blooms, billets, or solid-rolled bars forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged (Note 3) by hammering or pressing, and shall be brought as nearly as practicable to the finished shape and size by hot working.

NOTE 3—The cross-sectional area of the solid forging shall have a reduction by forging or by rolling and forging from that of the ingot in the ratio of not less than 3 to 1.

5.2.3 Unless otherwise specified, the final forging operation shall be followed by a treatment suitable to the grade as specified in 5.4.

5.3 *Machining:*

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250-µin. [6.4-µm] arithmetical average deviation (AA), terms as defined in ANSI B 46.1-1962, unless otherwise specified.

5.4 *Heat Treatment:*

5.4.1 All pipe of the grades shown in Table 1 other than FPA, FPB, FP1, FP2, FP12, FP91 Type 1 and Type 2, FP92, and FP115 shall be reheated and furnished in the full-annealed or normalized and tempered condition. If furnished in the normalized and tempered condition (Note 4), the temperature for tempering shall be 1250 °F [680 °C] or higher for Grades FP5, FP9, FP21, and FP22, and 1200 °F [650 °C] or higher for Grades FP36 and FP11.

NOTE 4—It is recommended that the temperature for tempering should be at least 100 °F [50 °C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100 °F [600 °C].

5.4.2 Pipe in Grades FPA and FPB as a final heat treatment shall be either normalized or shall be given a stress relieving treatment at 1200 to 1300 °F [650 to 705 °C]. Pipe in Grades FP1, FP2, and FP12, as a final heat treatment shall be given a stress-relieving treatment at 1200 to 1300 °F [650 to 705 °C].

NOTE 5—Certain of the ferritic steels covered by this specification tend to harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, hot-bending and other forming operations, should be followed by suitable heat treatment.

5.4.3 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP91 Type 1 and Type 2 shall be normalized and tempered by reheating within the temperature range from 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

5.4.4 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP92 shall be normalized and tempered by reheating within the temperature range of 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

5.4.5 Grade FP115 shall be normalized and tempered by reheating within the temperature range of 1920 to 2010 °F [1050 to 1100 °C] and tempered in the range of 1380 to 1455 °F [750 to 790 °C]. The rate of cooling at mid thickness from 1650 to 900 °F [900 to 482 °C] shall be no slower than 9 °F/minute [5 °C/minute].

5.5 *Repair by Welding:*

5.5.1 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

5.5.2 All repair welds in FP91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni + Mn content of all welding consumables used to weld repair FP91 Type 1 and Type 2 shall not exceed 1.0 %.

5.5.3 All repair welds in FP92 shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

5.5.4 After weld repair, Grades FP91 Type 1 and Type 2 and FP92 shall be heat treated at 1350–1470 °F [730–800 °C].

5.5.5 After weld repair, Grades FP115 shall be heat treated at 1345 to 1435 °F [730 to 780 °C].

6. Chemical Composition

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

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The

chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified.

7.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats, made in accordance with 7.1, shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

8.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in Section 7 or Section 8 does not conform to the requirements specified in Section 6 an analysis of each billet or pipe from the same heat may be made, and all billets or pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Tests for acceptance shall be made after final heat treatment of the forging.

9.2 For Grade FP91 Type 1 and Type 2, when requested by the purchaser, the tensile and hardness properties shall be met and verified on material taken from the half-thickness location.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

10.2 *Flattening Test*—For pipe NPS 14 or less, and diameter to wall thickness ratios of more than 7.0, a flattening test shall be carried out in accordance with Specification A999/A999M. A test shall be carried out on a specimen taken from one end of each length of pipe.

10.3 *Bend Test*—For pipe larger than NPS 14 or NPS where diameters to wall thickness ratio is 7.0 or less, a bend test shall be carried out in accordance with Test Methods E290. Unless otherwise specified, the test specimens shall be taken in a transverse direction. The diameter of the pin shall be ⅔ *t* for longitudinal specimens or 1⅓ *t* for transverse specimens, where *t* is the specimen thickness. The bend test specimens shall be bent at room temperature through 180° without cracking. One bend test shall be taken from one end of each length of pipe.

11. Workmanship

11.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

12. Ends

12.1 Pipe ends shall be machined as specified in the purchase order.

13. Finish

13.1 The finished pipe shall be reasonably straight and shall have a workmanlike finish.

13.2 Repair of defects by welding shall be permitted only subject to the approval of the purchaser. Defects shall be thoroughly chipped or ground out before welding. Only qualified operators and procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, shall be used. Local or full heat treatment in accordance with 5.4 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the wall thickness, piece mark, length, and additional symbol “S” if the pipe conforms to the supplementary requirements specified in Supplementary Requirements S1 to S5, and the heat number or the manufacturer’s number by which the heat can be identified. Indentation stamping, instead of stenciling, will be permitted only with the written approval of the purchaser.

14.2 For FP91, additional marking shall include the appropriate Type.

TABLE 2 Tensile Requirements

Grade	FPA	FPB	FP1, FP2	FP12	FP91 Type 1 and Type 2	FP92	FP115	All Others
Tensile strength, min; ksi [MPa]	48 [330]	60 [415]	55 [380]	60 [415]	85 [585]	90 [620]	90 [620]	60 [415]
Yield strength, min; ksi [MPa]	30 [210]	35 [240]	30 [210]	32 [220]	60 [415]	64 [440]	65 [450]	30 [210]

Grade	Elongation Requirements							
	FPA		FPB		FP91 Type 1 and Type 2 FP92 and FP115		All Others	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:								
Basic minimum elongation for wall 5/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full-section	35	25	30	17	27	18	30	20
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	13	22	14