Designation: A 105/A105M – 98

An American National Standard
Endorsed by
Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USDOE-NE Standards

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Carbon Steel Forgings for Piping Applications[1]

This standard is issued under the fixed designation A 105/A105M; 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 forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the ANSI and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products, (see 4.4) it does not cover raw material produced in these product forms.

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

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675, A 695, and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and 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 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—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components[3]

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[3,4,5]

A 675 Specification for Steel Bars, Carbon, Hot–Wrought, Special Quality, Mechanical Properties[3]

A 695 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications[3]

A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[3,4,5]

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

E 165 Test Method for Liquid Penetrant Examination[6]

E 340 Test Method for Macroetching Metals and Alloys[7]

2.2 *MSS Standards:*

SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions[8]

SP 44 Standard for Steel Pipe Line Flanges[8]

2.3 *ASME Standards:*

Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code[9]

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings[9]

B16.9 Wrought Steel Buttwelding Fittings[9]

B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[9]

B16.11 Forged Steel Fittings, Socket Weld, and Threaded[9]

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Valves, Fittings, Bolting, and Flanges for High Subatmospheric Temperatures.

Current edition approved March 10, 1998. Published September 1998. Originally published as A 105 – 26 T. Last previous edition A 105/A 105M – 97a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-105 in Section II of that Code.

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

[4] *Annual Book of ASTM Standards*, Vol 01.01.

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

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

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

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

[9] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

B16.34 Valves-Flanged, Threaded and Welding End[9]
B16.47 Large Diameter Steel Flanges[9]
2.4 *API Standards:*
API-600 Flanged and Butt-Welding-End Steel Gate Valves[10]
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use[10]
2.5 *AWS Standard:*
AWSA 5.1 Mild Steel Covered Arc-Welding Electrodes[11]

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information as 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 (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See Table 1 footnotes, 12.1, and 16.2).

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be fully killed.

4.2 A sufficient discard shall be made from source material to secure freedom from injurious piping and undue segregation.

4.3 The material shall be forged as close as practicable to the specified shape and size.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be machined from hot-rolled bar, forged 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 (up to and including NPS 4) not including flanges may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as permitted by 4.4, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,[12]

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure-temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

TABLE 1 Chemical Requirements

NOTE—For each reduction of 0.01 % below the specified carbon maximum (0.35 %), an increase of 0.06 % manganese above the specified maximum (1.05 %) will be permitted up to a maximum of 1.35 %.

Element	Composition, %
Carbon	0.35 max
Manganese	0.60–1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10–0.35
Copper	0.40 max[A]
Nickel	0.40 max[A]
Chromium	0.30 max[A,B]
Molybdenum	0.12 max[A,B]
Vanadium	0.05 max
Columbium	0.02 max

[A] The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00 %.
[B] The sum of chromium and molybdenum shall not exceed 0.32 %.

5.1.4 Piping components other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) above Class 300, and

5.1.5 Piping components of Special Class[13] other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or quenching and tempering.

5.2.1 *Annealing*—The procedure for annealing shall consist of allowing the forgings immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being known as an "annealing charge") and allowed to cool uniformly in the furnace.

5.2.2 *Normalizing*—The procedure for normalizing shall consist of allowing the forgings, immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be uniformly reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being known as a "normalizing charge") and allowed to cool in air.

5.2.3 *Tempering*—The procedure for tempering shall consist of heating the forgings to a temperature between 1100°F [593°C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness.

5.2.4 *Quenching*—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 as prescribed in 5.2.3.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements

[10] Available from American Petroleum Institute, 2101 L St. N.W., Washington, DC 20037.
[11] Available from American Welding Society, 550 LeJeune Rd., P.O. Box 351040, Miami, FL 33135.
[12] For definition of Class 300, see ASME B16.5.
[13] For definition of special class, see ASME B16.34.

specified in Table 1. Test Methods, Practices, and Terminology A 751 shall apply.

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

7. Cast or Heat (Formerly Ladle) Analysis

7.1 An analysis of each heat of steel shall be made from samples taken, preferably during the pouring of the heat, and the results shall conform with Table 1.

8. Product Analysis

8.1 The purchaser may make a product analysis on forgings supplied to this specification. Samples for analysis may be taken from 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 within the tolerances stated in Table 2.

9. Mechanical Properties

9.1 The material shall conform to the mechanical property requirements prescribed in Table 3 and Table 4.

9.2 For the purpose of determining conformance with Table 3 and Table 4, specimens shall be obtained from production forgings after heat treatment, when heat treatment is required, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product.

9.3 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the 1/4 *T* plane or deeper position, where *T* is the maximum heat-treated thickness of the represented forging. In addition, for quenched andtempered forgings, the midlength of the test specimen shall be at least *T* from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

TABLE 3 Mechanical Requirements[A]

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa][B]	36 000 [250]
Elongation in 2 in. or 50 mm, min, %:	
Basic minimum elongation for walls 5/16 in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each 1/32 -in. [0.8-mm] decrease in wall thickness below 5/16 in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 4	1.50[C]
Reduction of area, min, %[D]	30
Hardness, HB, max	187

[A] For small forgings, see 9.4.4.
[B] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[C] See Table 4 for computed minimum values.
[D] For round specimens only.

9.4 *Tension Tests*:

9.4.1 One tension test shall be made for each heat of as-forged components.

9.4.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

9.4.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

9.4.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the

TABLE 2 Permissible Variations in Product Analysis

NOTE—Product cross-sectional area (taken at right angles to the axis of the original ingot or billet) is defined as either:
(*a*) maximum cross-sectional area of rough machined forging (excluding boring),
(*b*) maximum cross-sectional area of the unmachined forging, or
(*c*) maximum cross-sectional area of the billet, bloom, or slab.

	Permissible Variations over the Maximum Limit or Under the Minimum Limit, %				
	200 in.^{2} [1290 cm^2] and Under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2], incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2], incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2] incl	Over 1600 in.^{2} [10 320 cm^2]
Carbon	0.02	0.03	0.04	0.05	0.05
Manganese:					
Up to and including 0.90	0.04	0.05	0.06	0.07	0.08
0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06
Copper	0.03	0.03	0.03	0.03	0.03
Nickel	0.03	0.03	0.03	0.03	0.03
Chromium	0.04	0.04	0.04	0.04	0.04
Molybdenum	0.01	0.01	0.01	0.01	0.01
Vanadium	0.01	0.01	0.01	0.01	0.01
Colombium	0.01	0.01	0.01	0.01	0.01

TABLE 4 Computed Minimum Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
5/16 (0.312)	7.9	30.00
9/32 (0.281)	7.1	28.50
1/4 (0.250)	6.4	27.00
7/32 (0.219)	5.6	25.50
3/16 (0.188)	4.8	24.00
5/32 (0.156)	4.0	22.50
1/8 (0.125)	3.2	21.00
3/32 (0.094)	2.4	19.50
1/16 (0.062)	1.6	18.00

Note—The above table gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:
E = elongation in 2 in. or 50 mm, %, and
T = actual thickness of specimen, in. [mm].

test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

9.4.4 Forgings too small to permit obtaining a subsize specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for the production of a separately forged test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2—A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

9.5 *Hardness Tests*—Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 9.4.2.1 to ensure that forgings are within the hardness limits given in Table 3. When only one forging is produced, it shall be hardness tested as defined in 9.4.2.1 to ensure it is within the hardness limits given in Table 3. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

10. Hydrostatic Tests

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S7 is specified.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirement specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 9.

12. Workmanship, Finish, and Appearance

12.1 The forgings shall be free of injurious imperfections, as defined below, and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 12.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish. Unless otherwise specified in the purchase order, the fittings shall be cleaned to remove all scale and processing compounds prior to final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned fittings shall be protected to prevent recontamination. Protective coatings on socket weld and butt welding fittings shall be suitable for subsequent welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

12.2 *Depth of Injurious Imperfections*—Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

12.3 *Machining or Grinding Imperfections Not Classified as Injurious*—Surface imperfections not classified as injurious shall be treated as follows:

12.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5 % of the nominal wall thickness or 1/16 in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

12.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 12.2 and if not deeper than 1/16 in. [1.6 mm]. If such imperfections are deeper than 1/16 in. [1.6 mm], but do not encroach on the minimum wall thickness of the forging, they shall be removed by grinding to sound metal.

12.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of the forging, and the remainder shall not be less than the minimum specified or required wall thickness.

13. Repair by Welding

13.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ANSI or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

13.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.3 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

13.4 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle inspection prior to welding.

13.5 After repair welding, the area welded shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection.

13.6 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 9 on completion of the cycle.

13.7 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 3 for the thermal condition of repair-welded forgings.

13.8 Repair by welding shall not exceed 10 % of the surface area of the forging nor 33⅓ % of the wall thickness of the finished forging or ⅜ in. [10 mm], whichever is less, without prior approval of the purchaser.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

15. Rejection and Rehearing

15.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

15.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

16. Certification

16.1 *Identification Marking*—For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in 17.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

16.2 *Test Reports*—When test reports are required, the manufacturer shall also provide the following, where applicable:

16.2.1 Type heat treatment, Section 5,

16.2.2 Tensile property results, Section 9 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

16.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02 %, then the anaylsis for that element may be reported as "< 0.02 %,"

16.2.4 Hardness results, Section 9 (Table 3), and

16.2.5 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 Identification marks consisting of the manufacturer's symbol or name (see Note 3), the heat number or manufacturer's heat identification, designation of service rating, this specification number, and size shall be forged or legibly stamped on each forging, and in such a position as not to injure the usefullness of the forging. The Standard Marking System of Valves, Fittings, Flanges, and Unions (SP-25-1978) of the Manufacturers' Standardization Society of the Valve and Fittings Industry may be followed except the word "Steel" shall not be substituted for this specification number.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

17.1.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

17.2 When test reports are required for larger products, the markings shall consist of the manufacturer's symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply). The specification number marked on the forgings need not include specification year of issue and revision letter.

17.3 *Bar Coding*—In addition to the requirements in 17.1 and 17.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis shall be made from each heat offered for delivery. The analysis shall conform to the requirements specified in Table 1 with tolerances in Table 2. If the results of any test fail to comply, two additional forgings or representative test pieces from the same heat shall be retested and the results shall comply with the tables listed. If the results of either one of these peices fail to comply, each forging shall be checked or the heat rejected. All results shall be reported to the purchaser and all forgings which do not comply shall be rejected.

S3. Hardness

S3.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S4. Tension Tests

S4.1 In addition to the requirements of Section 9, the heat identification shall be marked on each forging and one tensile specimen shall be obtained from a representative forging at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S5. Magnetic-Particle Examination

S5.1 All accessible surfaces of the finished forging shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S6. Liquid-Penetrant Examination

S6.1 All surfaces shall be examined by a liquid-penetrant method. The method shall be in accordance with Practice E 165. Acceptance limits shall be as agreed upon by the manufacturer and the purchaser.

S7. Hydrostatic Testing

S7.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

S8. Repair Welding

S8.1 No repair welding shall be permitted without prior approval of the purchaser.

S9. Heat Treatment

S9.1 All forgings shall be heat treated as specified by the purchaser.

S9.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 3 and Table 4 shall be hardness testing per 9.5 and either (*1*) tensile testing of heat treated forgings per 9.2, or (*2*) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S9.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S9.4 In addition to the marking required by Section 17, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered, as appropriate.

S10. Marking Small Forgings

S10.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S10.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S11. Carbon Equivalent

S11.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S11.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S11.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.