Designation: A 350/A 350M – 00b

An American National Standard

Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components[1]

This standard is issued under the fixed designation A 350/A 350M; 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[2] covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ASME and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 4.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation heat treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—Refer to Test Methods and Definitions A 370 for notes on significance of notched-bar impact testing.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[4]

A 788 Specification for Steel Forgings, General Requirements[3]

E 165 Test Method for Liquid Penetrant Examination[5]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[6]

2.2 *MSS Standard:*

MSS-SP 25 Standard Marking System for Valves, Fittings, Flanges and Unions[7]

2.3 *ASME Standards:*

Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code[8]

B 16.5 Steel Pipe Flanges and Flanged Fittings[8]

B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings[8]

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[8]

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded[8]

B 16.30 Unfired Pressure Vessel Flange Dimensions[8]

B 16.34 Valves-Flanged, Threaded, and Welding End[8]

B 16.47 Large Diameter Steel Flanges[8]

2.4 *AWS Standards:*

A 5.1 Mild Steel Covered Arc-Welding Electrodes[9]

A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes[9]

2.5 *API Standards:*[10]

600 Steel Gate Valves with Flanged or Butt-Welding Ends

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-350 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

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

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

[7] Available from the Manufacturer's Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.

[8] Available from ASME International, Three Park Avenue, New York, NY 10016–5990.

[9] Available from American Welding Society, 550 LeJeune Rd., P.O. Box 351040, Miami, FL 33135.

[10] Available from American Petroleum Institute, 1220 L Street N.W., Washington, DC 20005.

602 Compact Design Carbon Steel Gate Valves for Refinery Use
605 Large Diameter Carbon Steel Flanges

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number, grade, and class if applicable (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See Table 1 footnotes, 6.1.3.5, 8.1, 13.1, 13.2, and 14.2).

4. Manufacture

4.1 *Melting Process*—The steel shall be produced by any of the following primary processes: open-hearth, basic oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting (ESR), or vacuum-arc remelting (VAR).

4.1.1 The steel shall be fully killed, fine-grain practice.

4.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

4.2 *Discard*—A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

4.3 *Forging Process*:

4.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

4.3.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

4.3.3 Except for flanges of all types, hollow, cylindrically-shaped parts may be machined from rolled bar or seamless tubular materials provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, may be machined from hot-rolled or forged bar up through and including NPS4. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.4 *Heat Treatment*:

4.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

4.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or in the normalized and tempered, or in the quenched and tempered condition described by the following procedures:

4.4.2.1 *Normalize*—Heat to a temperature that produces an austenitic structure, holding sufficient time to attain uniform temperature throughout. Cool uniformly in still air.

4.4.2.2 *Normalize and Temper*—Subsequent to normalize, reheat to 1100°F [590°C] minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min. Cool in still air.

4.4.2.3 *Quench and Temper*—The procedure for quenching shall consist of either (*1*) fully austenitizing the forgings followed by quenching in a suitable liquid medium or (*2*) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered by reheating to a temperature between 1100°F [590°C] and the lower transformation temperature, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness but in no case less than 30 min. Cool in still air.

4.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation heat treated condition or in the quenched-and-precipitation heat treated condition. The heat treatment procedures shall be as follows:

4.4.3.1 *Normalized-and-Precipitation Heat Treated*—Heat to a temperature in the range from 1600 to 1725°F [870 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than 1/2 h, and remove from the furnace and cool in air. Subsequently, heat to a temperature in the range from 1000 to 1200°F [540 to 650°C], soak at the temperature for not less than 1/2 h, and cool at any convenient rate.

4.4.3.2 *Quenched-and-Precipitation Heat Treated*—Heat to

TABLE 1 Chemical Requirements[†]

Element	Composition, wt. %						
	Grade LF1	Grade LF2	Grade LF3	Grade LF5	Grade LF6	Grade LF9	Grade LF787
Carbon, max	0.30	0.30	0.20	0.30	0.22	0.20	0.07
Manganese	0.60–1.35	0.60–1.35	0.90 max	0.60–1.35	1.15–1.50	0.40–1.06	0.40–0.70
Phosphorus, max	0.035	0.035	0.035	0.035	0.025	0.035	0.025
Sulfur, max	0.040	0.040	0.040	0.040	0.025	0.040	0.025
Silicon[A]	0.15–0.30	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.30	...	0.40 max
Nickel	0.40 max[B]	0.40 max[B]	3.3–3.7	1.0–2.0	0.40 max[B]	1.60–2.24	0.70–1.00
Chromium	0.30 max[B,C]	0.30 max[B,C]	0.30 max[C]	0.30 max[C]	0.30 max[B,C]	0.30 max[C]	0.60–0.90
Molybdenum	0.12 max[B,C]	0.12 max[B,C]	0.12 max[C]	0.12 max[C]	0.12 max[B,C]	0.12 max[C]	0.15–0.25
Copper	0.40 max[B]	0.40 max[B]	0.40 max[C]	0.40 max[C]	0.40 max[B]	0.75–1.25	1.00–1.30
Columbium	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 min
Vanadium	0.05 max	0.05 max	0.03 max	0.03 max	0.04–0.11	0.03 max	0.03 max
Nitrogen	. . .	. . .	. . .	. . .	0.01–0.030	. . .	. . .

[A] When vacuum carbon-deoxidation is required by Supplementary Requirement S11, the silicon content shall be 0.12 % maximum.
[B] The sum of copper, nickel, chromium, vanadium and molybdenum shall not exceed 1.00 % on heat analysis.
[C] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.
[†] Revisions to Table 1 approved April 10, 1996.

a temperature in the range from 1600 to 1725°F [879 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than 1/2 h and quench in a suitable liquid medium by immersion; reheat to a temperature in the range from 1000 to 1225°F [540 to 665°C], hold at the temperature for not less than 1/2 h, and cool at any convenient rate.

5. Chemical Composition

5.1 *Heat Analysis*:

5.1.1 An analysis of each heat of steel shall be made by the steel producer from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

5.1.2 Steels to which lead has been added shall not be used.

5.1.3 Intentional additions of copper, nickel, chromium or molybdenum to Grades LF1, LF2 and LF6 are not permitted. Intentional additions of copper, chromium or molybdenum to Grades LF3 or LF5 are not permitted. Intentional additions of chromium or molybdenum to Grade LF9 are not permitted.

5.2 *Product Analysis*—An analysis may be made by the purchaser from a forging representing each heat of steel. Samples for analysis shall be taken midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1, with the tolerances as stated in Table 2.

5.3 *Methods of Analysis*—Test Methods, Practices, and Terminology A 751 shall apply.

6. Mechanical Properties

6.1 *Tension Tests*:

6.1.1 *Requirements*—The material shall conform to requirements for tensile properties in Table 3.

6.1.1.1 The test specimen shall be obtained from a rough or finished forging, or prolongation thereof. For forgings under 10 000 lbs, at time of heat treatment, it may be obtained from separately forged test blanks from the same heat of steel as the production forgings. The test blank shall be reduced by forging in a manner similar to that for the products represented, and shall receive approximately the same hot working and reduction and the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 6.1.2.1.

6.1.1.2 The test specimen shall represent all forgings from the same heat and heat-treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than ¼ in. [6 mm].

6.1.2 *Number of Tests*—One tension test at room temperature shall be made in accordance with 6.1.1.2 from each heat in each heat-treatment load.

6.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ±25°F [±14°C] of the required heat-treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat-treating cycles are used on the forgings represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 6.1.1.2.

6.1.3 *Test Locations and Orientations*—The test specimen shall be removed from the heaviest section of the forging or test blank, at locations described in 6.1.3.1, 6.1.3.2, 6.1.3.5 or as close to these locations as practical, subject to forging size and geometry.

6.1.3.1 For forgings or test blanks having a maximum heat-treated thickness, *T*, of 2 in. [50 mm] or less, the longitudinal axis of the test specimen shall be taken at

TABLE 2 Product Analysis Tolerances

Element	Permissible Variations Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %				
	Limit or Maximum of Specified Range	To 100 in.^{2} [645 cm^2] incl^A	Over 100 to 200 in.^{2} [645 to 1290 cm^2] incl^A	Over 200 to 400 in.^{2} [1290 to 2580 cm^2] incl^A	Over 400 to 800 in.^{2} [2580 to 5160 cm^2] incl^A
Carbon	to 0.30 incl	0.01	0.02	0.03	0.04
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.35 incl	0.04	0.05	0.06	0.07
	over 1.35 to 1.50 incl	0.10	0.10	0.10	0.10
Phosphorus	over maximum only	0.005	0.010	0.010	0.010
Sulfur	over maximum only	0.005	0.010	0.010	0.010
Silicon	to 0.35 incl	0.02	0.02	0.03	0.04
Nickel	up to and incl 1.00	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
	over 2.00 to 5.20 incl	0.07	0.07	0.07	0.07
Copper	up to and incl 0.75	0.03	0.03	0.03	0.03
	over 0.75 to 1.30 incl	0.05	0.05	0.05	0.05
Chromium	to 0.90 incl	0.04	0.04	0.04	0.04
Molybdenum	to 0.20 incl	0.01	0.01	0.01	0.01
	over 0.20 to 0.40 incl	0.03	0.03	0.03	0.03
Columbium	to 0.10 incl	0.01	0.01	0.01	0.01
Vanadium	up to and incl 0.10	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
Nitrogen	up to and incl 0.02	0.005	0.005	0.005	0.005
	over 0.02 to 0.19 incl	0.01	0.01	0.01	0.01

^{A} The significant cross section of the forging shall be governed by the main body diameter.

TABLE 3 Tensile Properties at Room Temperature[A]

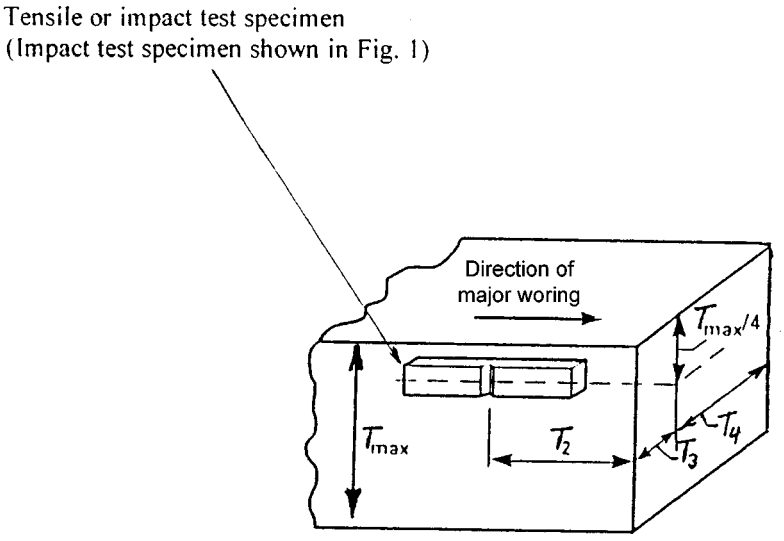
	Grades							
	LF1 and LF5 Class 1	LF2 Classes 1 and 2	LF3 and LF5 Class 2	LF6		LF9	LF787	
				Class 1	Classes 2 and 3		Class 2	Class 3
Tensile strength, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	70–95 [485–655]	66–91 [455–630]	75–100 [515–690]	63–88 [435–605]	65–85 [450–585]	75–95 [515–655]
Yield strength, min, ksi [MPa][B,C]	30 [205]	36 [250]	37.5 [260]	52 [360]	60 [415]	46 [315]	55 [380]	65 [450]
Elongation:								
Standard round specimen, or small proportional specimen, min % in 4D gage length	25	22	22	22	20	25	20	20
Strip specimen for wall thickness 5/16 in. (7.94 mm) and over and for all small sizes tested in full section; min % in 2 in. (50 mm)	28	30	30	30	28	28	28	28
Equation for calculating min elongation for strip specimens thinner than 5/16 in. (7.94 mm); min % in 2 in. (50 mm) t = actual thickness in inches	48*t* + 13	48*t* + 15	48*t* + 15	48*t* + 15	48*t* + 13	48*t* + 13	48*t* + 13	48*t* + 13
Reduction of area, min, %	38	30	35	40	40	38	45	45

[A] See 6.3 for hardness tests.
[B] Determined by either the 0.2 % offset method or the 0.5 % extension under load method.
[C] For round specimens only.

mid-thickness and its mid-length shall be at least 2 in. [50 mm] from a second heat treated surface, exclusive of the *T* dimension surfaces. (This is normally referred to as ½ *T* by 2 in. [50 mm]).

6.1.3.2 For forgings or test blanks having a maximum heat-treated thickness, *T*, greater than 2 in. [50 mm], the central axis of the test specimen shall be taken at least ¼ *T* from the nearest heat-treated surface and at least *T* or 4 in. [100 mm], whichever is less, from any second heat-treated surface. For quenched and tempered forgings, the midlength of the test specimen shall be at least *T* from any second heat-treated surface. See Fig. 1 for test specimen location in separately forged test blanks for quenched and tempered forgings.

6.1.3.3 *Metal Buffers*—The required distances from heat treated surfaces may be obtained with metal buffers instead of integral expansions. Buffer material may be carbon or low alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded



NOTE—For material with thickness *T* greater than 2 in. [50 mm], $T_2 = T_3 = T_4 \geq T_{max}$ T_{max} = maximum heat treated thickness

FIG. 1 Test Specimen Location for Quenched and Tempered Forgings