



Designation: A 521 – 03

Standard Specification for Steel, Closed-Impression Die Forgings for General Industrial Use¹

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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 General Requirements Specification **A 788**.

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

2. Referenced Documents

2.1 *ASTM Standards*:²

A 29/A 29M Specification for Steel Bars, Carbon and

Alloy, Hot-Wrought and Cold-Finished, 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 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

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

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

A 711 Specification for Steel Forging Stock

A 788 Specification for Steel Forgings General Requirements

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

E 3 Guide for Preparation of Metallographic Specimens

E 45 Practice for Determining the Inclusion Content of Steel

E 94 Guide for Radiographic Examination

E 112 Test Methods for Determining the Average Grain Size

E 340 Macro Etching Metals and Alloys

E 381 Method of Macroetch Testing, Inspection and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

E 407 Practice for Microetching of 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**, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, product analysis variations, marking, certification and additional supplementary requirements. Failure to comply with the requirements of Specification **A 788** constitutes non-conformance with this specification

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

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.



3.3 If the requirements of this specification should conflict with the requirements of [A 788](#), 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 [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](#) may be used.

5.3 Attention is drawn to the supplementary requirements included in Specification [A 788](#) regarding special chemical requirements.

5.4 The heat and product analyses requirements of [A 788](#) shall apply.

6. Metallurgical Requirements

6.1 Provision has been made, through the use of supplementary requirements in Specification [A 788](#) 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 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 gage length, or by

the total extension under load method, using an extension value of 0.005 in./in. (0.5 %) for Grades AD and AE, 0.006 in./in. (0.6 %) for Grades AF and AG, and 0.007 in./in. (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.

12. Keywords

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



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 normalized, and tempered)	...	12 (305)	...	...	80 (550)	50 (345)	24	40
AB (Normalized and tempered)	12 (305)	20 (508)	...	...	80 (550)	50 (345)	22	38
AC (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
AD (Normalized, quenched, 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
AE (Normalized, quenched, and tempered)	...	7 (178)	...	3½ (89)	96 (655)	70 (485)	20	50
	7 (178)	10 (254)	½ (89)	5 (127)	90 (620)	65 (450)	20	50
AF (Normalized, quenched, and tempered)	...	7 (178)	...	3½ (89)	105 (725)	80 (550)	20	50
	7 (178)	10 (254)	3½ (89)	5 (127)	100 (690)	75 (520)	19	50
AG (Normalized, quenched, and tempered)	10 (254)	20 (508)	5 (127)	8 (203)	95 (655)	70 (485)	19	50
	...	4 (102)	...	2 (51)	125 (860)	105 (725)	16	50
AH (Normalized, quenched, and 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
CA (Untreated)	...	4 (102)	...	2 (51)	145 (1000)	120 (830)	15	45
	4 (102)	7 (178)	2 (51)	3½ (89)	140 (965)	115 (795)	14	40
CC (Annealed, normalized, or normalized, and tempered)	7 (178)	10 (254)	3½ (89)	5 (127)	135 (930)	110 (760)	13	40
	...	4 (102)	...	2 (51)	170 (1175)	140 (965)	13	40
CC1 (Annealed, normalized, or normalized and 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
CE (Annealed, normalized, or normalized and tempered)	...	12 (305)	...	...	No tensile requirement except as covered by 8.1			...
CF (Normalized and tempered)	12 (305)	20 (508)	...	...	60 (415)	30 (205)	25	36
	...	8 (203)	...	...	60 (415)	30 (205)	24	36
CF1 (Double normalized and tempered)	12 (305)	20 (508)	...	...	66 (455)	33 (230)	23	36
	...	8 (203)	...	...	66 (455)	33 (230)	22	34
CG (Quenched, and tempered or normalized, quenched and tempered)	8 (203)	12 (305)	...	...	75 (520)	37 (290)	24	40
	12 (305)	20 (508)	...	...	75 (520)	37 (290)	22	35
CH (Normalized and tempered)	20 (508)	...	...	...	75 (520)	37 (290)	20	32
	...	8 (203)	...	...	80 (550)	40 (275)	22	36
CI (Normalized and tempered)	8 (203)	12 (305)	...	...	80 (550)	40 (275)	21	33
	12 (305)	20 (508)	...	...	80 (550)	40 (275)	20	31
CJ (Normalized and tempered)	...	8 (203)	...	...	85 (585)	44 (305)	25	40
	8 (203)	12 (305)	...	...	83 (570)	43 (295)	23	37
CK (Normalized and tempered)	12 (305)	20 (508)	...	...	83 (570)	43 (295)	22	35
	...	4 (102)	...	2 (51)	90 (620)	55 (380)	20	39
CL (Normalized 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
CM (Normalized and tempered)	...	...	5 (127)	10 (254)	82 (565)	48 (330)	19	36

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 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 Methods E 381 or 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

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 Method 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 method E 45 shall be used, and the acceptance limits shall be specified by the purchaser.

S3.4 Test Methods E 3 and 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 A 388 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 Practice E 94.

S7. Brinell Hardness

S7.1 When hardness is required, Brinell hardness tests taken in accordance with Test Method A 370 shall be made of sample forgings from each furnace charge of heat treated forgings. 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.

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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. 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.

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.

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