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Standard Specification for Steel, Closed-Impression Die Forgings for General Industrial Use[1]

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1. Scope

1.1 This specification covers untreated and heat-treated steel, closed-impression die forgings (Note 1) for general industrial use.

NOTE 1—For the definition of a forging, refer to Definition A 509.

1.2 The classes of forgings are as follows, the choice depending on design and stress or service to be imposed:

1.2.1 *Class CA*—Untreated, carbon steel forgings,

1.2.2 *Classes CC, CC1, and CE*—Annealed, normalized and tempered, carbon steel forgings,

1.2.3 *Class CF*—Normalized and tempered carbon steel forgings,

1.2.4 *Class CF1*—Double normalized and tempered carbon steel forgings,

1.2.5 *Class CG*—Quenched and tempered, or normalized, quenched and tempered carbon steel forgings,

1.2.6 *Class AA*—Annealed, normalized, or normalized and tempered alloy steel forgings,

1.2.7 *Classes AB and AC*—Normalized and tempered alloy steel forgings, and

1.2.8 *Classes AD, AE, AF, AG, and AH*—Normalized, quenched, and tempered alloy steel forgings.

NOTE 2—The appendix tables list recommended tolerances for a number of materials other than those covered by the above classes. The tables are for information only and the purchaser must define the condition in which he desires forgings made from materials not described above.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for[2]

A 322 Specification for Steel Bars, Alloy, Standard Grades[2]

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

A 509 Definition of Terms Relating to Steel Forging[4]

A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality[2]

A 711 Specification for Steel Forging Stock[2]

E 10 Test Method for Brinell Hardness of Metallic Materials[5]

E 23 Test Method for Notched Bar Impact Testing of Metallic Materials[5]

E 94 Guide for Radiographic Examination[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *annealing*—the forgings shall be reheated to a temperature which produces an austenitic structure and then cooled slowly. A furnace charge thus treated is termed an annealing charge.

3.1.2 *cooling prior to heat treatment*—after forging and before reheating for heat treatment, the forgings shall be cooled to provide substantially complete transformation of austenite.

3.1.3 *normalizing*—the forgings shall be reheated to a temperature which produces an austenitic structure and then withdrawn from the furnace and cooled in air. A furnace charge thus treated is termed a normalized charge.

3.1.4 *quenching*—the forgings shall be reheated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium by spraying or immersion. A group thus treated is termed a quenching charge.

3.1.5 *tempering*—the forgings shall be reheated to and held at the proper temperature, which will be below the austenitic transformation range, and then cooled under suitable conditions. A furnace charge thus treated is termed a tempering charge.

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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 *1982 Annual Book of ASTM Standards*, Vol 01.05.

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

[6] *Annual Book of ASTM Standards*, Vol 03.03.

4. Ordering Information

4.1 The purchaser shall specify in the inquiry, contract, and order the class of steel desired; and any exceptions, modifications, or agreements with regard to the provisions of this specification.

5. Process

5.1 The steel shall be made by any or all of the following processes: open-hearth, electric-furnace, or basic-oxygen.

6. Discard

6.1 Sufficient discard shall be made to secure freedom from piping and undue segregation.

7. Forging Manufacture

7.1 Manufacturing practice shall be in accordance with accepted commercial procedures designed to produce forgings free from harmful surface discontinuities, roughness, excessive scale, fins, indications of overheating, or other injurious discontinuities. The manufacturer may be required to certify that furnaces used for all heating operations for forging and heat treating are controlled to minimize scaling and decarburization and equipped with suitable controls.

8. Chemical Requirements

8.1 The steel shall conform to the requirements for chemical composition listed in Table 1 on alloy steel bars in Specification A 322 or in Table 1 on carbon steel bars in Specification A 576. Other limits may be specified for carbon steels using the ranges and limits in Table 2 of Specification A 576 or for alloy steels in Table 4 of A 29/A 29M.

8.2 The limits of elements other than those listed above may be agreed upon by the manufacturer and purchaser.

9. Dimensional Tolerances

9.1 Tolerances for impression die forgings (Appendix X1) shall apply.

10. Finish

10.1 The forgings shall be free of injurious discontinuities.

11. Heat Analysis

11.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur, and silicon; also the alloying elements agreed on in accordance with Section8. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and the percentages of phosphorus and sulfur, and also the alloying elements shall conform to the requirements specified and agreed upon in Section 8.

12. Product Analysis

12.1 An analysis may be made by the purchaser from a forging representing each heat. Drillings for analysis may be taken from the forging or from a full-size prolongation, at any point midway between the center and surface when solid, or between the inner and outer surfaces of the wall when bored; or turnings may be taken from the test specimen. The chemical composition thus determined shall not vary from the requirements specified in Section 8 by more than the amounts prescribed for product analysis in Specification A 711.

13. Tensile Properties

13.1 The material shall conform to the requirements for tensile properties prescribed in Table 1 when tested in accordance with the latest issue of Test Methods and Definitions A 370.

13.2 The yield strength shall be determined by the offset method, using an offset value of 0.2 % of the gage length, or by the total extension under load method, using an extension value of 0.005 in./in. (0.5 %) for Classes AD and AE, 0.006 in./in. (0.6 %) for Classes AF and AG, and 0.007 in./in. (0.7 %) for Class AH.

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

14. Number of Tests

14.1 One tension test shall be made for each heat of steel for each heat treat charge. For untreated forgings (Class CA) no tension tests shall be made except when specified in the purchase order and then one tension test shall be run on each heat.

14.2 If any test specimen fails because of mechanical reasons, such as testing equipment failure or improper specimen preparation, it may be discarded and another specimen taken.

14.3 For the purpose of tests of heat-treated forgings, the necessary extra forgings shall be provided. When it is impracticable to provide extra forgings for test purposes, test bars may be made from the billet or bar, provided they are given approximately the same reduction and heat treatment as the forgings and also represent the maximum cross section of the forging.

15. Retests

15.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may reheat treat such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made in accordance with Section 14.

15.2 If the percentage of elongation of any tension test specimen is less than that specified in Table 1 and any part of the fracture is outside of the middle half of the gage length, a retest shall be allowed.

15.3 If a test specimen fails to meet the specified mechanical property requirements due to a discontinuity other than a rupture, crack, or flake, a retest shall be allowed.

16. Test Specimen

16.1 Location, size, and number of test specimens shall be specified by the purchaser. Unless otherwise stated in the contract or purchase order, test bars may be separately forged or swaged from the same bars, billets, or blooms used in manufacture of the forgings. The percentage reduction given the forged tests bars shall not be greater than the minimum

TABLE 1 Tensile Requirements

Class	Solid Diameter or Thickness, in. (mm)		Bored Wall Thickness in. (mm)				Tensile Strength, min, ksi (MPa)	Yield Strength, min, ksi (MPa)	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
	Over	Not Over	Over		Not Over					
AA (Annealed, normalized, or	...	12 (305)	...		...		80 (550)	50 (345)	24	40
normalized, and tempered)	12 (305)	20 (508)	...		...		80 (550)	50 (345)	22	38
AB (Normalized and tempered)	...	7 (178)	...		4	(102)	80 (550)	55 (380)	26	52
	7 (178)	20 (508)	4	(102)	7½	(191)	80(550)	55(380)	24	50
AC (Normalized and tempered)	...	7 (178)	...		4	(102)	90 (620)	60 (415)	22	44
	7 (178)	20 (508)	4	(102)	7½	(191)	90 (620)	58 (400)	21	42
AD (Normalized, quenched, and	...	7 (178)	...		3½	(89)	96 (655)	70 (485)	20	50
tempered)	7 (178)	10 (254)	½	(89)	5	(127)	90 (620)	65 (450)	20	50
AE (Normalized, quenched, and	...	7 (178)	....		3½	(89)	105 (725)	80 (550)	20	50
tempered)	7 (178)	10 (254)	3½	(89)	5	(127)	100 (690)	75 (520)	19	50
	10 (254)	20 (508)	5	(127)	8	(203)	95 (655)	70 (485)	19	50
AF (Normalized, quenched, and	...	4 (102)	...		2	(51)	125 (860)	105 (725)	16	50
tempered)	4 (102)	7 (178)	2	(51)	3½	(89)	115 (795)	96 (655)	16	45
	7 (178)	10 (254)	3½	(89)	5	(127)	110 (760)	85 (585)	16	45
AG (Normalized, quenched, and	...	4 (102)	...		2	(51)	145 (1000)	120 (830)	15	45
tempered)	4 (102)	7 (178)	2	(51)	3½	(89)	140 (965)	115 (795)	14	40
	7 (178)	10 (254)	3½	(89)	5	(127)	135 (930)	110 (760)	13	40
AH (Normalized, quenched, and	...	4 (102)	...		2	(51)	170 (1175)	140 (965)	13	40
tempered)	4 (102)	7 (178)	2	(51)	3½	(89)	165 (1140)	135 (930)	12	35
	7 (178)	10 (254)	3½	(89)	5	(127)	160 (1105)	130 (895)	11	35
	(No Physical Requirements except as covered by 13.1.)									
CA (Untreated)	...	...	...		...		...	...	...	...
CC (Annealed, normalized, or	...	12 (305)	...		...		60 (415)	30 (205)	25	36
normalized, and tempered)	12 (305)	...	...		...		60 (415)	30 (205)	24	36
CC1 (Annealed, normalized, or	...	12 (305)	...		...		66 (455)	33 (230)	23	36
normalized and tempered)	12 (305)	20 (508)	...		...		66 (455)	33 (230)	22	34
CE (Annealed, normalized, or	...	8 (203)	...		...		75 (520)	37 (290)	24	40
normalized and tempered)	8 (203)	12 (305)	...		...		75 (520)	37 (290)	22	35
	12 (305)	20 (508)	...		...		75 (520)	37 (290)	20	32
	20 (508)	...	...		...		75 (520)	37 (290)	19	30
CF (Normalized and tempered)	...	8 (203)	...		...		80 (550)	40 (275)	22	36
	8 (203)	12 (305)	...		...		80 (550)	40 (275)	21	33
	12 (305)	20 (508)	...		...		80 (550)	40 (275)	20	31
CF1 (Double normalized and tempered)	...	8 (203)	...		...		85 (585)	44 (305)	25	40
	8 (203)	12 (305)	...		...		83 (570)	43 (295)	23	37
	12 (305)	20 (508)	...		...		83 (570)	43 (295)	22	35
CG (Quenched, and tempered or	...	4 (102)	...		2	(51)	90 (620)	55 (380)	20	39
normalized, quenched and tempered)	8 (203)	7 (178)	2	(51)	3½	(89)	85 (585)	50 (345)	20	39
	7 (178)	10 (254)	3½	(89)	5	(127)	85 (585)	50 (345)	19	37
	...	...	5	(127)	10	(254)	82 (565)	48 (330)	19	36

amount of reduction given the forging itself. The test bars shall be heat treated with the forgings they represent. The manufacturer may elect to submit an extra forging in lieu of forged test bars.

16.2 Unless otherwise specified, the axis of the specimen shall be located at any point midway between the center and the surface of solid forgings or at any point midway between the inner and outer surfaces of the wall of hollow forgings, and shall be parallel to the direction of maximum metal flow.

16.3 The specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370 for the standard or subsize round tension test specimens.

17. Cleaning

17.1 The forgings shall be furnished in a scale-free condition. Unless otherwise specified, the manufacturer may clean by acid pickling, grit blasting, sand blasting, or other abrasive method.

18. Marking

18.1 Marking of forgings shall be specified by the purchaser.

19. Inspection

19.1 Unless otherwise specified, the inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to those parts of the manufacturer's plant that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the plant.

20. Rejection

20.1 Any rejection based on tests made in accordance with Section 10 shall be reported to the manufacturer within 60 days from the receipt of samples by the purchaser.

20.2 Material that shows injurious discontinuities subsequent to its acceptance at the manufacturer's plant will be rejected, and the manufacturer shall be notified.

21. Certification

21.1 A certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report stating that the material has been sampled, tested, and inspected in accordance with the specified provisions of the specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

22. Repair of Forgings

22.1 Forgings shall not be weld repaired. Grinding to remove surface discontinuities will be permitted unless otherwise specified by the purchaser.

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 specified by purchaser.

S1. Magnetic Particle Test

S1.1 When magnetic particle inspection of forgings is required, the specific method, the areas to be inspected, and the standards of acceptability shall be specified by purchaser.

S2. Grain Flow

S2.1 When a specific pattern of grain flow is required by the purchaser, a sample forging shall be sectioned as specified. The section shall be ground and subjected to acid etching, using the type of acid, temperature and time of etching agreed upon to reveal flow lines. The section may be preserved using a coating of mineral oil or clear lacquer.

S3. Microscopical Test

S3.1 When microscopical examination is specified, the steel shall be inspected by utilizing samples cut from the undistorted portion of tension test specimens. Requirements for number of microscopical tests, grain size, cleanliness, or microstructure shall be specified by purchaser.

S4. Impact Test

S4.1 When impact tests are required, the type of specimen, number of tests, and standards for acceptance shall be specified by the purchaser. Reference shall be made to Test Method E 23.

S5. Ultrasonic Tests

S5.1 When ultrasonic tests are required, details as to procedure and standards shall be specified by the purchaser.

S6. Radiographic Tests

S6.1 When radiographic tests are required, the number of tests, location, and ASTM standards of acceptance shall be specified by the purchaser. Reference shall be made to Practice E 94.

S7. Brinell Hardness

S7.1 When hardness is required, Brinell hardness tests of sample forgings from each furnace charge of heat treated forgings shall be conducted. Number of samples per charge shall be specified by the purchaser. Reference should be made to the latest issue of Test Method E 10.

APPENDIXES

(Nonmandatory Information)

X1. FORGINGS PRODUCED ON HAMMERS AND PRESSES

X1.1 Units of Measure

X1.1.1 Where direct tolerances are not provided, use Table X1.1 in converting to fractional units of measure after making computations.

TABLE X1.1 Units of Measure

Dimensions, ft (m)		Units of Measure to the Closest
Over	Under	
...	2 (0.61)	1⁄32 in.
2 (0.61)	5 (1.52)	1⁄16 in.
5 (1.52)	10 (3.05)	1⁄8 in.
10 (3.05)	...	1⁄4 in.

X1.2 Length and Width Tolerances

X1.2.1 Length and width tolerances represent variations in dimensions measured parallel to the fundamental parting line of the dies. Normally, they are combined with tolerances for die wear.

X1.2.1.1 *Tolerance*—The length and width tolerance is ±0.003 in./in. and applies to all dimensions of length and

width including diameters. This tolerance includes allowance for shrinkage, die sinking, and die polishing variations.

X1.2.1.2 *Units of Measure*—Length and width tolerances, normally combined with tolerances for die wear, are expressed as fractions of an inch, in units of 1/32 in. or greater as shown in Table X1.1. Decimals used in computing tolerances are totaled, rounded off to two places after the decimal point, then converted to the next higher fractional unit of measure.

X1.3 Die Wear Tolerances

X1.3.1 Die wear varies according to the material forged and the shape of the forging. Consequently, die wear tolerances for various materials are applied in addition to length and width tolerances on dimensions pertaining to forged surfaces only. Die wear tolerances do not apply on center-to-center dimensions.

X1.3.1.1 *Tolerance*—Die wear tolerances for all *external* length, width, and diameter dimensions are computed by multiplying the *greatest external length or outside diameter* (measured parallel to the fundamental parting line of the dies) by the appropriate factor in Table X1.2 and are then combined with *plus* values of length and width tolerances. Die wear tolerances on *external* dimensions are expressed as *plus* values only.

X1.3.1.2 Die wear tolerances for all *internal* length, width and diameter dimensions are also computed by multiplying the *greatest external length or outside diameter* (measured parallel to the fundamental parting line of the dies) by the appropriate factor in Table X1.2, but are then combined with the *minus* values of length and width tolerances. Die wear tolerances on *internal* dimensions are expressed as *minus* values only.

X1.3.1.3 Allowances for die wear occurring on dimensions measured perpendicular to the fundamental parting line of the dies are included in die closure tolerances.

X1.3.1.4 Die wear tolerances, per surface, on both external and internal dimensions are one half the computed amount.

X1.3.1.5 *Units of Measure*—Die wear tolerances combined with length and width tolerances are expressed as fractions of an inch in units of 1/32 in. or greater as shown in Table X1.1. Decimals used in computing tolerances are totaled, rounded off to two places after the decimal point, then converted to the next higher fractional unit of measure.

X1.4 Die Closure Tolerances

X1.4.1 Die closure tolerances relate to variations in thickness of forgings as affected by the closing of the dies and die wear, and pertain to variations in dimensions crossing the fundamental parting line.

X1.4.1.1 *Tolerance*—Die closure tolerances on forgings having no portions extending more than 6 in. (152 mm) from the parting line are based on the projected area of the forging at the trim line—not including flash, but including all areas to be subsequently punched out. Except as explained in the following paragraph, they are applied as plus tolerances only and are applicable to the thickness of the forging at all sections. (See Table X1.3.)

X1.4.1.2 Tolerances on extremities of forgings extending perpendicularly *more* than 6 in. from the parting line include the die closure tolerance, and, *in addition*, a length tolerance of ±0.003 in./in. This tolerance is added to that derived from Table X1.3, but applies only to such extremities.

X1.4.1.3 *Units of Measure*—Die closure tolerances are expressed as fractions of an inch in units of 1/32 in. or greater. When decimals are used in computing tolerances, they are rounded off to two places after the decimal point, then converted to the next higher fractional unit of measure.

TABLE X1.2 Die Wear Tolerances

Materials	Factor (per inch)
Carbon	0.004
Low Alloy	0.005
400 Series Stainless	0.006
300 Series Stainless	0.007
Super Alloy	0.008
Titanium	0.009
Refractory Material	0.012
2014 Aluminum	0.004
7075 Aluminum	0.007
Magnesium	0.006
Brass	0.002
Copper	0.002

X1.5 Match Tolerances

X1.5.1 Match tolerances relate to displacement of a point in one die half from the corresponding point in the opposite die half in any direction parallel to the fundamental parting line of the dies. Match tolerances are applied separately and independently of all other tolerances. Where possible, measurements are made at areas of the forging unaffected by wearing of the dies.

X1.5.1.1 *Tolerance*—Match tolerances are based on weight of the forging after trimming and are expressed as fractions of an inch according to Table X1.4.

X1.5.1.2 *Measuring for Match Tolerances*— In cases where measurements for determining match tolerances must be made from surfaces of the forging where uneven wearing of the dies has caused surplus stock, accuracy depends on making the proper allowances for these wear-caused surpluses, and eliminating their influence from the computation.

X1.5.1.3 *Units of Measure*—Match tolerances are measured in units of 1/64 in. or greater.

X1.6 Flash Extension Tolerances

X1.6.1 Flash extension tolerances are based on the weight of the forging after trimming and relate to the amounts of flash extension. Flash is measured from the body of the forging to the trimmed edge of the flash.

X1.6.2 *Tolerance*—Flash extension tolerances are expressed in fractions of an inch according to Table X1.5.

X1.7 Straightness Tolerances

X1.7.1 Straightness tolerances relate to deviations of surfaces and centerlines from the specified contour as caused primarily by manipulation of the piece in post-forging processes and, in addition, by the effects of cooling from the forging operation, both of which may produce slight and gradual variations in straightness.

X1.7.2 Since the general shape of the forging determines the effect of cooling and post-forging manipulation on straightness,

TABLE X1.3 Die Closure Tolerances

NOTE 1—Tabulated figures are plus values only, expressed in inches.

Materials	Area at the Trim Line Flash not included, expressed in in.^{2}(cm^2)						
	10 (65) and under	Over 10 to 30 (65 to 194), incl	Over 30 to 50 (194 to 323), incl	Over 50 to 100 (323 to 645), incl	Over 100 to 500 (645 to 3225), incl	Over 500 to 1000 (3225 to 6450), incl	Over 1000 (6450)
Carbon, low alloys	1/32	1/16	3/32	1/8	5/32	3/16	1/4
400 series stainless	1/32	1/16	3/32	1/8	3/16	1/4	5/16
300 series stainless	1/16	3/32	1/8	5/32	3/16	1/4	5/16
Super alloys, titanium	1/16	3/32	1/8	3/16	1/4	5/16	3/8
Aluminum, magnesium	1/32	1/32	1/16	3/32	1/8	3/16	1/4
Refractory alloys	3/32	1/8	5/32	3/16	1/4	5/16	3/8

TABLE X1.4 Match Tolerances

NOTE 1— Tabulated figures are amounts of displacement, expressed in inches, of a point in one die-half from the corresponding point in the opposite die-half in any direction parallel to the parting line of the dies.

Materials	Weights of Forgings After Trimming, lb (kg)								
	Less than 2 (0.91)	Over 2 to 5 (0.91 to 2.3), incl	Over 5 to 25 (2.3 to 11.3), incl	Over 25 to 50 (11.3 to 22.7), incl	Over 50 to 100 (22.7 to 45.4), incl	Over 100 to 200 (45.4 to 90.6), incl	Over 200 to 500 (90.6 to 226.5), incl	Over 500 to 1000 (226.5 to 453.0), incl	Over 1000 (453.0)
Carbon, low alloys	customarily negotiated with purchaser	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16
Stainless steels		1/32	3/64	1/16	3/32	1/8	5/32	3/16	1/4
Super alloys, titanium		1/32	3/64	1/16	3/32	1/8	5/32	3/16	1/4
Aluminum, magnesium		1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16
Refractory alloys		1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8

TABLE X1.5 Flash Extension Tolerance

NOTE 1—Tabulated figures are ranges of flash extension, expressed in inches.

Weights of Forgings After Trimming, lb (kg)	Materials				
	Carbon & Low Alloy	Stainless	Super Alloys and Titanium	Aluminum & Magnesium	Refractory Alloy
10 (4.5) and under	0 to 1/32	0 to 1/16	0 to 1/16	0 to 1/32	0 to 1/8
Over 10 to 25 (4.5 to 11.3), incl	0 to 1/16	0 to 3/32	0 to 3/32	0 to 1/16	0 to 3/16
Over 25 to 50 (11.3 to 22.7), incl	0 to 3/32	0 to 1/8	0 to 1/8	0 to 3/32	0 to 1/4
Over 50 to 100 (22.7 to 45.4), incl	0 to 1/8	0 to 3/16	0 to 3/16	0 to 1/8	0 to 5/16
Over 10 to 200 (45.4 to 90.6), incl	0 to 3/16	0 to 1/4	0 to 1/4	0 to 3/16	0 to 3/8
Over 200 to 500 (90.6 to 226.5), incl	0 to 1/4	0 to 5/16	0 to 5/16	0 to 1/4	0 to 1/2
Over 500 to 1000 (226.5 to 453.0), incl	0 to 5/16	0 to 3/8	0 to 3/8	0 to 5/16	0 to 5/8
Over 1000 (453.0)	0 to 3/8	0 to 1/2	0 to 1/2	0 to 3/8	0 to 3/4

four classes of shape have been selected as guides in choosing appropriate straightness tolerances. Agreement between purchaser and forging engineer on tolerances and inspection methods may be desirable where the forging is not easily classified according to shape and may be subject to a combination of straightness tolerances. Straightness tolerances are applied independently of, and in addition to, all other tolerances.

X1.7.3 It is contemplated that, at times, straightening operations may be required in order to achieve the tolerances indicated in the following text. These tolerances are not intended to apply to refractory alloys, high-density alloys, titanium, and some stainless steels. Straightness tolerances for forgings of such materials are best determined on the basis of each individual forging design, since the configuration substantially influences the tendency of a forging to deviate from the specified contour. Straightness tolerances for these special forgings are commonly agreed upon by buyer and seller in advance of production.

X1.7.4 *Units of Measure*—Straightness tolerances are expressed as fractions of an inch in units of 1/32 in. or greater, as shown in Table X1.1. Decimals used in computing tolerances are rounded off to two places after the decimal point, then converted to the next higher fractional unit of measure.

X1.7.5 *Tolerances and Applications (*Table X1.6*)*:

X1.7.5.1 *Class A Shapes (Elongated*—Long in relation to width and height) Tolerance: 0.003 in./in. of the greatest dimension.

X1.7.5.2 *Class B Shapes (Flat, Relatively Thin) Tolerance*—Straightness tolerance for Class B shapes as shown in Table X1.7 below.

X1.7.5.3 *Class C Shapes (Thin, Flat Shapes with Appreciable Protrusion at Right Angles to the Parting Line) Tolerance*—Straightness tolerance on the flat disc portion of