SPECIFICATION FOR CARBON STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS

SA-266/SA-266M

(Identical with ASTM Specification A 266/A 266M-03a) 07

1. Scope

1.1 This specification covers four grades of carbon steel forgings for boilers, pressure vessels, and associated equipment.

NOTE 1 — Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 2	Class 2
Grade 3	Class 3
Grade 4	Class 4

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 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

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

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

A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining the Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

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

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging.

3.2 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, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

3.4 For hubbed flanges and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A 788 shall be specified in addition to Supplementary Requirement S8 of this specification.

4. Materials and Manufacture

4.1 The steel shall be made in accordance with the Melting Process Section of Specification A 788. A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

4.2 The material shall be forged as close as practical to the specified shape and size.

4.3 The finished product shall be a hot-worked forging as defined by Specification A 788.

5. Machining

5.1 Surfaces shall be machined as designated by the purchaser. Unmachined surfaces shall be sufficiently free of scale to permit inspection.

5.2 Machining may be performed either prior to or after heat treatment at the option of the manufacturer unless specified in accordance with Supplementary Requirement S1.

6. Heat Treatment

6.1 After forging and before reheating for heat treatment, the forgings shall be cooled in such a manner as to prevent injury and to accomplish transformation.

6.2 All forgings shall be annealed, normalized, or normalized and tempered, but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. When tempering is performed, it shall be at a subcritical temperature, but no less than 1100°F [595°C].

6.3 A multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, tempering at a temperature between 1100°F [595°C] and the lower critical temperature shall follow.

NOTE 2 — Although liquid quenching from the austenitizing temperatures is more effective in enhancing impact properties, air cooling from the austenitizing temperatures is also beneficial and may be used instead of the normalizing procedure in 6.2.

7. Chemical Composition

7.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except that the additional features of Supplementary Requirements S11 and S12 shall also apply as individually specified in the ordering information.

7.2 *Product Analysis* — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

8. Mechanical Properties

8.1 *General Requirements* — Except when otherwise specified in accordance with Supplementary Requirement S2, the material shall conform to the requirements for mechanical properties prescribed in Table 2 when tested in accordance with the latest issue of Test Methods and Definitions A 370. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 Except when otherwise specified in accordance with Supplementary Requirement S2, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging. For upset-disc forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 The longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed as defined in 8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane.

8.1.2 Except as specified herein, tests for acceptance shall be made after heat treatment has been completed. When the ends of the cylindrical forgings are closed in by reforging, the cylindrical forgings may be annealed, normalized, or normalized and tempered and tested prior to reforging. After reforging, the entire forging shall be reheat-treated in the same manner and at the same temperature range as employed when the forging was heat-treated prior to certification testing.

8.1.3 When mutually agreed upon between manufacturer and purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than T by T by $3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 3 — In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks.

8.2 *Specific Requirements* — The number and location of tests are based on forging length, weight, and heat treatment, and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed, Normalized, or Normalized and Tempered Steel Forgings:*

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat in each heat–treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings:*

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat in each heat–treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 lb [2250 kg] to 10 000 lb [4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 For quenched and tempered forgings and forged bars that exceed 12 ft [3.7 m] in length, one tension test shall be taken from each end of each forging.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

9. Repair Welding

9.1 Repair welding of forgings is permissible only at the option of the purchaser. If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10. Certification

10.1 In addition to the mandatory certification requirements of Specification A 788, the heat treatment cycle data shall be included.

11. Product Marking

11.1 Each forging shall be identified in accordance with the Marking Section of Specification A 788. In addition, the forging shall be marked following the grade designation by the letter "A" for annealed, "N" for normalized, "NT" for normalized and tempered, and "S" for liquid quenched and tempered, as applicable.

12. Keywords

12.1 pressure vessel service; steel forgings—carbon

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grades 1 and 2	Grade 3	Grade 4
Carbon, max	0.30	0.35	0.30
Manganese	0.40–1.05	0.80–1.35	0.80–1.35
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35

TABLE 2
TENSILE REQUIREMENTS

	Grade 1	Grades 2 and 4	Grade 3
Tensile strength, min, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	75–100 [515–690]
Yield strength (0.2% offset), min, ksi [MPa]	30 [205]	36 [250]	37.5 [260]
Elongation in 2 in. or 50 mm, min,%	23	20	19
Reduction of area, min,%	38	33	30

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be as specified by the purchaser.

S2. Alternative Tension Test Orientation

S2.1 In lieu of the requirements of Section 8, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 2, with the exception of the ductility limits that shall be as follows:

Grade	1	2 and 4	3
Elongation in 2 in. [50 mm], min, %	20	19	18
Reduction of area, min, %	30	25	25

S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S4. Magnetic Particle Examination

S4.1 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 275 M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 After forgings have been heat treated by liquid quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E 165 as an alternative to magnetic particle examination.

S6. Macroetch Test

S6.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Method E 381. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S7. Product Analysis

S7.1 A product analysis in accordance with Section 7 shall be made from one randomly selected forging representing each size and shape of forging on the order. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S8. Specimen Location on Forged Hubs

S8.1 Forged hubs to be butt-welded to shells shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. A tension specimen (subsize if necessary) shall be taken in this direction and as close to the finished hub outside diameter as practical.

S9. Hardness

S9.1 The purchaser may check the Brinell hardness of the forging at any location on the surface of the forging, and the hardness shall be within the following limits:

Grade	Brinell Hardness Limits
1	121 to 170
2 and 4	137 to 197
3	156 to 207

S10. Grain Size

S10.1 The austenitic grain size of the steel shall be 1 to 5 as determined using Test Methods E 112.

S11. Restriction on Residual Elements (Applicable to Heat Analysis)

S11.1 Nickel, chromium, and molybdenum shall be determined and shall not exceed the following limits:

Nickel	0.25% max
Chromium	0.20% max
Molybdenum	0.08% max

S12. Restriction on Carbon (Applicable to Grade I)

S12.1 The carbon content shall be 0.30% max.

S13. Impact Tests

S13.1 Charpy impact tests shall be made. The number and location of the tests, minimum properties, and test temperatures shall be specified.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A 370.

S13.3 Retests may be conducted in accordance with Section 10 of Specification A 788.

S14. Individual Forging

S14.1 Forgings, whether identical or not, shall be produced individually. They shall not be forged in multiples and separated prior to or after heat treatment.

S14.2 The shape and size of individual forgings shall be agreed upon between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

S15. Carbon Equivalancy

S15.1 The heat analysis including the residual element restrictions of S1 in Specification A 788 shall be limited such that the carbon equivalent shall not exceed 0.45 for Grade 1 or 0.50 for Grade 2 or 4 when calculated in accordance with the following formula:

$$CE = \%\ \mathrm{C} + \frac{\%\ \mathrm{Mn}}{6} + \frac{\%\ \mathrm{Cr} + \%\ \mathrm{Mo} + \%\ \mathrm{V}}{5} + \frac{\%\ \mathrm{Ni} + \%\ \mathrm{Cu}}{15}$$