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American Association State Highway and Transportation Officials Standard
AASHTO No.: M 102

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

This standard is issued under the fixed designation A668/A668M; 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 A788/A788M, 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lists the current classes corresponding to the various classes of Specifications A235, A237, and A243, which have been superseded by this specification.

1.7 The values stated in either ~~inch-pound~~SI units or ~~SI~~inch-pound 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;~~ may not be exact equivalents; therefore, each system ~~must~~shall be used independently of the other. Combining values from the two systems may result in nonconformance with the ~~specification.~~ standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A388/A388M Practice for Ultrasonic Examination of Steel Forgings
A788/A788M Specification for Steel Forgings, General Requirements
E290 Test Methods for Bend Testing of Material for Ductility
E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

3. Terminology

3.1 ~~*The terminology section of Specification A788/A788M is applicable to this specification.*~~ The terminology section of Specification A788/A788M is applicable to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

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[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**

3.2.1 ~~*hollow cylindrical forging—class—*~~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.~~description of steel forgings based on heat treatment, mechanical properties and composition.

3.2.2 ~~*ring-shaped or disk-shaped forging—*~~*controlling cross section thickness (T_C)—*~~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.~~ the diameter of the largest theoretical sphere which can be inscribed within the volume of the forging.

3.2.3 *T_P*—designates prolongations which have a size other than the controlling cross section thickness (T_C).

4. Ordering Information and General Requirements

4.1 Material supplied to this specification shall conform to the requirements of Specification A788/A788M 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 A788/A788M, 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 A788/A788M~~.~~,

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 5.3.2~~5.4.2,~~, 6.1~~7.6.3,~~, and 7.3~~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~~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~~requirements 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 A788/A788M. If a standard grade has been used to manufacture the forging the permissible variations in composition of Specification A788/A788M 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.

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~~
Sulfur	0.025	0.025

7. Mechanical Properties

7.1 *Tensile Requirements:*

7.1.1 The material shall conform to the tensile properties prescribed in Table 2. See Test Methods A370.

7.1.2 ~~*Size Classification—*~~*All Forgings*—The dimensions of the controlling cross section thickness (T_C) of the forging at time of heat treatment determine the ~~size classification~~ mechanical properties to be met within each class (see Table 2~~).~~) except as noted in 7.1.4.2.

~~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.~~

TABLE 2 Tensile Requirements[A,B]

Class	~~Size,~~ Controlling Cross Section (T_C), 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 (HBW)
	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

[A] Forgings with controlling cross section thickness (T_C) in excess of 20 in. [508 mm] for all classes other than class D may be certified to Specification A668/A668M provided they meet the requirements for controlling cross sections of 20 in. [508 mm] listed in Table 2. Alternatively, the manufacturer and purchaser may agree upon the required mechanical property values as described in Supplement S9.1.

[B] Requirements presented in Table 2 are to be met at the test locations given in 7.1.4. Tests from other locations may not exhibit the property values shown in Table 2.

~~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~~ as-heat treated weights (excluding test prolongations) 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~~ as-heat treated weights (excluding test prolongations) 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~~ as-heat treated weights (excluding test prolongations) of 7000 lb [3200 kg] or more, two tests will be taken: on ring and disk forgings ~~180 °~~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 °~~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 °~~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~~Examples of test ~~specimens~~locations for various ~~types of forgings shall be as~~ forging configurations are shown in ~~Fig. 1~~Figs. 1 and 2.

NOTE 1—Figures provided demonstrate the concept of controlling cross section thickness (T_C) but do not encompass all possible test prolongation configurations which meet the requirements of Section 7.

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,~~For all forgings of non-uniform cross section in classes A, B, C, D, E, G and H: The prolongation(s) may be extensions of sections other than the controlling cross section thickness (T_C ~~normalized, or normalized~~), that is T_P ~~and tempered~~≠ T_C ~~shafts may be extensions of the small diameter end of~~ . In this case, the dimension of T_P~~the shaft, as shown in~~ shall determine the mechanical properties to be ~~Fig. 1.~~met within each class. When $T_P \neq T_C$, T_P shall not have more reduction than the smallest cross section to be qualified.

(1) For annealed, normalized, or normalized and tempered forgings in classes A, B, C, D, E, G and H the center of the gage length axis of tension test specimens shall be ¼ the controlling cross section thickness (T_C) from one surface except as noted in 7.1.4.2 (2).

(2) If the prolongation thickness (T_P) is less than the controlling cross section thickness (T_C) the center of the gage length axis of the tension test shall be ¼ of the prolongation thickness (T_P) from one surface.

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)~~ axis of the tension test specimen shall be at a minimum ¼ (T_C) from one quenched surface and 3½~~the following locations:~~ in. [90 mm] from all other quenched surfaces. The prolongation length shall be a minimum of 7 in. which has been demonstrated to be sufficient length to meet the test location requirements given above.

~~(*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.~~

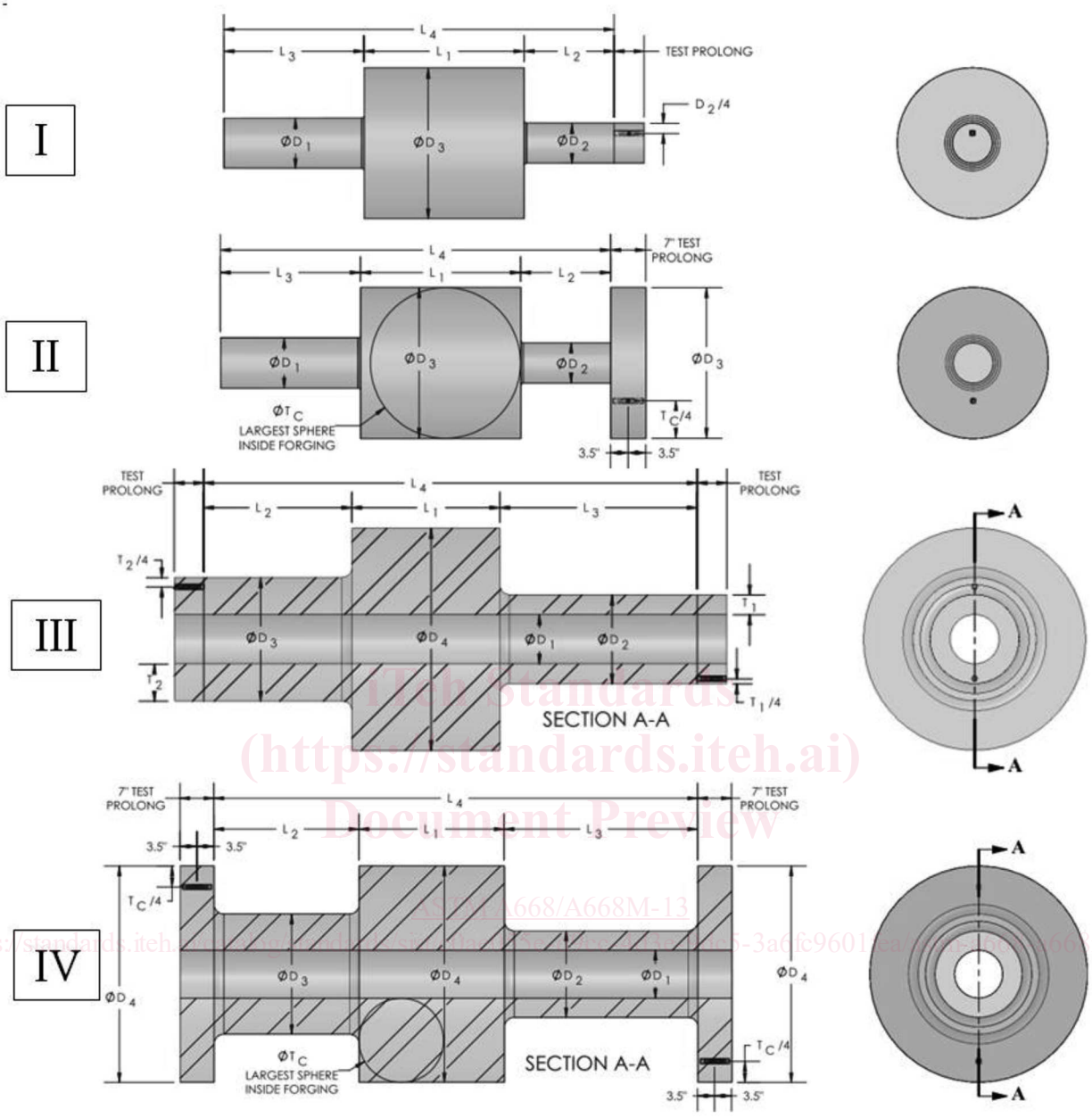
~~(*3*) On disk forgings (see Fig. 1(*c*)) (with prolongation on OD), at midthickness and from the OD 3½ in. [90 mm] or ½ the thickness, whichever is less.~~

~~(*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.~~

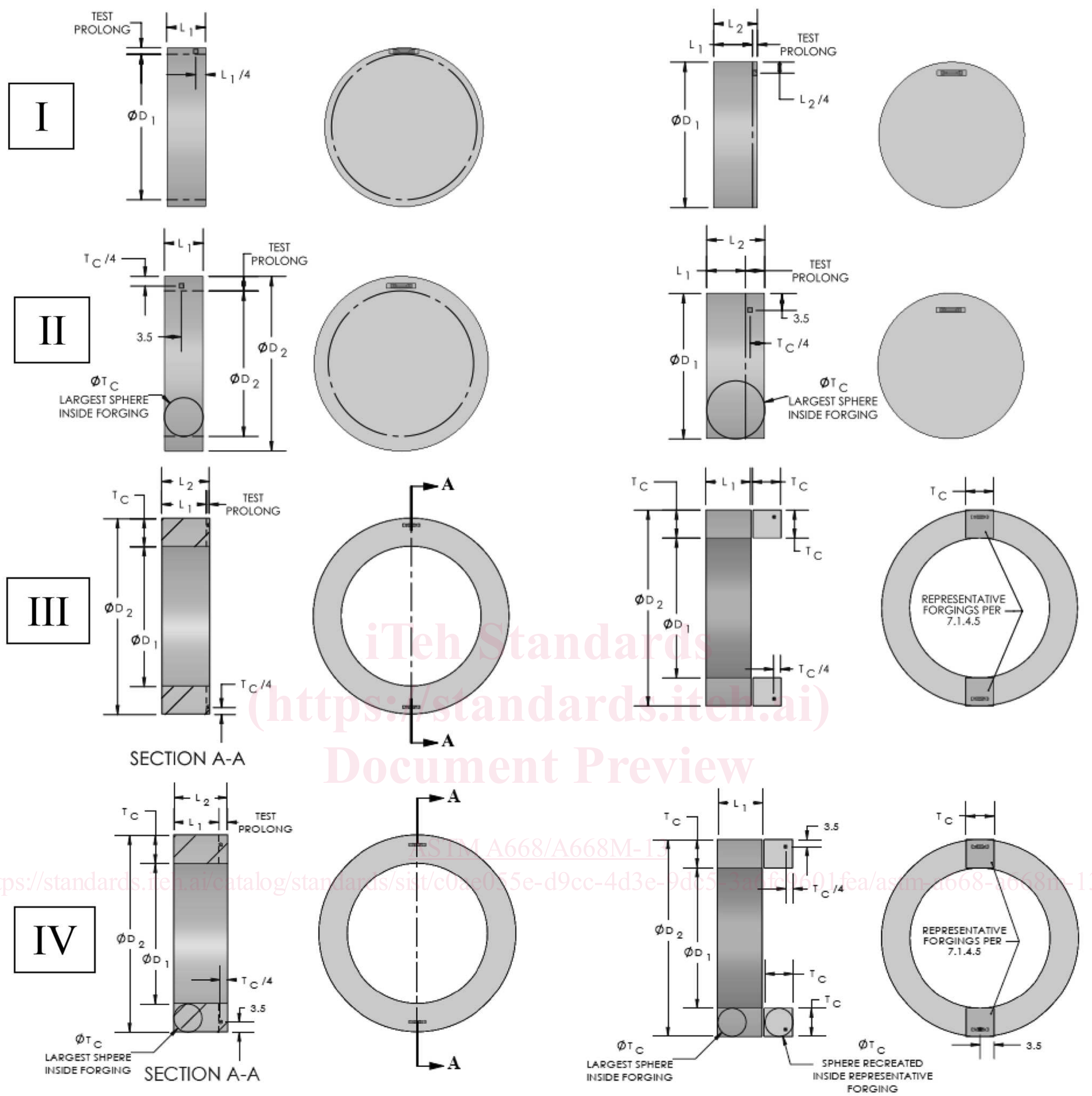
~~(*6*) On ring forgings (see Fig. 1(*d*)) (with prolongation on the OD), at midwidth and from the OD 3½ in. [90 mm] or ½ the width, whichever is less.~~

7.1.4.4 In place of ~~prolongs,~~prolongations, the manufacturer may: (*1*) elect to submit ~~an extra~~a representative 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~~ must not receive more reduction than the forging it represents, must receive the same type of hot ~~working,~~ working it represents, be of the same ~~nominal thickness,~~ controlling cross section thickness (T_C), 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~~ the required depth is met.~~7.1.4.3.~~



I: Solid forging per class A, B, C, D, E, G and H. Annealed, normalized or normalized and tempered.
Examples shown are under 80" long and under 7000 pounds, excluding prolong, at time of heat treatment
II: Solid forging per class F, J, K, L, M and N. Quenched and tempered.
Examples shown are under 80" long and under 7000 pounds, excluding prolong, at time of heat treatment
III: Hollow forging per class A, B, C, D, E, G and H. Annealed, normalized or normalized and tempered.
Examples shown are over 80" long and over 7000 pounds, excluding prolong, at time of heat treatment
IV: Hollow forging per class F, J, K, L, M and N. Quenched and tempered.
Examples shown are over 80" long and over 7000 pounds, excluding prolong, at time of heat treatment

FIG. 1 Examples of Locations of Test Specimens for Various Types of Forgings (see Note 1).



I: Disk forging per class A, B, C, D, E, G and H. Annealed, normalized or normalized and tempered.
Examples shown are under 7000 pounds, excluding prolong, at time of heat treatment
II: Disk forging per class F, J, K, L, M and N. Quenched and tempered.
Examples shown are under 7000 pounds, excluding prolong, at time of heat treatment
III: Ring forging per class A, B, C, D, E, G and H. Annealed, normalized or normalized and tempered.
Examples shown are over 7000 pounds, excluding prolong, at time of heat treatment
IV: Ring forging per class F, J, K, L, M and N. Quenched and tempered.
Examples shown are under 7000 pounds, excluding prolong, at time of heat treatment

FIG. 2 Examples of Locations of Test Specimens for Various Types of Forgings (see Note 1).