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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 Provision, with the suffix H for certification and marking, for the supply of forgings after hardness testing only.

1.5 Supplementary requirements, including those in Specification A 788, of an optional nature are provided. These shall apply only when specified by the purchaser.

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the current classes corresponding to the various classes of Specifications A 235, A 237, and A 243, which have been superseded by this specification.

1.7 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.

1.8 Unless the order specifies the applicable ″M″ specification, the forgings shall be furnished to the inch-pound units

2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

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

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

A 788 Specification for Steel Forgings, General Requirements

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

3. Terminology

3.1 *The terminology section of Specification A 788 is applicable to this specification.*

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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.

3.2.2 *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 and General Requirements

4.1 Material supplied to this specification shall conform to the requirements of Specification A 788 which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations and additional supplementary requirements.

4.1.1 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

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

4.2.1 The ordering information required by Specification A 788.

[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] 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.**

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4.2.2 The class of forging desired as listed in Section Table 1,

4.2.3 Location(s) of areas of significant loading if test specimens are to be located in accordance with 7.1.4.5.

4.2.4 The options which may be selected as found in 5.4.2, 7.6.3, and 7.7, and

4.2.5 Any applicable supplementary requirements.

5. Materials and Manufacture

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

5.2 *Forging Process*

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

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

5.3 *Heat Treatment*:

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

5.3.2 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.

6.4 *Product Analysis*—An analysis may be made by the purchaser according to the requirements of Specification A 788. If a standard grade has been used to manufacture the forging the permissible variations in composition of Specification A 788 shall apply. If a non-standard grade of steel has been used, and composition limits have not been supplied, the product analysis can be used only to confirm the type of steel supplied.

7. Mechanical Properties

7.1 *Tensile Requirements*:

7.1.1 The material shall conform to the tensile properties prescribed in Table 2.

7.1.2 *Size Classification*—The dimensions of the forging at time of heat treatment determine the size classification (see Table 2):

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

7.1.2.1 *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.

7.1.2.2 *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.

7.1.3 *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:

7.1.3.1 For all classes of heat-treated forgings with rough machined weights less than 5000 lb [2250 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 [2250 kg] each, one test from each heat shall be made.

7.1.3.2 On all classes, for forgings with rough machined weights of 5000 lb [2250 kg] or more, at least one test from each forging shall be made.

7.1.3.3 On all classes, for forgings with rough machined weights of 7000 lb [3200 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.

7.1.3.4 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 7.1.3.1, 7.1.3.2, and 7.1.3.3.

7.1.4 *Prolongations*:

7.1.4.1 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.

7.1.4.2 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.

7.1.4.3 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. [90 mm] or ½ the diameter, whichever is less.

(*2*) On solid rectangular forgings, bars, or billets, at ¼ the thickness and width and from the end, 3½ in. [90 mm] or ½ the thickness, whichever is less.

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TABLE 2 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 [500]	60 000	415	30 000	205	24	36	120–174
C (CH) (Annealed, or normalized, or normalized and tempered)	...	12 [300]	66 000	455	33 000	230	23	36	137–183
	12 [300]	20 [500]	66 000	455	33 000	230	22	34	137–183
D (DH) (Normalized, annealed, or normalized and tempered)	...	8 [200]	75 000	515	37 500	260	24	40	149–207
	8 [200]	12 [300]	75 000	515	37 500	260	22	35	149–207
	12 [300]	20 [500]	75 000	515	37 500	260	20	32	149–207
	20 [500]		75 000	515	37 500	260	19	30	149–207
E (EH) (Normalized and tempered or double-normalized and tempered)	...	8 [200]	85 000	585	44 000	305	25	40	174–217
	8 [200]	12 [300]	83 000	570	43 000	295	23	37	174–217
	12 [300]	20 [500]	83 000	570	43 000	295	22	35	174–217
F (FH) (Quenched and tempered, or normalized, quenched and tempered)	...	4 [100]	90 000	620	55 000	380	20	39	187–235
	4 [100]	7 [175]	85 000	585	50 000	345	20	39	174–217
	7 [175]	10 [254]	85 000	585	50 000	345	19	37	174–217
	10 [250]	20 [500]	82 000	565	48 000	330	19	36	174–217
Alloy Steel									
G (GH) (Annealed, or normalized, or normalized and tempered)	...	12 [300]	80 000	550	50 000	345	24	40	163–207
	12 [300]	20 [500]	80 000	550	50 000	345	22	38	163–207
H (HH) (Normalized and tempered)	...	7 [175]	90 000	620	60 000	415	22	44	187–235
	7 [175]	10 [250]	90 000	620	58 000	400	21	42	187–235
	10 [250]	20 [500]	90 000	620	58 000	400	18	40	187–235
J (JH) (Normalized and tempered, or normalized, quenched, and tempered)	...	7 [175]	95 000	655	70 000	485	20	50	197–255
	7 [175]	10 [250]	90 000	620	65 000	450	20	50	187–235
	10 [250]	20 [500]	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 [175]	10 [250]	100 000	690	75 000	515	19	50	207–269
	10 [250]	20 [500]	100 000	690	75 000	515	18	48	207–269
L (LH) (Normalized, quenched, and tempered)	...	4 [100]	125 000	860	105 000	725	16	50	255–321
	4 [100]	7 [175]	115 000	795	95 000	655	16	45	235–302
	7 [175]	10 [250]	110 000	760	85 000	585	16	45	223–293
	10 [250]	20 [500]	110 000	760	85 000	585	14	40	223–293
M (MH) (Normalized, quenched, and tempered)	...	4 [100]	145 000	1000	120 000	825	15	45	293–352
	4 [100]	7 [175]	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 [250]	20 [500]	135 000	930	110 000	758	12	38	269–341
N (NH) (Normalized, quenched, and tempered)	...	4 [100]	170 000	1175	140 000	965	13	40	331–401
	4 [100]	7 [175]	165 000	1140	135 000	930	12	35	331–401
	7 [175]	10 [250]	160 000	1100	130 000	900	11	35	321–388
	10 [250]	20 [500]	160 000	1100	130 000	900	11	35	321–402

(*3*) On disk forgings (see Fig. 1(*c*)) (with prolongation on OD), at midthickness and from the OD 3½ in. [90 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. [90 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. [90 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. [90 mm] or ½ the width, whichever is less.

7.1.4.4 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 7.1.4.3.

7.1.4.5 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

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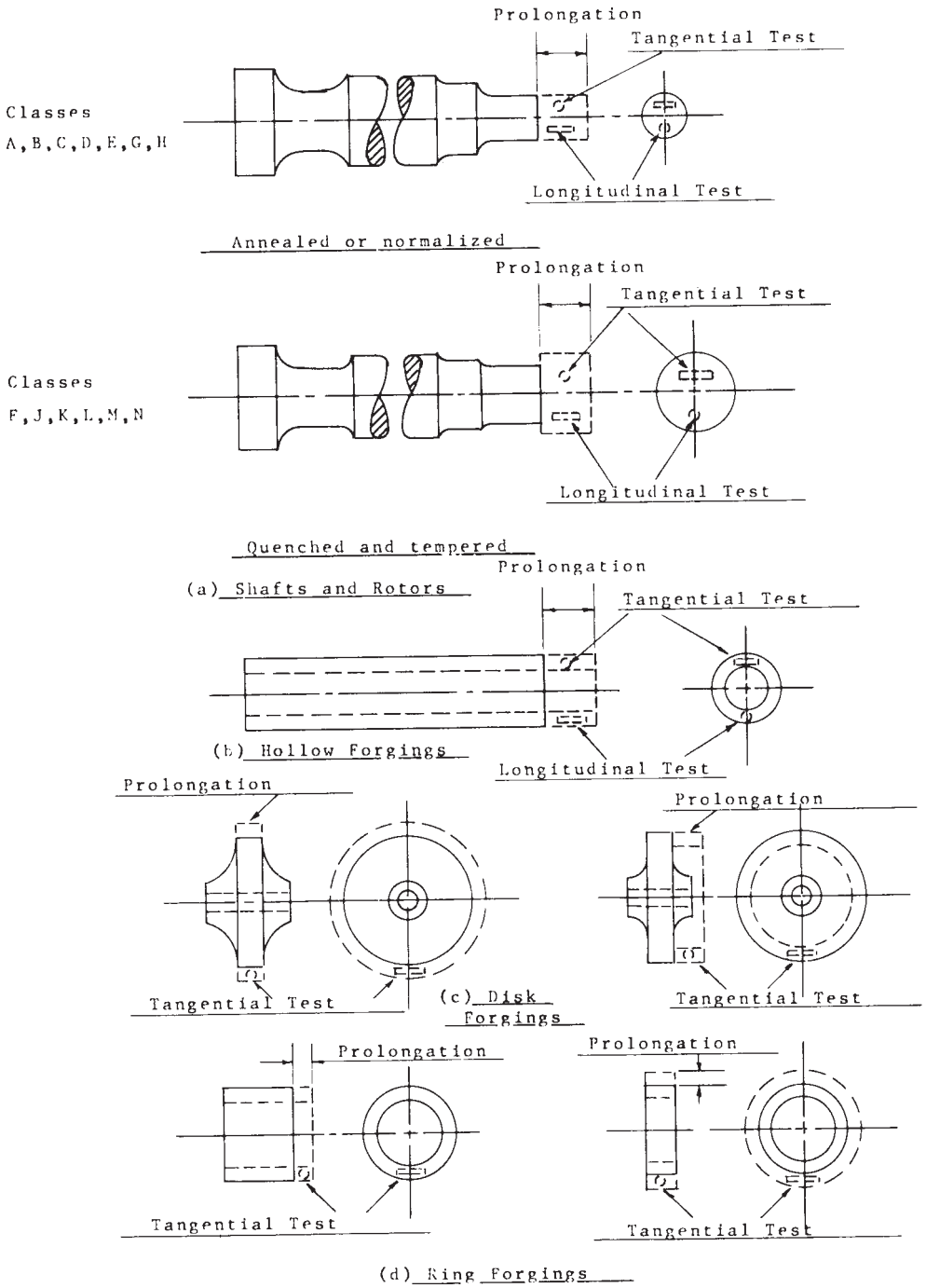


FIG. 1 Locations of Test Specimens for Various Types of Forgings

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.

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

7.1.6 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 were expanded by forging, and disks shall be tested in the tangential direction.

7.1.7 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.

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 [3200 kg] and each multiple forging made in accordance with 7.1.3.3 weighing under 7000 lb [3200 kg]. For exceptions see 7.1.3.4 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

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2. The permissible variation in hardness in any forging over 250 lb [110 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 [110 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 [110 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 [110 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 of Table 2. If the purchaser desires Brinell testing of each forging, Supplementary Requirement S11 may be used.

7.3 If so specified by the purchaser, forgings may be supplied on the basis of hardness tests alone. If this option is exercised, the class shall be identified in certification and marking with the suffix "H," that is, "AH," "BH," "CH," etc.

8. Retreatment

8.1 When heat-treated forgings are specified, and the mechanical test results of any test lot do not conform to the requirements specified, the manufacturer may retreat the lot not more than three additional times, and retests shall be made according to Section 7. Retreatment is defined as complete re-austenization. Multiple retempering is not precluded by this requirement.

8.2 When untreated forgings (Class A) are specified, and the mechanical test results of any test lot do not conform to the requirements specified, the manufacturer may anneal, normalize, or normalize and temper, one or more times, but not more than three times; and retests shall be made in accordance with Section 7. The tensile properties shall conform to the requirements for the class of forgings ordered (Class A).

9. Inspection, Rejection, and Certification

9.1 Facilities for inspection at the place of manufacture, rejection of forgings and certification shall comply with Specification A 788.

10. Product Marking

10.1 The marking requirements of Specification A 788 shall be augmented as follows.

10.2 Each forging over 250 lb [110 kg] shall be legibly stamped by the manufacturer with the manufacturer's name or trademark, the manufacturer's serial number, the specification identification number, followed by the appropriate class number and, where applicable, a standard Grade designation.

10.3 For forgings 250 lb [110 kg] and under, the purchaser may indicate the nature and location of identification marks.

10.4 The type of stamps to be used shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of 1/32 in. [0.79 mm].

11. Keywords

11.1 alloy steel forgings; carbon steel forgings; general industrial applications; heat treatment classifications; strength classifications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Chemical Composition

S1.1 The supplier shall obtain approval of the grade of steel he proposes to apply to the order and reach agreement with the purchaser on the ranges of each element specified in the composition.

S2. Special Forging Techniques

S2.1 Special forging techniques are required to produce metal flow during the hot working operation in the direction most favorable for resisting the stresses encountered in service. Verification of forging flow lines shall be by macro-etch testing of sample forgings in accordance with Method E 381.

S3. Rough Turning and Boring

S3.1 The position of any rough turning or boring in the sequence of manufacturing operations.

S4. Carbon Content for Welding

S4.1 For forgings intended for welding, the carbon content (product analysis) shall be limited to 0.35 max %.

S5. Bend Tests

S5.1 The test specimen shall withstand being bent at room temperature through 180° without cracking on the outside of the bent portion of an inside diameter of 1½ in. [40 mm].

S6. Magnetic Particle Test

S6.1 Forgings shall be magnetic particle tested in accordance with the latest issue of Test Method A 275/A 275M.

S7. Ultrasonic Test

S7.1 Forgings shall be ultrasonically tested in accordance with the latest issue of Practice A 388/A 388M.

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S8. Vacuum Treatment

S8.1 Vacuum degassed steel shall be supplied.

S9. Tensile Requirements

S9.1 When sizes larger than permitted in Table 2 are required, ductility values may be reduced from the specified values.

S9.2 Yield strengths higher than those listed in Table 2 for quenched and tempered grades may be specified.

S10. Heat Treatment

S10.1 A minimum tempering temperature shall be specified.

S11. Additional Tests

S11.1 Tests in addition to those prescribed in Section 7 may be specified.

S12. Additional Marking

S12.1 Additional identification marking or the locations of the stamping or both may be specified.

S14. Forge Procedure

S14.1 The forge procedure shall be submitted by the manufacturer to the purchaser for approval prior to production of the forging.

S15. Rough Forging Sketches

A dimensioned sketch or drawing of the proposed rough forging shall be supplied by the producer for approval before the forging is produced. This drawing or sketch shall indicate also the proposed heat treatment contour, including bores, if any, and the position of the required mechanical test coupons.

APPENDIXES

(Nonmandatory Information)

X1. COMPARISON OF SPECIFICATION A 668/A 668M VERSUS SUPERSEDED SPECIFICATIONS A 235, A 237, and A 243

X1.1 See specification comparison in Table X1.1.

TABLE X1.1 Specification Comparison

Superseded Specification and Class	Use A 668/A 668M, Class
A 235, A	A
A 235, C	B
A 235, C1	C
A 235, E	D
A 235, F	. . .
A 235, F1	E
A 235, G	F
A 237, A	G
A 237, B	. . .
A 237, C	H
A 237, C1	. . .
A 237, D	J
A 237, E	K
A 237, F	L
A 237, G	M
A 237, H	N
A 243, A	A
A 243, C	B
A 243, C1	C
A 243, E	D
A 243, F	. . .
A 243, F1	E
A 243, G	F
A 243, H	G
A 243, I	. . .
A 243, J	H
A 243, K	J
A 243, L	K
A 243, M	L
A 243, N	M
A 243, O	N

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X2. TYPICAL GRADES OF STEEL USED FOR A 668/A 668M CLASSES

X2.1 See chemical composition and class/grade guide for typical grades of steel in Tables X2.1 and X2.2, respectively.

TABLE X2.1 Chemical Composition (Maximum Weight Percentage)

Element	Grade X1	Grade X2	Grade X3	Grade X4	Grade X5	Grade X6
Carbon	0.30	0.45	0.40	0.45	0.45	0.40
Manganese	0.90	0.90	0.85	1.10	0.90	0.90
Phosphorous	0.04	0.04	0.025	0.025	0.025	0.015
Sulfur	0.04	0.04	0.025	0.025	0.025	0.015
Silicon	0.35	0.35	0.35	0.35	0.35	0.35
Nickel	. . .	. . .	3.75	. . .	2.00	2.50
Chromium	. . .	. . .	. . .	1.10	1.00	1.25
Molybdenum	. . .	. . .	. . .	0.25	0.30	0.60
Vanadium	. . .	. . .	. . .	. . .	. . .	0.20

TABLE X2.2 Class/Grade Guide

Class	Brinell Hardness	Applicable Grades
Carbon Steel		
A	183 max	X1
B	120–174	X1
C	137–183	X1, X2
D	149–207	X1, X2
E	174–217	X2
F	187–235	X2
Alloy Steel		
G	163–207	X3, X4
H	187–235	X3, X4
J	197–255	X3, X4, X5
K	212–269	X3, X5
L	255–321	X4, X5
M	293–352	X5, X6
N	331–401	X6

SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 668/A 668M-03 that may impact the use of this standard.

(1) Deletion of Table 2 and Incorporation of Section 10 with Section 4..
(2) Deletion of original sections 8, 9, 12, 13, 14 and 15.
(3) Addition of new section 9.
(4) Sections 11, and 16 renumbered as 8 and 10 respectively.
(5) New scope items 1.4 and 1.8 added and original 1.4, 1.5 and 1.6 renumbered. Supplementary requirement S13 deleted.
(1) Added 7.1.4.5, added new 4.2.3, re-numbered prior 4.1.3 and 4.1.4 to 4.1.4 and 4.1.5, respectively.

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