



Designation: **A356/A356M—16 A356/A356M – 21**

## Standard Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines<sup>1</sup>

This standard is issued under the fixed designation A356/A356M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 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.

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

1.2.1 Within the text, the SI units are shown in brackets.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

- [A370 Test Methods and Definitions for Mechanical Testing of Steel Products](#)
- [A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel](#)
- [A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys](#)
- [E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film](#)
- [E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings](#)
- [E165/E165M Practice for Liquid Penetrant Testing for General Industry](#)
- [E186 Reference Radiographs for Heavy-Walled \(2 to 4½ in. \(50.8 to 114 mm\)\) Steel Castings](#)
- [E280 Reference Radiographs for Heavy-Walled \(4½ to 12 in. \(114 to 305 mm\)\) Steel Castings](#)
- [E446 Reference Radiographs for Steel Castings Up to 2 in. \(50.8 mm\) in Thickness](#)
- [E709 Guide for Magnetic Particle Testing](#)

#### 2.2 *Manufacturers' Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*<sup>3</sup>

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

<sup>1</sup> 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.

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<sup>2</sup> 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.

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

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

### 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.

**TABLE 1 Chemical Requirements<sup>A</sup>**

Grade/ UNS Number	Material	Composition, %										
		Carbon	Manganese	Silicon	Phosphorus, max	Sulfur, max	Molybdenum	Chromium	Nickel	Vanadium		
1 J03502	carbon-steel	0.35 <sup>B</sup> max	0.70 <sup>B</sup> max	0.60 max	0.035	0.030	...	...	...	...	...	...
2 J12523	½ % molybdenum	0.25 <sup>B</sup> max	0.70 <sup>B</sup> max	0.60 max	0.035	0.030	0.45-0.65	...	...	...	...	...
5 J12540	½ % chromium, ½ % molybdenum	0.25 <sup>B</sup> max	0.70 <sup>B</sup> 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	...	...	...	...
CA6NM J91540	martensitic 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	...	...	...

**TABLE 1 Chemical Composition Requirements<sup>A,B</sup>**

Grade (UNS Number)	Type	Element, %									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	
1 (J03502)	Carbon Steel	0.35 <sup>C</sup>	0.70 <sup>C</sup>	0.035	0.030	0.60	...	...	...	...	
2 (J12523)	0.5Mo	0.25 <sup>C</sup>	0.70 <sup>C</sup>	0.035	0.030	0.60	...	...	0.45-0.65	...	
5 (J12540)	0.5Cr-0.5Mo	0.25 <sup>C</sup>	0.70 <sup>C</sup>	0.035	0.030	0.60	...	0.40-0.70	0.40-0.60	...	
6 (J12073)	1.25Cr-0.5Mo	0.20	0.50-0.80	0.035	0.030	0.60	...	1.00-1.50	0.45-0.65	...	
8 (J11697)	1Cr-1Mo-V	0.20	0.50-0.90	0.035	0.030	0.20-0.60	...	1.00-1.50	0.90-1.20	0.05-0.15	
9 (J21610)	1Cr-1Mo-V	0.20	0.50-0.90	0.035	0.030	0.20-0.60	...	1.00-1.50	0.90-1.20	0.20-0.35	
10 (J22090)	2.25Cr-1Mo	0.20	0.50-0.80	0.035	0.030	0.60	...	2.00-2.75	0.90-1.20	...	
CA6NM (J91540)	Martensitic Cr-Ni	0.06	1.00	0.040	0.030	1.00	3.5-4.5	11.5-14.0	0.4-1.0	...	

<sup>A</sup> Where ellipses appear in this table, there is no requirement and the element need not be analyzed for or reported.

<sup>B</sup> All values are maximums unless a range is provided.

<sup>C</sup> 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.

## 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~~ Castings of any grade in this specification may receive such preliminary heat treatment as the founder may elect to employ.

### 6.2 Heat Treatment for ~~Final Properties~~: Mechanical Properties (Grades 1, 2, 5, 6, 8, 9, and 10):

6.2.1 *Normalizing*—The castings shall be heated to and held at the proper temperature for a sufficient time to effect the desired transformation and withdrawn from the furnace and allowed to cool to effect 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].

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~~: Casting (CA6NM only in this specification):

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**.

## 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 **A370**.

## 9. Number of Tests and Retests

9.1 One tension test shall be made from each heat in each heat-treatment ~~charge~~ hatchlot 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.



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
CA6NM	martensitic chromium-nickel	110 [760]	80 [550]	15.0	35.0

TABLE 2 Tensile Requirements<sup>A</sup>

Grade	Type	Tensile Strength, ksi [MPa]	Yield Strength, ksi [MPa]	Elongation in 2 in. [50 mm], %	Reduction of Area, %
1	Carbon Steel	70 [485]	36 [250]	20.0	35.0
2	0.5Mo	65 [450]	35 [240]	22.0	35.0
5	0.5Cr-0.5Mo	70 [485]	40 [275]	22.0	35.0
6	1.25Cr-0.5Mo	70 [485]	45 [310]	22.0	35.0
8	1Cr-1Mo-V	80 [550]	50 [345]	18.0	45.0
9	1Cr-1Mo-V	85 [585]	60 [415]	15.0	45.0
10	2.25Cr-1Mo	85 [585]	55 [380]	20.0	35.0
CA6NM	Martensitic Cr-Ni	110 [760]	80 [550]	15.0	35.0

<sup>A</sup> All values are minimums.

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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~~ an optional (Supplementary Requirement S1) micro-examination 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~~ an optional (Supplementary Requirement S1) micro-examination 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. 54 of Test Methods and Definitions A370.

## 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.

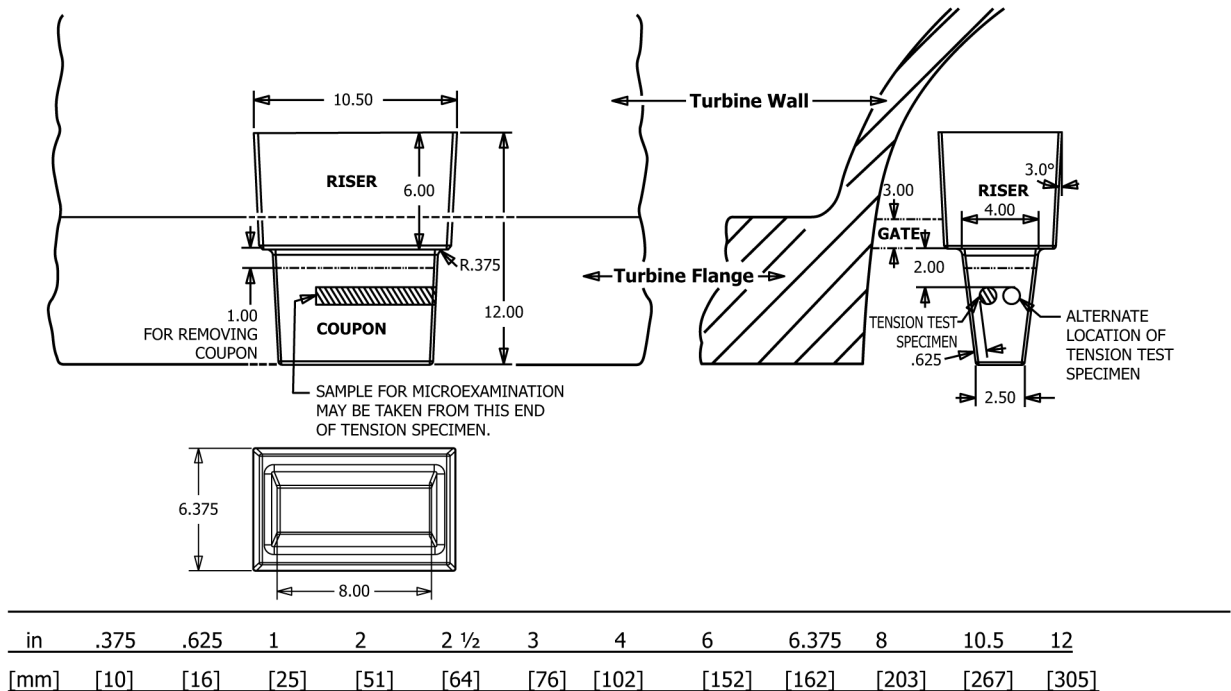


FIG. 1 Dimensions and Location of Test Coupons for Turbine Castings

## 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.