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Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use[1]

This standard is issued under the fixed designation A 668/A 668M; 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 untreated and heat-treated carbon and alloy steel forgings for general industrial use. Other ASTM specifications for forgings are available for specific applications such as pressure vessels, railroad use, turbine generators, gearing, and others involving special temperature requirements.

1.2 Hot-rolled or cold finished bars are not within the scope of this specification.

1.3 Six classes of carbon steel and seven classes of alloy steel forgings are listed (see Section 7) , which indicates their required heat treatments, as well as mechanical properties.

1.4 Supplementary requirements of an optional nature are provided. These shall apply only when specified by the purchaser.

1.5 Appendix X1 lists the grades corresponding to the various grades of Specifications A 235, A 237, and A 243, which have been superseded by this specification.

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

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings[2]

A 654 Specification for Special Requirements for Steel Forgings and Bars for Nuclear and Other Special Applications[4]

A 788 Specification for Steel Forgings, General Requirements[2]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *hollow cylindrical forging*—a forging whose length, as measured on its longitudinal axis is more than its diameter, shall be considered as a hollow cylinder within the scope of this specification if it has been lengthened by extrusion or forged in a manner similar to that of a ring, namely, expanded in diameter on a mandrel.

3.1.2 *ring-shaped or disk-shaped forging*—a forging whose length, as measured on its longitudinal axis, is less than its diameter or main transverse dimension is considered a ring or disk within the meaning of this specification.

4. Ordering Information

4.1 When this specification is to be applied to an inquiry, contract, or order, the purchaser should furnish the following information:

4.1.1 The ordering information required by Specification A 788.

4.1.2 The class of forging desired as listed in Section 7,

4.1.3 Location(s) of areas of significant loading if test specimens are to be located in accordance with 7.1.5.5.

4.1.4 The options which may be selected as found in 5.4.2, 7.1.2, 7.3, and 14.1, and

4.1.5 Applicable supplementary requirements.

5. Materials and Manufacture

5.1 *Melting Process*—The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 *Discard*—Sufficient discard shall be made from each ingot to secure freedom from piping and undue segregation.

[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 A01.06 on Steel Forgings and Billets.

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[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] Discontinued. See 1983 *Annual Book of ASTM Standards*, Vol 01.05.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

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

5.3 *Forging Process*

5.3.1 The forging shall be brought as close as practical to finished shape and size by hot mechanical work.

5.3.2 Supplementary requirements S2, S14, and S15 may be specified by the purchaser to satisfy concerns about the utility of the proposed forging.

5.4 *Heat Treatment*:

5.4.1 All forgings, other than Class A, shall be heat treated. See Section 7.

5.4.2 Where options exist within a class, the choice of heat treatment shall be left to the discretion of the manufacturer, unless the purchaser specifies one of the available options.

6. Chemical Composition

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

6.2 The choice of chemical composition is left to the discretion of the manufacturer, unless otherwise specified by the purchaser. See Appendix X2.

6.3 *Heat Analysis*:

6.3.1 An analysis of each heat shall be made by the manufacturer. When possible, the test sample shall be taken during the pouring of the heat. If the test sample is lost or declared inadequate for chemical determinations, the manufacturer may take alternative samples from locations near the surface of an ingot or bloom, as necessary to establish the analysis.

6.3.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats shall conform to the requirements specified in Table 1 or by agreement (see 6.2).

6.4 *Product Analysis*—An analysis may be made by the purchaser from a forging representing each heat, or multiple heat if made in accordance with 6.3.2. Samples for analysis may be taken from the forging, or from a full-size prolongation at any point from the midradius to the outside diameter in the case of disk or solid forgings, or midway between the inner and outer surfaces of hollow forgings or rings, or from a test specimen. The chemical composition thus determined shall not vary from the requirements specified in Table 1 or agreed upon (see 6.2) by more than the amounts prescribed in Table 2.

7. Mechanical Properties

7.1 *Tensile Requirements*:

7.1.1 The material shall conform to the tensile properties prescribed in Table 3.

7.1.2 Tensile specimens shall be machined to the form and dimensions illustrated in Test Methods and Definitions A 370 and shall be tested in accordance with the latest issue of Test Methods and Definitions A 370.

TABLE 1 Chemical Requirements

Elements	Composition, max, %	
	Classes A to F and AH to FH	Classes G to N and GH to NH
Manganese	1.35	...
Phosphorus	0.050	0.040
Sulfur	0.050	0.040

7.1.3 *Size Classification*—The dimensions of the forging at time of heat treatment determine the size classification (see Table 3):

7.1.3.1 *Solid Forgings*—Either the as forged or rough machined diameter or thickness of solid forgings, disregarding large ends, collars, flanges, and journals, at time of heat treatment shall determine the size classification.

7.1.3.2 *Ring or Hollow Cylinder Forging*— The size classification shall be determined by its wall thickness or width, whichever is the smaller dimension of either the as forged or rough machined forging at time of heat treatment.

7.1.4 *Number of Tests*—Unless the purchaser specifies that forgings shall be furnished in accordance with the requirements of 7.3, the number of tension tests performed shall be as follows:

7.1.4.1 For all classes of heat-treated forgings with rough machined weights less than 5000 lb [2270 kg] each, one test shall be made from each size classification represented in each heat in each annealing or normalizing charge, or from each size classification in each heat in each normalizing or quenching charge represented in each tempering charge. For untreated forgings (Class A) weighing less than 5000 lb each, one test from each heat shall be made.

7.1.4.2 On all classes, for forgings with rough machined weights of 5000 lb or more, at least one test from each forging shall be made.

7.1.4.3 On all classes, for forgings with rough machined weights of 7000 lb [3180 kg] or more, two tests will be taken: on ring and disk forgings 180 ° apart; on shafts and long hollow cylinders (over 80 in. [2.0 m] in length excluding test material), one from each end and offset 180 °. Shafts and cylinder forgings 80 in. [2.0 m] or less in length (excluding test material) may have both tests located at one end 180 ° apart.

7.1.4.4 When forgings are made in multiple as a single forging, that is, forged as one piece and divided after heat treatment, the multiple forging shall be considered as one forging, and the number of tests required shall be as designated in 7.1.4.1, 7.1.4.2, and 7.1.4.3.

7.1.5 *Prolongations*:

7.1.5.1 A sufficient number of the forgings shall have prolongations for extracting specimens for testing. Locations of test specimens for various types of forgings shall be as shown in Fig. 1.

7.1.5.2 The nominal or principal outside rough machine diameter or thickness of the forgings, disregarding large ends, collars, flanges, and journals shall determine the size of the prolongations for test specimens; however, the prolongations on annealed, normalized, or normalized and tempered shafts may be extensions of the small diameter end of the shaft, as shown in Fig. 1.

7.1.5.3 For quenched forgings in Classes F, J, K, L, M, and N, the prolongations shall be sufficiently long so that the center of the gage length (for longitudinal specimens) or axis (for tangential specimens) of the tension test specimen shall be at the following locations:

(*1*) On solid round forgings, bars, or billets (see Fig. 1 (*a*)), at midradius and from the end, 3½ in. [89 mm] or ½ the diameter, whichever is less.

TABLE 2 Permissible Variations in Product Analysis

NOTE 1—Product cross-sectional area is defined as either (Area taken at right angles to the axis of the original ingot or billet):
(*a*) maximum cross-sectional area of rough machined forging (excluding boring), or
(*b*) maximum cross-sectional area of the unmachined forging, or
(*c*) maximum cross-sectional area of the billet.

Element	Unit or Maximum Specified Range, %	Permissible Variation over the Maximum Limit or Under the Minimum Limit, %				
		Up to and incl. 200 in.^{2} incl [645 to 1290 cm^2]	Over 200 in.^{2} to 400 in.^{2} incl [1290 to 2580 cm^2]	Over 400 in.^{2} to 800 in.^{2} incl [2580 to 5160 cm^2]	Over 800 in.^{2} to 1600 in.^{2} incl [5160 to 10320 cm^2]	Over 1600 in.^{2} [over 10320 cm^2]
Carbon	Up to and incl 0.25	0.03	0.03	0.04	0.05	0.05
	0.26 to 0.55	0.04	0.04	0.05	0.06	0.06
	0.56 and over	0.05	0.05	0.06	0.07	0.07
Manganese	Up to and incl 0.90	0.04	0.05	0.06	0.07	0.08
	0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	Up to and incl 0.05	0.008	0.010	0.010	0.015	0.015
Sulfur	Up to and incl 0.030	0.005	0.005	0.005	0.006	0.006
	0.030 and over	0.010	0.010	0.010	0.015	0.015
Silicon	Up to and incl 0.35	0.03	0.04	0.04	0.05	0.06
	0.35 and over	0.06	0.06	0.07	0.07	0.09
Nickel	Up to and incl 1.00	0.03	0.03	0.03	0.03	0.03
	1.01 to 2.00 incl	0.05	0.05	0.05	0.05	0.05
	2.01 to 5.30 incl	0.07	0.07	0.07	0.07	0.07
Chromium	Up to and incl 0.90	0.04	0.04	0.05	0.05	0.06
	0.91 to 2.10 incl	0.06	0.06	0.07	0.07	0.03
	2.11 to 10.00 incl	0.10	0.12	0.14	0.15	0.16
Molybdenum	Up to and incl 0.20	0.02	0.02	0.02	0.03	0.03
	0.21 to 0.40 incl	0.03	0.03	0.03	0.04	0.04
	0.41 to 1.15 incl	0.04	0.05	0.06	0.07	0.08
	1.16 to 5.50 incl	0.06	0.08	0.10	0.12	0.12
Vanadium	Up to and incl 0.10	0.01	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02	0.02
	0.26 to 0.50 incl	0.03	0.03	0.03	0.03	0.03
	0.51 to 1.25 incl	0.04	0.04	0.04	0.04	0.04

(*2*) On solid rectangular forgings, bars, or billets, at ¼ the thickness and width and from the end, 3½ in. [89 mm] or ½ the thickness, whichever is less.

(*3*) On disk forgings (see Fig. 1(*c*)) (with prolongation on OD), at midthickness and from the OD 3½ in. [89 mm] or ½ the thickness, whichever is less.

(*4*) On disk forgings (see Fig. 1(*c*)) (with prolongation on the width or thickness) 3½ in. [89 mm] or ½ the thickness, whichever is less, from any heat treated surface.

(*5*) On ring forgings (see Fig. 1(*d*)) (with prolongation on width), at midwall and from the ring face 3½ in. [89 mm] or ½ the wall thickness, whichever is less.

(*6*) On ring forgings (see Fig. 1(*d*)) (with prolongation on the OD), at midwidth and from the OD 3½ in. [89 mm] or ½ the width, whichever is less.

7.1.5.4 In place of prolongs, the manufacturer may: (*1*) elect to submit an extra forging(s) to represent each test lot; in this event, the representative forging must be made from the same heat of steel, have received the same reduction and type of hot working, be of the same nominal thickness, and have been heat treated in the same furnace charge as the forging(s) it represents; or (*2*) obtain the test specimen from the trepanned material of transverse or radial holes, provided depth is equal to or greater than the minimum depth required by 7.1.5.3.

7.1.5.5 With prior purchaser approval, test specimens may be taken 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 (2t) from any second surface. However, the test depth shall not be nearer to one heat-treated surface than ¾ in. [19 mm] and to the second heat treated surface than 1 ½ in. [38 mm]. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.1.6 Tests for acceptance shall be made after final heat treatment of the forgings.

7.1.7 Test specimens shall be parallel to the axis of the forging in the direction in which the metal is most drawn out except that rings, hollow forgings which are expanded, and disks shall be tested in the tangential direction.

7.1.8 Yield point shall be determined on carbon steel Grades A through F, and yield strength on alloy steel Grades G through N. For carbon steel grades not showing a yield point, the yield strength at 0.2 % offset shall be reported.

TABLE 3 Tensile Requirements

Class	Size, in. [mm]		Tensile Strength, min		Yield Point, Yield Strength 0.2 % Offset, min		Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %	Brinell Hardness
	Over	Not Over	psi	MPa	psi	MPa			
Carbon Steel									
A (AH) (Untreated)	...	20 [500]	47 000	325	...	...	...	...	183 max
B (BH) (Annealed, or normalized, or normalized and tempered)	...	20 [508]	60 000	415	30 000	205	24	36	120–174
C (CH) (Annealed, or normalized, or normalized and tempered)	...	12 [203]	66 000	455	33 000	230	23	36	137–183
	12 [305]	20 [508]	66 000	455	33 000	230	22	34	137–183
D (DH) (Normalized, annealed, or normalized and tempered)	...	8 [203]	75 000	515	37 500	260	24	40	149–207
	8 [203]	12 [305]	75 000	515	37 500	260	22	35	149–207
	12 [305]	20 [508]	75 000	515	37 500	260	20	32	149–207
	20 [508]		75 000	515	37 500	260	19	30	149–207
E (EH) (Normalized and tempered or double-normalized and tempered)	...	8 [203]	85 000	585	44 000	305	25	40	174–217
	8 [203]	12 [305]	83 000	570	43 000	295	23	37	174–217
	12 [305]	20 [508]	83 000	570	43 000	295	22	35	174–217
F (FH) (Quenched and tempered, or normalized, quenched and tempered)	...	4 [102]	90 000	620	55 000	380	20	39	187–235
	4 [102]	7 [178]	85 000	585	50 000	345	20	39	174–217
	7 [178]	10 [254]	85 000	585	50 000	345	19	37	174–217
	10 [254]	20 [508]	82 000	565	48 000	330	19	36	174–217
Alloy Steel									
G (GH) (Annealed, or normalized, or normalized and tempered)	...	12 [305]	80 000	550	50 000	345	24	40	163–207
	12 [305]	20 [508]	80 000	550	50 000	345	22	38	163–207
H (HH) (Normalized and tempered)	...	7 [178]	90 000	620	60 000	415	22	44	187–235
	7 [178]	10 [254]	90 000	620	58 000	400	21	42	187–235
	10 [254]	20 [508]	90 000	620	58 000	400	18	40	187–235
J (JH) (Normalized and tempered, or normalized, quenched, and tempered)	...	7 [178]	95 000	655	70 000	485	20	50	197–255
	7 [178]	10 [254]	90 000	620	65 000	450	20	50	187–235
	10 [254]	20 [508]	90 000	620	65 000	450	18	48	207–255
K (KH) (Normalized, quenched, and tempered)	...	7 [178]	105 000	725	80 000	550	20	50	212–269
	7 [178]	10 [254]	100 000	690	75 000	515	19	50	207–269
	10 [254]	20 [508]	100 000	690	75 000	515	18	48	207–269
L (LH) (Normalized, quenched, and tempered)	...	4 [102]	125 000	860	105 000	725	16	50	255–321
	4 [102]	7 [178]	115 000	795	95 000	655	16	45	235–302
	7 [178]	10 [254]	110 000	760	85 000	585	16	45	223–293
	10 [254]	20 [508]	110 000	760	85 000	585	14	40	223–293
M (MH) (Normalized, quenched, and tempered)	...	4 [102]	145 000	1000	120 000	825	15	45	293–352
	4 [102]	7 [178]	140 000	965	115 000	790	14	40	285–341
	7 [178]	10 [254]	135 000	930	110 000	758	13	40	269–331
	10 [254]	20 [508]	135 000	930	110 000	758	12	38	269–341
N (NH) (Normalized, quenched, and tempered)	...	4 [102]	170 000	1175	140 000	965	13	40	331–401
	4 [102]	7 [178]	165 000	1140	135 000	930	12	35	331–401
	7 [178]	10 [254]	160 000	1105	130 000	905	11	35	321–388
	10 [254]	20 [508]	160 000	1105	130 000	905	11	35	321–402

7.2 *Hardness Tests*—Brinell hardness tests shall be performed after heat treatment (except on Class A forgings) and rough machining on each forging weighing under 7000 lb [3180 kg] and each multiple forging made in accordance with 7.1.4.3 weighing under 7000 lb. For exceptions see 7.1.4.4 and 7.2.3.

7.2.1 The average value of the hardness readings on each forging shall fall within the hardness ranges specified in Table 3. The permissible variation in hardness in any forging over 250 lb [113 kg] shall not exceed 30 HB for Classes A through E, 40 HB for Classes F through J, 50 HB for Classes K through N.

7.2.2 At least two hardness tests shall be taken on each flat face of disks, rings, and hollow forgings over 250 lb [113 kg] approximately at midradius and 180° apart, for example, at the 3:00 and 9:00 positions on one face, and 6:00 and 12:00 positions on the opposite face. On solid forgings over 250 lb [113 kg], at least four tests shall be taken on the periphery of the forging, two at each end 180° apart.

7.2.3 For forgings 250 lb [113 kg] and less, Brinell testing shall be performed on the broken test specimens representing the heat or heats included in each heat treating charge, or in the case of untreated forgings (Class A), on the test specimen representing each heat. The results shall meet the requirements