Designation: A 356/A 356M – 07

# Standard Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines[1]

This standard is issued under the fixed designation A 356/A 356M; 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 covers one grade of martensitic stainless steel and several grades of ferritic steel castings for cylinders (shells), valve chests, throttle valves, and other heavy-walled castings for steam turbine applications.

1.2 Optional supplementary requirements (S1 through S5) shall apply as selected by and specified by the purchaser.

1.3 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.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

E 94 Guide for Radiographic Examination

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E 165 Test Method for Liquid Penetrant Examination

E 186 Reference Radiographs for Heavy-Walled (2 to 412-in. [51 to 114-mm]) Steel Castings

E 280 Reference Radiographs for Heavy-Walled (412 to 12-in. [114 to 305-mm]) Steel Castings

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers' Standardization Society of the Valve and Fitting Industry Standard:*[3]

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)

## 3. Classification

3.1 The castings are furnished in the grades shown in Table 1.

## 4. Ordering Information

4.1 Orders for material to this specification should include the following information:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

## 5. Melting Process

5.1 The steel shall be made by the open-hearth or electric-furnace process.

5.2 *Deoxidation Practice*:

5.2.1 Deoxidation of the carbon and low-alloy steel grades shall be by manganese and silicon. Furnace or ladle deoxidation with other agents is permissible with the approval of the purchaser.

5.2.2 The purchaser may specify that no aluminum be added.

5.2.3 Vacuum deoxidation is acceptable. The specific method shall be subject to approval by the purchaser.

## 6. Heat Treatment

6.1 *Preliminary Heat Treatment*—The castings may receive such preliminary heat treatment as the founder may elect to employ.

[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 A01.18 on Castings.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1952. Last previous edition approved in 2005 as A 356/A 356M – 05.

[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.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

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

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.



Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS



**TABLE 1 Chemical Requirements[A]**

| Grade/ UNS Number | Material | Composition, % | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Carbon | Manganese | Silicon | Phosphorus, max | Sulfur, max | Molybdenum | Chromium | Nickel | Vanadium | Columbium | Nitrogen | Aluminum | Other |
| 1 J03502 | carbon steel | 0.35[B] max | 0.70[B] max | 0.60 max | 0.035 | 0.030 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| 2 J12523 | ½ % molybdenum | 0.25[B] max | 0.70[B] max | 0.60 max | 0.035 | 0.030 | 0.45-0.65 | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| 5 J12540 | ½ % chromium, ½ % molybdenum | 0.25[B] max | 0.70[B] max | 0.60 max | 0.035 | 0.030 | 0.40-0.60 | 0.40-0.70 | . . . | . . . | . . . | . . . | . . . | . . . |
| 6 J12073 | 1¼ % chromium, ½ % molybdenum | 0.20 max | 0.50-0.80 | 0.60 max | 0.035 | 0.030 | 0.45-0.65 | 1.00-1.50 | . . . | . . . | . . . | . . . | . . . | . . . |
| 8 J11697 | 1 % chromium, 1 % molybdenum, vanadium | 0.20 max | 0.50-0.90 | 0.20-0.60 | 0.035 | 0.030 | 0.90-1.20 | 1.00-1.50 | . . . | 0.05-0.15 | . . . | . . . | . . . | . . . |
| 9 J21610 | 1 % chromium, 1 % molybdenum, vanadium | 0.20 max | 0.50-0.90 | 0.20-0.60 | 0.035 | 0.030 | 0.90-1.20 | 1.00-1.50 | . . . | 0.20-0.35 | . . . | . . . | . . . | . . . |
| 10 J22090 | 2¼ % chromium, 1 % molybdenum | 0.20 max | 0.50-0.80 | 0.60 max | 0.035 | 0.030 | 0.90-1.20 | 2.00-2.75 | . . . | . . . | . . . | . . . | . . . | . . . |
| 12A[C] J84090 | 9 % chromium, 1 % molybdenum, vanadium | 0.08-0.12 | 0.30-0.60 | 0.20-0.50 | 0.030 | 0.010 | 0.85-1.05 | 8.0-9.5 | 0.40 max | 0.18-0.25 | 0.060-0.10 | 0.030-0.070 | 0.02 max | titanium, 0.01 max; zirconium, 0.01 max |
| CA6NM J91540 | martensic chromium nickel | 0.06 max | 1.00 max | 1.00 max | 0.040 | 0.030 | 0.4-1.0 | 11.5-14.0 | 3.5-4.5 | . . . | . . . | . . . | . . . | . . . |

[A] Where ellipses appear in this table, there is no requirement.
[B] For each 0.01 % reduction in carbon below the maximum specified, an increase of 0.04 percentage points of manganese over the maximum specified for that element will be permitted up to 1.00.
[C] The designation of Grade 12, formerly covered by this specification, has been changed to Grade 12A.



Not for Resale

6.2 *Heat Treatment for Final Properties*:

6.2.1 *Normalizing*—The castings shall be heated to and held at the proper temperature for a sufficient time to affect the desired transformation and withdrawn from the furnace and allowed to cool to affect complete transformation. Grade 12A castings shall be normalized at 1900-1975°F [1040-1080°C] and withdrawn from the furnace and allowed to cool to affect complete transformation.

6.2.2 *Tempering*—The casting shall be heated to and held at the proper temperature, which shall be below the transformation range, and then cooled under suitable conditions. The tempering temperature shall not be less than 1100°F [595°C]. Grade 12A castings shall be tempered at 1350-1470°F [730-800°C].

6.2.3 *Stress Relieving*—The stress relieving operation shall be carried out in the same manner as tempering. The temperature shall be within 50°F [28°C], but not exceeding the final tempering temperature.

6.3 *Stainless Steel Casting*:

6.3.1 *Normalizing*—The castings shall be heated to 1850°F [1010°C] minimum, held sufficiently at that temperature to uniformly heat the castings, and air cooled to below 200°F [93°C].

6.3.2 *Tempering*—The castings shall be final tempered from 1050 to 1150°F [565 to 620°C].

6.3.3 *Stress Relieving*—The stress relieving operation shall be performed in the same manner as tempering. Temperature shall be between 1050°F [565°C] and 1150°F [620°C].

## 7. Chemical Composition

7.1 The steel shall conform to the requirements given in Table 1 (Note 1).

NOTE 1—The role of alloying elements in the development of Grade 12A has been extensively investigated. V and Cb contribute to precipitation strengthening by forming fine and coherent precipitates of M(C,N)X carbo-nitrides in the ferritic matrix. V also precipitates as VN during tempering or creep. The two elements are more effective in combination. Therefore, the addition of strong nitride-forming elements, those with a stronger affinity for nitrogen than Cb and V, as deoxidation agents during melting of this grade, interferes with these high-temperature strengthening mechanisms.[4]

[4] Viswanathan, R. and Bakker, W. T., *Materials for Ultra Supercritical Fossil Power Plants*, EPRI, Palo Alto, CA, 2000. TR-114750.

## 8. Tensile Requirements

8.1 Tensile properties shall conform to the requirements listed in Table 2 as determined by the test specimen set forth in Section 9.

8.2 Tension tests shall be performed in accordance with Test Methods and Definitions A 370.

## 9. Number of Tests and Retests

9.1 One tension test shall be made from each heat in each heat-treatment charge and from each casting on which attached coupons are specified. The bar from which the test specimen is taken shall be heat treated with the casting represented.

9.2 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted from the same heat.

9.3 If the results of the mechanical tests for any lot or casting do not conform to the requirements specified, the founder may reheat treat and retest such lot or casting.

## 10. Test Specimen

10.1 Tension test specimens and samples for microexamination may be taken from coupons conforming substantially to the dimensions shown in Fig. 1 and from the locations in the coupon as indicated in Fig. 1. These coupons shall have been cast attached to the castings, except as provided in 10.2, and have remained attached, without partial severing, until the completion of the heat treatment for final properties.

10.2 If, in the opinion of the manufacturer, the design of any casting is such as to preclude the use of an attached coupon, then the tension test specimen and sample for microexamination for that casting may be taken from a coupon attached to a special block. The coupon shall conform substantially to the dimensions shown in Fig. 1 and shall have remained attached, without partial severing, to its special block until after all heat treatment for final properties.

10.3 Test specimens may be cut from heat-treated castings instead of from test coupons when agreed upon between the manufacturer and the purchaser.

10.4 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage-length specimen shown in Fig. 5 of Test Methods and Definitions A 370.

**TABLE 2 Tensile Requirements**

| Grade | Material | Tensile Strength, min, ksi [MPa] | Yield Strength, min, ksi [MPa] | Elongation in 2 in. [50 mm] min, % | Reduction of Area, min, % |
|---|---|---|---|---|---|
| 1 | carbon steel | 70 [485] | 36 [250] | 20.0 | 35.0 |
| 2 | ½ % molybdenum | 65 [450] | 35 [240] | 22.0 | 35.0 |
| 5 | ½ % chromium, ½ % molybdenum | 70 [485] | 40 [275] | 22.0 | 35.0 |
| 6 | 1¼ % chromium, ½ % molybdenum | 70 [485] | 45 [310] | 22.0 | 35.0 |
| 8 | 1 % chromium, 1 % molybdenum, vanadium | 80 [550] | 50 [345] | 18.0 | 45.0 |
| 9 | 1 % chromium, 1 % molybdenum, vanadium | 85 [585] | 60 [415] | 15.0 | 45.0 |
| 10 | 2¼ % chromium, 1 % molybdenum | 85 [585] | 55 [380] | 20.0 | 35.0 |
| 12A | 9 % chromium, 1 % molybdenum, vanadium | 85 [585] | 60 [415] | 20.0 | . . . |
| CA6NM | martensitic chromium nickel | 110 [760] | 80 [550] | 15.0 | 35.0 |



Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

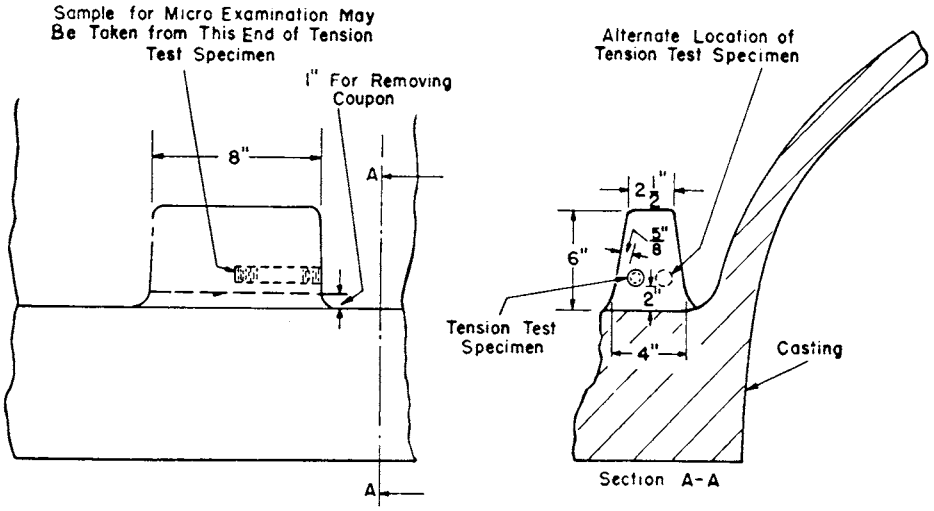


**FIG. 1 Dimensions and Location of Test Coupons for Turbine Castings**

## 11. Inspection

11.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with operation of the works.

## 12. Rejection and Rehearing

12.1 Any rejection based on tests made in accordance with Sections 7 or 8, or both, shall be reported to the manufacturer within 60 days from the receipt of samples by the purchaser.

12.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

12.3 Samples tested in accordance with Section 7 that represent rejected material shall be preserved for 60 days from the date of transmission of the test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

## 13. Certification

13.1 The manufacturer shall submit to the purchaser a certified record of the results of the chemical analysis and mechanical tests, together with a statement that all the requirements of this specification (including year date) have been met.

## 14. Product Marking

14.1 Pressure-containing castings, made in accordance with any of the grades of steel covered by this specification, shall be marked for material identification with the ASTM symbols for the grade of alloy steel (Grade 1, Grade 2, and so forth) and the heat number or heat identification. Marking shall be positioned so as not to impair the usefulness of the castings.

## 15. Quality Assurance

15.1 *Surface Finish*—The castings shall be clean when offered for inspection. A standard practice that may be used as a basis for visual inspection is SP-55.

15.2 *Soundness*—The degree of soundness and the method for its determination shall be subject to agreement between the manufacturer and the purchaser. Castings may be produced in accordance with Supplementary Requirement S2, Supplementary Requirement S3, Supplementary Requirement S4, or any combination of these.

15.3 *Welding*—Assembly welds and repair welds shall be made using procedures and welders qualified under Practice A 488/A 488M.

15.3.1 Welding shall be accomplished with a filler material known to produce weld deposits having a chemical composition and mechanical properties compatible with those of the castings.

15.3.2 Welds shall be inspected to the same quality standards as are used to inspect the castings.

15.3.2.1 When castings are produced with Supplementary Requirement S2 specified, welds shall be inspected by magnetic particle examination to the same standards as are used to inspect the castings.

15.3.2.2 When castings are produced with Supplementary Requirement S3 specified, welds shall be inspected by radiography to the same standards as are used to inspect the castings.

15.3.3 Welds shall receive at least a stress-relief heat treatment. A complete heat treatment consisting of a normalize and temper may be required for certain welds, subject to agreement between the manufacturer and purchaser.

15.3.4 When methods involving high temperatures are used in the removal of discontinuities, casting shall be preheated to at least the minimum temperatures in Table 3.



Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

**TABLE 3 Minimum Preheat Temperatures**

| Grade | Thickness, in. [mm] | Minimum Preheat Temperature, °F [°C] |
|---|---|---|
| 1 | over 1 [25] | 175 [80] |
| | 1 [25] and under | 50 [10] |
| 2 | over ⅝ [16] | 250 [120] |
| | ⅝ [16] and under | 50 [10] |
| 5 | over ⅝ [16] | 250 [120] |
| | ⅝ [16] and under | 50 [10] |
| 6 | over ½ [13] | 300 [150] |
| | ½ [13] and under | 50 [10] |
| 8 | over ½ [13] | 300 [150] |
| | ½ [13] and under | 50 [10] |
| 9 | over ½ [13] | 300 [150] |
| | ½ [13] and under | 50 [10] |
| 10 | over ½ [13] | 400 [200] |
| | ½ [13] and under | 300 [150] |
| 12A | all thicknesses | 400 [200] |
| CA6NM | all | 50 [10] |

15.3.5 Assembly and repair welds on Grade 12A shall be post-weld heat treated at 1350-1470°F [730-800°C].

## 16. Keywords

16.1 carbon steel; low-alloy steel; stainless steel; steam turbines; steel castings

## SUPPLEMENTARY REQUIREMENTS

Any of the following supplementary requirements may become a part of the specification when specified on the inquiry or invitation to bid, and when made a part of the purchase order or contract after mutual agreement by the manufacturer and the purchaser on the exact standards to be applied to each method of inspection.

### S1. Microstructural Requirements

S1.1 There shall be no microstructural requirements for Grade 1.

S1.2 The microstructural requirements of grades, other than Grade 1, may be specified by the purchaser.

S1.3 If microstructural requirements are specified by the purchaser, he shall furnish suitable standards to serve as a satisfactory basis for acceptance or rejection.

S1.4 If microstructural requirements are specified, the sample for examination may be taken from the end of the broken tension test specimens.

### S2. Magnetic Particle Inspection

S2.1 The purchaser may specify magnetic particle inspection of castings made in accordance with this specification.

S2.2 If magnetic particle inspection is specified, the purchaser shall designate the zones of the casting to be so inspected.

S2.3 If magnetic particle inspection is specified, the purchaser shall designate acceptance standards for each type of discontinuity, preferably in accordance with Reference Photographs E 125.

S2.4 Magnetic particle inspection shall preferably be performed in accordance with Guide E 709.

S2.5 The circular or coil method of overall magnetization or the wet method of magnetic particle inspection, or both, may be used subject to agreement between the manufacturer and purchaser.

### S3. Radiographic Inspection

S3.1 The purchaser may specify radiographic inspection of castings made in accordance with this specification.

S3.2 If radiographic inspection is specified, radiography shall be performed in accordance with Guide E 94.

S3.3 If radiographic inspection is specified, the purchaser shall designate the areas of the castings to be so inspected.

S3.4 If radiographic inspection is specified, the purchaser shall designate acceptance standards for each type of discontinuity in each area of the castings to be so inspected.

S3.5 If radiographic inspection is specified, the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. The types and severity levels of discontinuities may be judged by reference to three ASTM standards: (*1*) Reference Radiographs E 446, (*2*) Reference Radiographs E 186, and (*3*) Reference Radiographs E 280.

### S4. Examination of Weld Preparation

S4.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125 of Degree 2 in sections up to 2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

### S5. Aluminum Restriction (Carbon and Low-Alloy Steel)

S5.1 Aluminum shall not be added directly or as a constituent of other deoxidizers in an amount exceeding ½ lb/ton [0.25 g/kg] of steel.



Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 356/A 356M - 05) that may impact the use of this standard. (Approved May 1, 2007)

(*1*) In Table 1, for Grade 12A, revised Al max and established max limits for Ti and Zr.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).*



Copyright ASTM International
Provided by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale