Designation: A 765/A 765M – 07

# Standard Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements[1]

This standard is issued under the fixed designation A 765/A 765M; 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[2] covers heat-treated carbon steel and alloy steel forgings with mandatory toughness requirements. These forgings are intended for pressure vessels, feedwater heaters, and similar uses.

1.2 These forgings include tube sheets, covers, channel barrels, integral forged channels, rings, nozzles, flanges, and similar parts.

1.3 All grades are considered weldable under proper conditions.

1.4 The maximum thickness of forgings produced to this specification is limited only by the capacity of the selected grade to respond to any heat treatment specified and to meet the specified mechanical tests, including impact tests at the specified temperature.

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

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

1.7 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.

1.8 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:* [3]

A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings

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

E 112 Test Methods for Determining Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

2.2 *ASME Standards:*[4]

ASME Boiler and Pressure Vessel Code

## 3. Ordering Information

3.1 In addition to the ordering information requirements of Specification A 788/A 788M, a detailed sketch or written description of the forging and the method of selecting the test location (see 6.2) should be supplied to the producer, when appropriate areas of significant in-service loading of the forging need to be designated.

3.2 The required impact test temperature should be supplied if different than the temperature listed in Table 3, otherwise the impact test shall be conducted at the temperature listed in Table 3 for the chosen Grade.

3.3 If a hubbed tube sheet is to be supplied for ASME Boiler and Pressure Code Application Supplementary Requirement S12 of Specification A 788/A 788M shall be specified.

[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 ASME Boiler and Pressure Vessel Code applications see related Specification SA–765/SA–765M in Section II of that code.

[3] 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.

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

***A Summary of Changes section appears at the end of this standard.**

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**TABLE 1 Chemical Requirements**

| | Composition, % | | | | |
|---|---|---|---|---|---|
| | Grade I | Grade II | Grade III | Grade IV | Grade V |
| Carbon, max | 0.30 | 0.30 | 0.20 | 0.20 | 0.30 |
| Manganese | 0.60 to 1.35 | 0.60 to 1.35 | 0.90 max | 1.00–1.60 | 0.60–1.35 |
| Phosphorus, max | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 |
| Sulfur, max | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 |
| Silicon | 0.15 to 0.35 | 0.15 to 0.35 | 0.15 to 0.35 | 0.15–0.50 | 0.15–0.35 |
| Nickel, max[A] | 0.50 | 0.50 | 3.3 to 3.8 | 0.50 max | 1.0–2.0 |
| Vanadium, max | 0.05 | 0.05 | 0.05 | 0.06 | 0.03 |
| Aluminum, max | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Chromium,[A] max | 0.40 | 0.40 | 0.20 | 0.40 | 0.30 |
| Molybdenum,[A] max | 0.10 | 0.10 | 0.06 | 0.10 | 0.12 |
| Copper, max | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |

[A] Intentional additions of Cr, Mo, and Ni up to the specified maximum are permitted to be made to Grades I, II, and IV by the manufacturer.

3.4 If steel is required to be vacuum degassed, Supplementary Requirement S8 of Specification A 788/A 788M should be specified.

## 4. Heat Treatment for Mechanical Properties

4.1 Heat treatment shall consist of one of the following heat treatment options of the manufacturer's choice.

4.1.1 Normalize and temper.

4.1.2 Double normalize, wherein the second austenitizing temperature is at the same or lower temperature than the first, followed by tempering.

4.1.3 Quench and temper, with the option of adding a preliminary normalize before austenitizing for quenching in a suitable liquid medium. The type of cooling medium used shall be reported.

4.1.4 Use of an intercritical heat treatment cycle in accordance with Specification A 788/A 788M in which cooling from the full and partial austenitization stages may be done by liquid quenching or air cooling. The method of cooling and type of quench medium, if used, shall be reported.

4.1.5 The minimum tempering temperature shall be 1100ºF [590ºC].

## 5. Chemical Requirements

5.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A 788/A 788M shall comply with Table 1.

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

## 6. Mechanical Requirements

6.1 *General Requirements*—The forgings shall conform to the tension test requirements of Table 2. The forgings shall also conform to the impact test requirements of Table 3. The largest obtainable round tension test specimen as specified in Test Methods and Definitions A 370 shall be used. Impact specimens shall be Charpy V-notch, Type A, as in Test Methods and Definitions A 370. The usage of subsize impact specimens must have prior purchaser approval.

6.1.1 When agreed upon between the purchaser and the producer and specified on the order, impact tests may be made at temperatures different from those shown in Table 3 provided the test temperature is at least as low as the intended service temperatures and the provided impact energy requirements of Table 3 are met. Such forgings shall be suitably marked in accordance with 9.1 to identify the test temperature.

6.2 *Test Location*—Test coupons shall be taken so that the longitudinal axis and mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods:

6.2.1 *Method 1*—Forgings with 2 in. [50 mm] maximum thickness. The specimens shall have their longitudinal axis at the midthickness or the center of the cross section and with the midlength of the specimen at least 2 in. [50 mm] from any second surface.

6.2.2 *Method 2*—Grade I and Grade II forgings with thicknesses greater than 2 in. up to 4 in. [50 to 100 mm] inclusive, or Grade III and IV forgings with thicknesses greater than 2 in. up to 6 in. [50 to 150 mm] inclusive. The specimens shall have their longitudinal axis at least ¼ *T* of maximum heat-treated thickness from any surface and with the midlength of the specimen at least one *T* from any second surface. This is normally referred to as ¼ *T* by *T* when *T* is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the condition in 6.3. Unless otherwise agreed upon, the following limitation for heat-treated thickness shall apply:

| Grade | in. [mm], min | in. [mm], max |
|---|---|---|
| I | 2 [50] | 4 [100] |
| II | 2 [50] | 4 [100] |
| III | 2 [50] | 6 [150] |
| IV | 2 [50] | 6 [150] |
| V | 2 [50] | 6 [150] |
| (Classes 1 and 2) | | |

6.2.3 *Method 3*—For forgings thicker than described in Method 2 (6.2.2):

6.2.3.1 Prior to heat treatment the forging shall be machined to a purchaser supplied or approved drawing that indicates the locations of significant in-service loading in the finished part. The mechanical test specimens shall be located as an integral part of the forging such that the mid-point of the gauge length of the tension test specimen and the area under the notch of the impact specimens are located no closer than the dimension *t* from one heat treated surface and 2*t* from any other heat treated surface where *t* is the dimension from the area of significant loading to the heat treated surface, or ¾ in. [20 mm] whichever is the greater.

6.2.4 *Method 4*—This method shall be limited to forgings with a rough machined weight of not more than 1000 lb [455 kg]. Separate test forging when agreed upon between the purchaser and the supplier. Test coupons representing forgings from one heat and one heat treatment lot may be taken from a separately forged piece under the following conditions:

6.2.4.1 The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forging it represents.



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**TABLE 2 Tensile Requirements**

| | Grade I | Grade II | Grade III | Grade IV | Grade V | |
|---|---|---|---|---|---|---|
| | | | | | Class 1 | Class 2 |
| Tensile strength, ksi [MPa] | 60 to 85 [415 to 585] | 70 to 95 [485 to 655] | 70 to 95 [485 to 655] | 80–105 [550–725] | 60–85 [415– 585] | 70–95 [485–655] |
| Yield strength,[A] in, ksi [MPa] | 30 [205] | 36 [250] | 37.5 [260] | 50 [345] | 30 [205] | 37.5 [260] |
| Elongation in 2 in. [50 mm], min, % | 25 | 22 | 22 | 22 | 25 | 22 |
| Reduction of area, min, % | 38 | 30 | 35 | 30 | 38 | 35 |

[A] 0.2 % offset or 0.5 % total extension underload method.

**TABLE 3 Charpy V-Notch Impact Requirements**

| | Grade I | Grade II | Grade III | Grade IV | Grade V (Classes 1 and 2) |
|---|---|---|---|---|---|
| Minimum average value of set of three specimens, ft-lbf (J) | 13 [18] | 15 [20] | 15 [20] | 26 [35][A] | 15 [20] |
| Minimum value of one specimen, ft-lbf (J) | 10 [14] | 12 [16] | 12 [16] | 20 [27][A] | 12 [16] |
| Test temperature of,[B] °F [°C] | –20 [–30] | –50 [–45] | –150 [–100] | –20 [–30] | -75 [-60] |

[A] Mandatory conformance to the values listed is a matter of agreement between the purchaser and the manufacturer. The energy values above are shown for information as to guarantees that are generally available.
[B] Actual test temperature should be established at time of order. If no temperature is specified, tests will be made at test temperatures shown in this table.

6.2.4.2 The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forging.

6.2.4.3 The separate test forging shall be of the same nominal thickness as the production forging.

6.2.4.4 Test coupons for small forgings as described in Method 2 shall be taken so that specimens shall have their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the forging thickness except when the thickness-to-length ratio of the production forging does not permit, in which case a production forging shall be used as the test forging and the midlength of the specimens shall be at the midlength of the test forging.

6.2.4.5 Test coupons for larger forgings shall be taken in accordance with Method 3 (6.2.3).

6.3 *Metal Buffers*—The required distances from treated surfaces may be obtained with metal buffers instead of integral extensions. 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 areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.4 Samples shall be removed from forgings after heat treatments. This sample material shall be subjected to a simulated post-weld heat treatment if Supplementary Requirement S6 is specified.

6.5 *Test Orientation*:

6.5.1 For upset disk forgings such as tube sheets the longitudinal axis of test specimens may be oriented in the radial or tangential direction, or parallel to the axis of the forging, as shown in Supplementary Requirement S12 of Specification A 788/A 788M.

6.5.2 For all other forgings the longitudinal axis of test specimens may be oriented parallel to the direction of maximum hot working of the forging.

6.6 *Number of Tests*:

6.6.1 *Forgings Under 500 lb [230 kg] As Treated*—For duplicate forgings weighing less than 500 lb as treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding an 8-h duration.

6.6.2 *Forging Weighing 500 to 10 000 lb [230 to 4500 kg] As-Heat Treated*—One tension and one impact test (three specimens) shall be made for each forging.

6.6.3 Each forging weighing over 10 000 lb [4500 kg] shall require two tension tests and two impact tests (three specimens). When the length (excluding prolongs) is equal to or less than 1½ times the diameter, the tests may be taken from one end of the forging with a tension test and one set of impact tests at each of two locations oriented 180° apart. When the length (excluding prolongs) is greater than 1½ times the diameter, one tension test and one set of impact tests must be taken from each location from opposite ends of the forging and the locations on each end should be oriented 180° apart from each other.

## 7. Repair Welding

7.1 Repair welding, as permitted by the purchaser, shall be performed in accordance with the ASME Boiler and Pressure Vessel Code.

## 8. Reporting

8.1 The type of quenching medium used for the heat treatment cycle in 4.1.3 shall be reported, or in the case of 4.1.4, whether air cooling or quenching was used and the type



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of quench medium if applicable. The other certification requirements of Specification A 788/A 788M also apply.

## 9. Product Marking

9.1 The test temperature, if different from that given in Table 3, shall be marked on the forging as a suffix to the Grade and Class designation. A prefix of 0 to the test temperature indicates that the temperature was under 0°F, or 0°C if the M designation specification is being used. For example, A765-11-075 would indicate that the impact testing for Grade 11 was done at -75°F instead of -50°F. A marking of A765M-11-10 would indicate that the impact testing was done at 10°F for a Grade 11 forging. For forgings tested under the M designation an example would be A765M-11-060 for a Grade 11 forging tested at -60°C or A765M-11-10 for a Grade 11 forging tested at 10°C.

## 10. Keywords

10.1 alloy steel forgings; carbon steel forgings; heat-treated; impact tested; intercritical heat treatment; pressure vessel; weldable

## SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the order. Details of these supplementary requirements shall have been previously negotiated and mutually agreed to between the forging manufacturer and the purchaser.

## S1. Product Analysis

S1.1 The manufacturer shall use the product analysis provision of Specification A 788/A 788M to obtain a product analysis from a forging representing each heat or multiple heat.

## S2. Grain Size

S2.1 The forgings, subsequent to the final heat treatment, shall have prior austenitic grain size of 5 or finer as determined by the McQuaid-Ehn Test (Test Methods E 112).

## S3. Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature versus absorbed-energy curve. The test temperature range shall be wide enough to establish the upper and the lower shelf foot-pound-force (or joules) energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

## S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. This method shall be in accordance with Test Method A 275/A 275M.

S4.2 Acceptance criteria shall be specified.

## S5. Liquid Penetrant Examination

S5.1 All surfaces shall be examined by a liquid penetrant method. The method shall be in accordance with Test Method E 165.

S5.2 Acceptance criteria shall be specified.

## S6. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S6.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

## S7.

Deleted

## S8. Ultrasonic Examination

S8.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A 388M.

S8.2 Acceptance criteria shall be specified.

## S9.

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## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 765/A 765M – 04) that may impact the use of this standard. (Approved Sept. 1, 2007.)

(*1*) Augmented 4.1.

(*2*) Added Section 8 and renumbered subsequent sections.

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