Designation: A 521/A 521M – 06

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

This standard is issued under the fixed designation A 521/A 521M; 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 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 General Requirements Specification A 788/A 788M.

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

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

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

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

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

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

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

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

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

1.3 Unless the order specifies the applicable "M" specification designation, the forgings shall be furnished with the inch-pound units.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall 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:* [2]

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

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

A 322 Specification for Steel Bars, Alloy, Standard Grades

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 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

A 788/A 788M Specification for Steel Forgings, General Requirements

A 921/A 921M Specification for Steel Bars, Microalloy, Hot-Wrought, Special Quality, for Subsequent Hot Forging

E 3 Guide for Preparation of Metallographic Specimens

E 45 Test Methods for Determining the Inclusion Content of Steel

E 94 Guide for Radiographic Examination

E 112 Test Methods for Determining Average Grain Size

E 340 Test Method for Macroetching Metals and Alloys

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

E 407 Practice for Microetching Metals and Alloys

3. Ordering Information and General Requirements

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

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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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supplementary requirements. Failure to comply with the requirements of Specification A 788/A 788M constitutes nonconformance with this specification

3.2 In addition to the ordering information required by Specification A 788/A 788M, the purchaser may require that the tolerances stated in the appendices to this specification shall apply.

3.3 If the requirements of this specification should conflict with the requirements of A 788/A 788M, then the requirements of this specification shall prevail.

4. Forging Manufacture

4.1 Sufficient discard shall be taken from the ingot or forging stock to secure freedom from piping and undue segregation.

4.2 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, burning, or other injurious conditions. 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.

4.3 Heat treatment, if required, shall be in accordance with the ordered Grade description.

5. Chemical Requirements

5.1 Depending on the forging size, type of heat treatment, and the requirements of the purchaser, the chemical composition shall be as specified by the purchaser. To assist in this choice attention is drawn to the chemical requirements of Specification A 576 for carbon steels, Specification A 322 for alloy steels, and Specification A 29/A 29M for both carbon and alloy steels; however, the purchaser may wish to specify more restrictive sulfur and phosphorous limits than are provided in these specifications.

5.2 For microalloyed forgings, forging stock to Specification A 921/A 921M may be used.

5.3 Attention is drawn to the supplementary requirements included in Specification A 788/A 788M regarding special chemical requirements.

5.4 The heat and product analyses requirements of Specification A 788/A 788M shall apply.

6. Metallurgical Requirements

6.1 Provision has been made, through the use of supplementary requirements in Specification A 788/A 788M and this specification, for the purchaser to specify preferred grain flow and limits for grain size as well as any microscopic examination requirements.

7. Dimensional Tolerances

7.1 The purchaser may specify tolerances for impression die forgings according to Appendix X1 or Appendix X2 as appropriate.

8. Tensile Properties

8.1 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.

8.2 The yield strength shall be determined by the offset method, using an offset value of 0.2 % of the gauge length, or by the total extension under load method, using an extension value of 0.005 in./in. [0.005 mm/mm] (0.5 %) for Grades AD and AE, 0.006 in./in. [0.006 mm/mm] (0.6 %) for Grades AF and AG, and 0.007 in./in. [0.007 mm/mm] (0.7 %) for Grade AH.

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

9. Number of Tests and Orientation

9.1 Unless otherwise specified, one tension test shall be made for each heat of steel for each heat treat charge. For untreated forgings (Grade CA) no tension tests need be made unless when specified in the purchase order, when one tension test shall represent each heat.

9.2 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 same billet or bar material, provided they represent the maximum cross section of the forging, do not exceed the production forging reduction, and are heat treated with the forgings they represent.

9.3 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.

10. Test Specimen

10.1 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 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.

10.2 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.

10.3 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.

11. Cleaning

11.1 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.

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TABLE 1 Tensile Requirements

Grade	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 [300]	...		...		80 [550]	50 [345]	24	40
normalized, and tempered)	12 [300]	20 [500]	...		...		80 [550]	50 [345]	22	38
AB (Normalized and tempered)	...	7 [175]	...		4	[100]	80 [550]	55 [380]	26	52
	7 [175]	20 [500]	4	[100]	7½	[190]	80 [550]	55 [380]	24	50
AC (Normalized and tempered)	...	7 [175]	...		4	[100]	90 [620]	60 [415]	22	44
	7 [175]	20 [500]	4	[100]	7½	[190]	90 [620]	58 [400]	21	42
AD (Normalized, quenched, and	...	7 [175]	...		3½	[85]	96 [655]	70 [485]	20	50
tempered)	7 [175]	10 [250]	3½	[85]	5	[125]	90 [620]	65 [450]	20	50
AE (Normalized, quenched, and	...	7 [175]	....		3½	[85]	105 [725]	80 [550]	20	50
tempered)	7 [175]	10 [250]	3½	[85]	5	[125]	100 [690]	75 [520]	19	50
	10 [250]	20 [500]	5	[125]	8	[200]	95 [655]	70 [485]	19	50
AF (Normalized, quenched, and	...	4 [100]	...		2	[50]	125 [860]	105 [725]	16	50
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	115 [795]	96 [655]	16	45
	7 [175]	10 [250]	3½	[85]	5	[125]	110 [760]	85 [585]	16	45
AG (Normalized, quenched, and	...	4 [100]	...		2	[50]	145 [1000]	120 [830]	15	45
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	140 [965]	115 [795]	14	40
	7 [175]	10 [250]	3½	[85]	5	[125]	135 [930]	110 [760]	13	40
AH (Normalized, quenched, and	...	4 [100]	...		2	[50]	170 [1175]	140 [965]	13	40
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	165 [1140]	135 [930]	12	35
	7 [175]	10 [250]	3½	[85]	5	[125]	160 [1105]	130 [895]	11	35
CA (Untreated)	No tensile requirement except as covered by 8.1									
CC (Annealed, normalized, or	...	12 [300]	...		...		60 [415]	30 [205]	25	36
normalized, and tempered)	12 [300]	...	...		...		60 [415]	30 [205]	24	36
CC1 (Annealed, normalized, or	...	12 [300]	...		...		66 [455]	33 [230]	23	36
normalized and tempered)	12 [300]	20 [500]	...		...		66 [455]	33 [230]	22	34
CE (Annealed, normalized, or	...	8 [200]	...		...		75 [520]	37 [290]	24	40
normalized and tempered)	8 [200]	12 [300]	...		...		75 [520]	37 [290]	22	35
	12 [300]	20 [500]	...		...		75 [520]	37 [290]	20	32
	20 [500]	...	...		...		75 [520]	37 [290]	19	30
CF (Normalized and tempered)	...	8 [200]	...		...		80 [550]	40 [275]	22	36
	8 [200]	12 [300]	...		...		80 [550]	40 [275]	21	33
	12 [300]	20 [500]	...		...		80 [550]	40 [275]	20	31
CF1 (Double normalized and tempered)	...	8 [200]	...		...		85 [585]	44 [300]	25	40
	8 [200]	12 [300]	...		...		83 [570]	43 [295]	23	37
	12 [300]	20 [500]	...		...		83 [570]	43 [295]	22	35
CG (Quenched, and tempered or	...	4 [100]	...		2	[50]	90 [620]	55 [380]	20	39
normalized, quenched and tempered)	8 [200]	7 [175]	2	[50]	3½	[85]	85 [585]	50 [345]	20	39
	7 [175]	10 [250]	3½	[85]	5	[125]	85 [585]	50 [345]	19	37
	...	...	5	[125]	10	[250]	82 [565]	48 [330]	19	36

12. Keywords

12.1 alloy steel; carbon steel; closed die; forging tolerances; heat treated; impression die; Steel Forgings

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 areas to be inspected, and the acceptance standards shall be specified by purchaser.

S1.2 Unless otherwise required by the purchaser, Test Method A 275/A 275M shall be used.

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.

S2.2 Unless otherwise specified by the purchaser, Method E 381 or Test Method E 340 shall be used.

S3. Microscopic Examination

S3.1 When microscopical examination is specified, the steel shall be inspected by utilizing samples cut from the undistorted

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portion of tension test specimens. Requirements for number of microscopical tests, grain size, cleanliness, or microstructure shall be specified by purchaser.

S3.2 For grain size determination Test Methods E 112 or the grain size provisions of Specification A 29/A 29M shall be used, and the grain size requirement shall be as specified by the purchaser.

S3.3 For non-metallic inclusion rating Test Methods E 45 shall be used, and the acceptance limits shall be specified by the purchaser.

S3.4 Guide E 3 and Practice E 407 shall be used for the determination of the microstructure. Acceptance criteria shall be specified by the purchaser.

S4. Impact Test

S4.1 Impact testing in accordance with Test Methods A 370 shall be done on specimens taken adjacent to the tension test. The test temperature and acceptance criteria shall be as specified by the purchaser.

S5. Ultrasonic Examination

S5.1 Ultrasonic examination shall be conducted in accordance with Practice A 388/A 388M unless otherwise specified by the purchaser who will also specify the acceptance criteria.

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 Guide E 94.

S7. Brinell Hardness

S7.1 When hardness is required, Brinell hardness tests taken in accordance with Test Methods A 370 shall be made of sample forgings from each furnace charge of heat-treated forgings, or from an 8 h shift for continuous furnaces. The number of samples per charge and location of the hardness impressions shall be specified by the purchaser.

S7.2 The acceptance criteria shall be specified by the purchaser, but shall be consistent both with the tensile properties specified in Table 1, and the relative locations of the tension test specimens and the specified surfaces to be hardness tested.

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.

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. [±0.003 mm/mm] 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 [millimetre], in units of 1/32 in. [0.75 mm] 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

TABLE X1.1 Units of Measure

Dimensions, ft [m]		Units of Measure to the Closest
Over	Under	
...	2 [0.6]	1/32 in. [0.75 mm]
2 [0.6]	5 [1.5]	1/16 in. [1.5 mm]
5 [1.5]	10 [3]	1/8 in. [3 mm]
10 [3]	...	1/4 in. [6 mm]

TABLE X1.2 Die Wear Tolerances

Materials	Factor per inch or millimetre
Carbon	0.004
Low Alloy	0.005
400 Series Stainless	0.006
300 Series Stainless	0.007
Super Alloy	0.008

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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 [millimetre] in units of 1/32 in. [0.75 mm] 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. [150 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. [150 mm] from the parting line include the die closure tolerance, and, *in addition*, a length tolerance of ±0.003 in./in. [±0.003 mm/mm]. 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. [1.0 mm] 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.

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 [millimetre] 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. [0.50 mm] 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, 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.

TABLE X1.3 Die Closure Tolerances

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

Materials	Area at the Trim Line, expressed in in.^{2} [cm^2]. Flash not included.						
	10 [6.5] and under	Over 10 to 30 [6.5 to 190], incl	Over 30 to 50 [190 to 315], incl	Over 50 to 100 [315 to 650], incl	Over 100 to 500 [650 to 3250], incl	Over 500 to 1000 [3250 to 6500], incl	Over 1000 [6500]
Carbon, low alloys	1/32 [0.75]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]
400 series stainless	1/32 [0.75]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	3/16 [4.5]	1/4 [6]	5/16 [7.5]
300 series stainless	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]	5/16 [7.5]
Super alloys	1/16 [1.5]	3/32 [2.25]	1/8 [3]	3/16 [4.5]	1/4 [6]	5/16 [7.5]	3/8 [9]

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TABLE X1.4 Match Tolerances

NOTE—Tabulated figures are amounts of displacement, expressed in inches [millimetres], 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 [1]	Over 2 to 5 [1 to 2.5], incl	Over 5 to 25 [2.5 to 10], incl	Over 25 to 50 [10 to 20], incl	Over 50 to 100 [20 to 40], incl	Over 100 to 200 [40 to 80], incl	Over 200 to 500 [80 to 200], incl	Over 500 to 1000 [200 to 400], incl	Over 1000 [400]
Carbon, low alloys	customarily negotiated with purchaser	1/64 [0.4]	1/32 [0.75]	3/64 [1.15]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]
Stainless steels		1/32 [0.75]	3/64 [1.15]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]
Super alloys		1/32 [0.75]	3/64 [1.15]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]

TABLE X1.5 Flash Extension Tolerance

NOTE—Tabulated figures are ranges of flash extension, expressed in inches [millimetres]

Weights of Forgings After Trimming, lb [kg]	Materials		
	Carbon & Low Alloy	Stainless	Super Alloys
10 [5] and under	0 to 1/32 [0.75]	0 to 1/16 [1.5]	0 to 1/16 [1.5]
Over 10 to 25 [5 to 10], incl	0 to 1/16 [1.5]	0 to 3/32 [2.25]	0 to 3/32 [2.25]
Over 25 to 50 [10 to 25], incl	0 to 3/32 [2.25]	0 to 1/8 [3]	0 to 1/8 [3]
Over 50 to 100 [25 to 50], incl	0 to 1/8 [3]	0 to 3/16 [4.5]	0 to 3/16 [4.5]
Over 100 to 200 [50 to 100], incl	0 to 3/16 [4.5]	0 to 1/4 [6]	0 to 1/4 [6]
Over 200 to 500 [100 to 250], incl	0 to 1/4 [6]	0 to 5/16 [7.5]	0 to 5/16 [7.5]
Over 500 to 1000 [250 to 500], incl	0 to 5/16 [7.5]	0 to 3/8 [9]	0 to 3/8 [9]
Over 1000 [500]	0 to 3/8 [9]	0 to 1/2 [13]	0 to 1/2 [13]

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. [0.75 mm] 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. [0.003 mm/mm] 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.

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 Class C shapes is computed first. It is considered separately from the tolerance on the protruding portion and is determined in an identical manner as for Class B shapes using Table X1.7. Straightness tolerance on protuberance is 0.003 in./in. [0.003 mm/mm] of length.

X1.7.5.4 *Class D Shapes (Massive, Block-type Forgings) Tolerance*—Since departures from the specified configuration are seldom caused by subsequent handling, straightness tolerances are not provided. Where tolerances are desired, agreement between purchaser and forging engineer is normally reached before production proceeds.

X1.8 Surface Tolerances

X1.8.1 Surface tolerances relate to depth of dressouts and scale pits on the forging, based on purchaser's specification or drawing.

X1.8.1.1 *Tolerances and Conditions*—Localized dressouts or scale pits are commonly allowed on surfaces to be finish-machined unless purchaser's specification or drawing states otherwise. Where purchaser specifies stock for machining,

TABLE X1.6 Classes of Shapes

NOTE 1—For use in selecting appropriate Straightness Tolerances.

Class	Shape of Forging	Examples
A	Elongated—Length dimensions great in relation to width and height	long connecting rods, shafts, levers, etc.
B	Flat, relatively thin	disc, plates, etc.
C	Flat, relatively thin, with appreciable protrusion at right angles to the parting line	wear plates, crawler track shoes, disc with hub, etc.
D	Massive block-type forgings with neither length, nor width, nor thickness being predominant	hydraulic pump bodies, high pressure steam chests, etc

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TABLE X1.7 Straightness Tolerances, Class B Shapes

Materials	Area at the Trim Line, expressed in in.^{2} [cm^2]. Flash not included.						
	10 [65] and under	Over 10 to 30 [65 to 195], incl	Over 30 to 50 [195 to 325], incl	Over 50 to 100 [325 to 645], incl	Over 100 to 500 [645 to 3225], incl	Over 500 to 1000 [3225 to 6450], incl	Over 1000 [6450]
Carbon, low alloy	1/32 [0.75]	1/16 [1.5]	3/32 [2.25]	1/8 3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]
400 series stainless	1/32 [0.75]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	3/16 [4.5]	1/4 [6]	5/16 [7.5]
300 series stainless	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]	3/16 [4.5]	1/4 [6]	5/16 [7.5]

dressouts or scale pits are commonly permitted to within 1/16 in. [1.5 mm] of the finished surface or to within one-half of the stock allowance, whichever is smaller.

X1.8.1.2 Where surfaces of forgings are intended for use in "as forged" condition, dressouts or scale pits are commonly permitted on these surfaces to a depth equal to one-half of the die closure tolerance.

X1.9 Draft Angle Tolerances

X1.9.1 Draft angle tolerances apply to all draft angles, relate to variation from draft angle specifications, and are commonly measured as an addition to tolerances for die wear.

X1.9.1.1 *Tolerance*—Draft angle tolerances are +2° and −1° on all draft angles, unless modified by prior agreement between buyer and seller.

X1.10 Finish Allowances for Machining

X1.10.1 Finish allowance refers to the amount of material that is to be machined from the forging to obtain the finished part. Forging dimensions are commonly analyzed independently, with consideration given to all applicable tolerances, in making certain that a minimum desired clean-up exists after the forging is completed. (See Table X1.8.)

TABLE X1.8 Finish Allowances

Greatest Dimension		Minimum Finish Stock per Surface in. [mm]
Over, in. [mm]	But Not Over, in. [mm]	
...	8 [200]	1/16 [1.5]
8 [200]	16 [400]	3/32 [2.25]
16 [400]	24 [600]	1/8 [3]
24 [600]	36 [900]	5/32 [3.75]
36 [900]	...	3/16 [4.5]

X2. FORGINGS PRODUCED ON FORGING MACHINES (UPSETTERS)

X2.1 Length Tolerances

X2.1.1 Length tolerances relate to variations in dimensions measured parallel to the axis of the stock and apply to all intermediate and over-all dimensions of length *except* flange thickness dimensions and internal length (gap) dimensions between flanges (see X2.2). Length tolerances include allowances for die wear, shrinkage, die sinking, and die polishing variations.

X2.1.2 *Tolerance*—Length tolerances are plus values only, expressed in fractions of an inch according to Table X2.1.

X2.2 Flange Tolerances

X2.2.1 Flange tolerances relate to variations in flange thickness measured parallel to the axis of the stock. When more than one flange is formed, these tolerances also apply to the dimension (gap) between flanges. Flange tolerances are applied separately and independently of other tolerances.

X2.2.1.1 *Tolerance*—Tolerances for flange thickness and dimensions (gaps) between flanges are such that the effect is to add stock on both internal and external dimensions. The amount of flange tolerance is dependent on the flange diameter (see Table X2.2).

X2.2.1.2 When two flanges are formed, the tolerance on the dimension (gap) between them is a minus tolerance only, with a value identical to the thickness tolerance for the flange nearest the unforged stem.

X2.2.1.3 Flange tolerances are shown in Table X2.2.

X2.3 Diameter Tolerances

X2.3.1 Diameter tolerances relate to variation in dimensions measured perpendicularly to the axis of the stock, and are applied separately for each of a forging's diameters and only to those diameters formed in the heading tool or dies.

X2.3.2 Diameter tolerances are commonly applied and measured in a plane other than that described by the parting line of the forging.

X2.3.3 Permissible variations in diameter on *unforged stem portions* of the forging are commonly governed by steel mill tolerances. Tolerance provisions for shear-cut ends and slight irregularities in diameter on the unforged stem caused by grip dies are commonly determined by special agreement between buyer and seller.

X2.3.4 These tolerances apply only to forgings with circular shapes. Tolerances for non-circular forgings are customarily determined by special agreement between buyer and seller in advance of production.

X2.3.4.1 *Tolerance*—Tolerances for all external forged diameters are expressed as plus tolerances only, according to Table X2.3.

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X2.3.4.2 Tolerances for internal diameters of holes formed by the heading tool are commonly +0 in.; −1/16 in. [+0 mm; −1.5 mm].

X2.4 Match Tolerances

X2.4.1 Match tolerances relate to the amount of die displacement in a direction parallel to the parting line of the grip dies. These tolerances are applied independently of, and in addition to, all other tolerances.

X2.4.2 *Tolerance*—Match tolerances are expressed as fractions of an inch in units of 1/64 in. [0.4 mm] or greater, according to Table X2.4. They are based on the weight of the forging exclusive of the weight of the unforged stem. The weight of the stem is deducted from the weight of the forging *before* Table X2.4 is used.

X2.5 Concentricity Tolerances

X2.5.1 Concentricity tolerances apply to contours formed by the heading tool and relate to variations of the axis of the contour from the axis of the stock. This tolerance is commonly applied only to contours of a depth not less than one diameter. Concentricity tolerances are applied independently of, and in addition to, match tolerances.

X2.5.1.1 *Tolerance*—Concentricity tolerances are expressed in fractions of an inch [millimetre] as total indicator readings (TIR), according to Table X2.5.

X2.6 Straightness Tolerances

X2.6.1 Straightness tolerances relate to deviations of the centerline of the stem and body of the forging from the true centerline as caused by manipulation of the piece after forging, and by the effects of cooling from the forging operation—both of which may produce slight and gradual variations in straightness.

X2.6.1.1 *Tolerance*—Straightness tolerances on the original bar stock as provided by the material suppliers commonly apply.

X2.7 Draft Angle Tolerances

X2.7.1 When draft angles are required on a forging, the size of the angles is generally dependent on the contour of the forging and is therefore commonly determined by agreement between buyer and seller.

X2.7.2 Draft angle tolerances apply to all draft angles and relate to variation from draft angle specifications.

X2.7.3 *Tolerance*—Draft angle tolerances are +2° and −1° on all draft angles, unless modified by prior agreement between buyer and seller.

X2.8 Radii Tolerances

X2.8.1 Radii tolerances relate to variation from purchaser's radii specifications on all fillet radii and on corner radii where draft is not subsequently removed by trimming or punching.

X2.8.1.1 *Tolerance*—Radii tolerances are plus or minus one-half the specified radii, except where corner radii are affected by subsequent removal of draft, in which case the minus tolerance is commonly modified to allow a square corner to be formed.

X2.9 Surface Tolerances

X2.9.1 Surface tolerances relate to depth of dressouts and scale pits on the forging, based on purchaser's specification or drawing.

X2.9.1.1 *Tolerances and Conditions*—Localized dressouts or scale pits are commonly allowed on surfaces to be finish-machined unless purchaser's specification or drawing states otherwise. Where purchaser specifies stock for machining, dressouts or scale pits are commonly permitted to within 1/16 in. [1.5 mm] of the finished surface or to within one-half of the stock allowance, whichever is smaller.

X2.9.1.2 Where surfaces of forgings are intended for use in "as forged" condition, dressouts or scale pits are commonly permitted on these surfaces to a depth equal to one-half of the die closure tolerance.

X2.10 Finish Allowances for Machining

X2.10.1 Finish allowance refers to the amount of material that is to be machined from the forging to obtain the finished part. Forging dimensions are analyzed independently, with consideration given to all applicable tolerances, in making certain that a minimum desired clean-up exists after the forging is completed.

X2.10.1.1 *Allowances*—Table X2.6 indicates finish allowances commonly applied.

TABLE X2.1 Length Tolerances

NOTE—Tabulated figures are plus values only and apply to overall and intermediate dimensions of length, except flange thickness and gap dimensions.

Length Dimensions		Tolerances	
Over, in. [mm]	But Not Over, in. [mm]	Intermediate Length, in. [mm]	Over-All Length, in. [mm]
...	3 1/8 [80]	1/32 [0.75]	1/16 [1.5]
3 1/8 [80]	6 1/4 [155]	1/16 [1.5]	3/32 [2.25]
6 1/4 [155]	9 5/16 [230]	3/32 [2.25]	1/8 [3]
9 5/16 [230]	12 1/2 [315]	1/8 [3]	1/8 [3]
12 1/2 [315]	15 5/8 [400]	5/32 [3.75]	5/32 [3.75]
15 5/8 [400]	18 3/4 [460]	3/16 [4.75]	3/16 [4.75]
18 3/4 [460]	21 7/8 [550]	7/32 [5.25]	7/32 [5.25]
21 7/8 [550]	25 [625]	1/4 [6]	1/4 [6]
25 [625]	...	Commonly determined by special agreement between buyer and seller in advance of production	

TABLE X2.2 Flange Tolerances

NOTE—Based on diameters of flange (or flanges) formed.

Diameters		Tolerances	
Over, in. [mm]	But Not Over, in. [mm]	Plus, in. [mm]	Minus[A]
...	7 [175]	1/16 [1.5]	...
7 [175]	...	3/32 [2.25]	...

[A] Determined individually as defined in X2.2.

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TABLE X2.3 Tolerances on Forged Diameters

Diameters		Tolerances	
Over, in. [mm]	But Not Over, in. [mm]	Plus, in. [mm]	Minus
...	2 [50]	1/32 [0.75]	...
2 [50]	7 [175]	1/16 [1.5]	...
7 [175]	...	3/32 [2.25]	...

TABLE X2.4 Match Tolerances

NOTE—Tabulated figures are amounts of die displacement in a direction parallel to the parting line of the grip dies, expressed in inches [millimetres].

Materials	Weights of Forgings, lb [kg]					
	10 [4.5] and under	Over 10 to 25 [4.5 to 11], incl	Over 25 to 50 [11 to 22], incl	Over 50 to 100 [22 to 45], incl	Over 100 to 200 [45 to 90], incl	Over 200 to 500 [90 to 225], incl
Carbon and low alloy	1/64 [0.4]	1/64 [0.4]	3/64 [1.2]	1/16 [1.5]	3/32 [2.25]	1/8 [3]
Stainless steels	1/32 [0.75]	3/64 [1.2]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]
Super alloys	1/32 [0.75]	3/64 [1.2]	1/16 [1.5]	3/32 [2.25]	1/8 [3]	5/32 [3.75]

TABLE X2.5 Concentricity Tolerances on Holes

Depth of Hole		Total Indicator Reading (Tolerance)
Over, in. [mm]	But Not Over, in. [mm]	
...	8 [200]	1/8 [3] TIR
8 [200]	12 [300]	5/32 [3.75] TIR
12 [300]	...	3/16 [4.5] TIR

TABLE X2.6 Finish Allowances

Greatest Diameter		Minimum Finish Stock per Surface, in. [mm]
Over, in. [mm]	But Not Over, in. [mm]	
...	2 [50]	1/16 [1.5]
2 [50]	8 [200]	3/32 [2.25]
8 [200]	...	1/8 [3]

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 521 – 03) that may impact the use of this standard. (Approved Sept. 1, 2006.)

(*1*) Converted to dual format, with revisions to the SI values in the text and tables.

(*2*) Added reference to continuous furnaces in S7.

(*3*) Corrected Grade CG in Table 1.

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