



## Standard Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures<sup>1</sup>

This standard is issued under the fixed designation A 732/A732M; 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.

<sup>ε1</sup> NOTE—Section 2 was revised editorially in January 2002.

### 1. Scope

1.1 This specification covers carbon and low-alloy steel castings made by the investment casting process.

1.2 Fifteen grades of steel and two cobalt alloy grades are covered (see Appendix).

NOTE 1—An investment casting is one that is produced in a mold, obtained by investing (surrounding) an expendable pattern with a refractory slurry which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material and is removed by heating prior to filling the mold with liquid metal.

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:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel<sup>3</sup>

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys<sup>4</sup>

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials<sup>5</sup>

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron<sup>6</sup>

E 94 Guide for Radiographic Testing<sup>7</sup>

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings<sup>7</sup>

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials<sup>5</sup>

E 165 Test Method for Liquid Penetrant Examination<sup>7</sup>

E 192 Reference Radiographs of Investment Steel Castings for Aerospace Applications<sup>7</sup>

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron<sup>6</sup>

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness<sup>7</sup>

E 709 Guide for Magnetic Particle Examination<sup>7</sup>

### 3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Description of the casting by part or pattern number or drawing,

3.1.2 ASTM designation and year of issue,

3.1.3 Grade of steel,

3.1.4 Quantity,

3.1.5 Options in the specification (4.1, 5.3, 6.1, 9.1, and 10.3), and

3.1.6 Supplementary requirements.

### 4. Heat Treatment

4.1 Castings shall be supplied in the heat-treated condition with the exception of Grades 21 and 31. Heat treatment shall be either annealing, normalizing and tempering, or quenching and tempering to obtain either the specified properties or other properties that might be agreed upon within each grade. In this latter instance, Supplementary Requirement S19 should be used. Grades 21 and 31 shall be supplied in the as-cast condition unless otherwise agreed upon.

4.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

<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.

Current edition approved Sept. 10, 1998. Published October 1998. Originally published as A 732 – 76. Last previous edition A 732/A 732M – 94<sup>ε1</sup>.

<sup>2</sup> *Annual Book of ASTM Standards*, Vols 01.02 and 01.03.

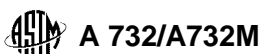
<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 03.03.



4.3 Definitions of terms relating to heat treatment shall be in accordance with Terminology A 941.

### 5. Chemical Composition

5.1 The castings shall conform to the requirements for chemical composition specified in Table 1 and Table 2.

5.2 *Cast or Heat Analysis*—An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1 and Table 2. The analysis shall be made from a test sample taken preferably during the pouring of the heat, or from a master heat (Note 2) which is remelted with only minor additions for deoxidization. The chemical composition determined from the heat or master heat shall be reported to the purchaser, or his representative, and shall conform to the requirements in Table 1.

NOTE 2—A master heat is refined and alloyed metal of a single furnace charge, not exceeding 10 000 lb [4500 kg].

5.3 *Product-Check-Verification Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburiza-

**TABLE 2 Chemical Requirements**

Type	Grade 21	Grade 31
Carbon	0.20–0.30	0.45–0.55
Manganese	1.00 max	1.00 max
Silicon, max	1.00	1.00
Phosphorus, max	0.040	0.040
Sulfur, max	0.040	0.040
Chromium	25.00–29.00	24.50–26.50
Nickel	1.75–3.75	9.50–11.50
Cobalt	remainder	remainder
Molybdenum	5.00–6.00	...
Tungsten	...	7.00–8.00
Vanadium	...	...
Columbium + tantalum	...	...
Nitrogen	...	...
Iron	3.00 max	2.00 max
Boron	0.007 max	0.005–0.015

tion, carbon and alloy steel samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in Table 1 and Table 2.

**TABLE 1 Chemical Requirements**

Grade	1A	2A,2Q	3A,3Q	4A,4Q	5N	6N	7Q	8Q
Type	Low Carbon IC 1020 <sup>A</sup>	Medium Carbon IC 1030	Medium Carbon IC 1040	Medium Carbon IC 1050	Vanadium IC 6120	Manganese Molybdenum IC 4020	Chromium Molybdenum IC 4130	Chromium Molybdenum IC 4140
Carbon	0.15 to 0.25	0.25 to 0.35	0.35 to 0.45	0.45 to 0.55	0.30 max	0.35 max	0.25 to 0.35	0.35 to 0.45
Manganese	0.20 to 0.60	0.70 to 1.00	0.70 to 1.00	0.70 to 1.00	0.70 to 1.00	1.35 to 1.75	0.40 to 0.70	0.70 to 1.00
Phosphorus, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80
Nickel	...	...	...	...	...	...	...	...
Chromium	...	...	...	...	...	...	0.80 to 1.10	0.80 to 1.10
Molybdenum	...	...	...	...	...	0.25 to 0.55	0.15 to 0.25	0.15 to 0.25
Vanadium	...	...	...	...	0.05 to 0.15	...	...	...
<i>Residual Elements:</i>								
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	0.50	...	0.50	0.50	...	0.50
Chromium	0.35	0.35	0.35	...	0.35	0.35	...	...
Molybdenum + Tungsten	0.25	...	...	...	0.25	...	...	...
Tungsten	...	0.10	0.10	0.10	...	0.25	0.10	0.10
Total content of unspecified elements	1.00	1.00	1.00	0.60	1.00	1.00	0.60	1.00

Grade	9Q	10Q	11Q	12Q	13Q	14Q	15A
Type	Chrome Nickel Molybdenum IC 4330	Chrome Nickel Molybdenum IC 4340	Nickel Molybdenum IC 4620	Chromium Vanadium IC 6150	Chrome Nickel Molybdenum IC 8620	Chrome Nickel Molybdenum IC 8630	Chromium IC 52100
Carbon	0.25 to 0.35	0.35 to 0.45	0.15 to 0.25	0.45 to 0.55	0.15 to 0.25	0.25 to 0.35	0.95 to 1.10
Manganese	0.40 to 0.70	0.70 to 1.00	0.40 to 0.70	0.65 to 0.95	0.65 to 0.95	0.65 to 0.95	0.25 to 0.55
Phosphorus, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80
Nickel	1.65 to 2.00	1.65 to 2.00	1.65 to 2.00	...	0.40 to 0.70	0.40 to 0.70	...
Chromium	0.70 to 0.90	0.70 to 0.90	...	0.80 to 1.10	0.40 to 0.70	0.40 to 0.70	1.30 to 1.60
Molybdenum	0.20 to 0.30	0.20 to 0.30	0.20 to 0.30	...	0.15 to 0.25	0.15 to 0.25	...
Vanadium	...	...	...	0.15 min	...	...	...
<i>Residual Elements:</i>							
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	...	...	...	0.50	...	...	0.50
Chromium	...	...	0.35	...	...	...	...
Molybdenum + Tungsten	...	...	...	0.10	...	...	...
Tungsten	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total content of unspecified elements	0.60	1.00	1.00	1.00	1.00	1.00	0.60

<sup>A</sup> Investment Casting (IC) numbers are to be used only for nomenclature comparison.



5.4 *Referee Analysis*—Test Methods E 30 and E 350 shall be used for reference purposes. When a comparison is made between the heat analysis and product analysis, the reproducibility data,  $R_2$ , in the precision statement of Test Methods E 350 shall be used as a guide.

## 6. Workmanship, Finish, and Appearance

6.1 The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser. Casting tolerances or deviations from drawing dimensions shall be agreed upon between the purchaser and the manufacturer and shall be on the drawing.

## 7. Quality Assurance

7.1 The surface of the casting shall be examined visually and shall be free of adhering refractory, scale, cracks, hot tears, and other injurious imperfections. Castings may have a gate evidence of 0.03 in. [0.8 mm] maximum on surfaces subject to subsequent machining and 0.01 in. [0.3 mm] maximum on the surfaces not subject to machining.

7.2 When additional inspection is desired, Supplementary Requirements S4, S5, or S6 may be ordered.

7.3 The castings shall not be peened or plugged or impregnated to stop leaks.

## 8. Repair by Welding

8.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

8.2 Welding shall be accomplished with a filler metal that produces a weld deposit with a chemical composition similar to the casting. Castings ordered in the annealed condition or for subsequent hardening shall be annealed after weld repairs. Castings ordered heat treated shall be tempered in accordance with the qualified welding procedure after weld repairs with the exception of Grades 1A and 2A where postheat treatment is optional.

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

## 9. Inspection

9.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections with the exception of product analysis (see 5.3) shall be made either at the place of manufacture or a laboratory with the capability to perform analyses or mechanical tests to the applicable ASTM specifications.

## 10. Rejection and Reheating

10.1 Any rejection based on tests made in accordance with 5.3 shall be reported to the manufacturer within 30 days from receipt of samples by the purchaser.

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

10.3 Castings rejected in accordance with this specification shall be made available to the manufacturer for his review and concurrence.

## 11. Certification

11.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with the specification (including year date), together with a report of the test results, shall be furnished at the time of shipment.

## 12. Product Marking

12.1 Castings shall be marked for identification as agreed upon by the manufacturer and the purchaser.

## 13. Keywords

13.1 steel castings; investment castings; carbon steel; alloy steel; cobalt alloys

## SUPPLEMENTARY REQUIREMENTS

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

### S1. Residual Elements

S1.1 The manufacturer shall determine the percentage of residual elements shown in Table 1 and Table 2 and report these results to the purchaser or his representative.

### S3. Tension Test (Castings Heat-Treated by Manufacturer)

S3.1. Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat-treated with production castings to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table 3, or to

properties agreed upon, and shall be reported to the purchaser or his representative.

S3.2 The test specimens shall be cast in the same type mold as the casting. They may be cast to shape or machined from blocks. The specimens shall be machined to dimensions in accordance with Test Methods and Definitions A 370 or the ICI bar shown in Fig. 1. Tension tests shall be performed in accordance with Test Methods and Definitions A 370.

S3.3 If the results of the mechanical test for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested. If any test specimen shows defective machining or develops flaws, it may be discarded, and