Designation: A 732/A732M – 05

Standard Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[1]

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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

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

1.2 Fifteen grades of steel and two cobalt alloy grades are covered.

1.3 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.4 This specification is expressed in both inch-pound units and SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply. 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 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 this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 957 Specification for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use

A 994 Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys

A 997 Practice for Investment Castings, Surface Accepted Standards, Visual Examination

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

3. Ordering Information

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

3.1.1 Quantity,

3.1.2 ASTM designation and issue date,

3.1.3 Grade designation (Tables 1 and 2), and

3.1.4 Description of casting by part, pattern, or drawing number. (Dimensional tolerances and machined surfaces shall be indicated on the casting drawing.).

3.2 The purchaser should specify any of the following information to describe adequately the desired material:

3.2.1 Heat-treat condition (see 5.1 and 5.2),

3.2.2 Repair welding (see Section 8 and Specification A 957),

3.2.3 Source inspection, if any (see Specification A 957), and

3.2.4 Supplementary requirements required (marking, certification, mechanical properties, NDT, and the like).

4. General Requirements

4.1 Material furnished to this specification shall conform to the requirements of Specification A 957, including any supplementary requirements that are indicated on the purchase order. Failure to comply with the requirements of Specification A 957 constitutes nonconformance with this specification. In case of conflict of this specification and Specification A 957, this specification shall prevail.

5. Heat Treatment

5.1 Steel castings shall be heat treated either by full annealing, normalizing, normalizing and tempering, or quenching and tempering to obtain the specified properties or other properties that have been agreed upon within each grade. In this latter instance, Supplementary Requirement S23 shall be used.

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

[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 Jan. 1, 2005. Published January 2005. Originally approved in 1976. Last previous edition approved in 2002 as A 732/A 732M – 02.

[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.

***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
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005

TABLE 1 Chemical Requirements

Grade	1A	2A,2Q	3A,3Q	4A,4Q	5N	6N	7Q	8Q
Type	Low Carbon IC 1020[A]	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			
Residual Elements:								
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 these residual 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			
Residual Elements:							
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50
				0.50			0.50
Chromium			0.35				
Molybdenum + Tungsten				0.10			
Tungsten	0.10	0.10	0.10		0.10	0.10	0.10
Total content of these residual elements	0.60	1.00	1.00	1.00	1.00	1.00	0.60

[A] Investment Casting (IC) numbers are to be used only for nomenclature comparison.

TABLE 2 Chemical Requirements-Cobalt Alloys

Grade	21	31
Carbon	0.20–0.30	0.45–0.55
Manganese, max.	1.00	1.00
Silicon, max	1.00	1.00
Phosphorus, max	0.040	0.040
Sulfur, max	0.040	0.040
Chromium	25.0–29.0	24.5–26.5
Nickel	1.7–3.8	9.5–11.5
Cobalt	remainder	remainder
Molybdenum	5.0–6.0	...
Tungsten	...	7.0–8.0
Iron, max.	3.00	2.00
Boron	0.007 max	0.005–0.015

5.2 Cobalt alloy castings shall be supplied in the as-cast condition unless otherwise agreed upon by supplier and purchaser.

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

6. Chemical Composition

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

7. Quality

7.1 The surface of the casting shall be examined visually to meet the requirements of Practice A 997. Acceptance criteria to be mutually agreed upon between supplier and purchaser.

7.2 The castings shall not be peened or plugged or impregnated.

8. Repair by Welding

8.1 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 post weld heat treated in accordance with the qualified welding procedure after weld repairs with the exception of Grades 1A and 2A where post weld heat treatment is optional.

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

9. Keywords

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

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Copyright by ASTM Int'l (all rights reserved);
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005
Not for Resale

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 957. Those ordinarily considered suitable for use with this specification are given below, together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in Specification A 957 may be used with this specification upon agreement between supplier and purchaser.

S1. Magnetic Particle Inspection

S2. Radiographic Inspection

S3. Liquid Penetrant Inspection

S6. Certification

S7. Prior Approval of Major Weld Repairs

S8. Marking

S13. Unspecified Elements

S16. Weld Repair Charts

S19. Decarburization

S23. Mechanical Properties

S23.1 Mechanical properties other than those specified in Table S24 may be ordered for each of the grades. The properties shall be agreed upon between the supplier and the purchaser.

S24. Tension Test (Castings Heat Treated by Supplier)

S24.1 Tensile properties shall be determined from material representing each re-melted heat. The results shall conform to the requirements specified in Table S24, or to properties agreed upon, and shall be reported to the purchaser or his representative. See Specification A 957 for additional details and requirements.

S25. Tension Test (Castings Heat Treated by Purchaser)

S25.1 The supplier shall heat treat a tension specimen from a re-melted heat of same primary heat to determine whether the castings are capable of being heat treated to the specified properties. The results shall conform to the requirements specified in Table S24, or to properties agreed upon, and shall be reported to the purchaser or his representative. See Specificatioin A 957 for additional details and requirements.

S26. High Temperature Tension Test

S26.1 High-temperature tension tests shall be required when specified in the inquiry, contract, or order. When so specified, the properties obtained shall be reported to the purchaser or his representative and shall conform to the requirements prescribed in Table S26. The tension test shall be performed in accordance with Test Methods E 21.

S27. Stress Rupture Test

S27.1 Stress rupture tests shall be required when specified in the inquiry, contract, or order. When so specified, the properties obtained shall be reported to the purchaser or his

TABLE S24 Tensile Requirements

Grade	Tensile strength, min		Yield strength, min		Elongation, in 2-in. [50-mm] or 4 diameters	Heat Treatment
	ksi	[MPa]	ksi	[MPa]		
1A	60	[414]	40	[276]	24	A[A]
2A	65	[448]	45	[310]	25	A
2Q	85	[586]	60	[414]	10	Qt[B]
3A	75	[517]	48	[331]	25	A
3Q	100	[689]	90	[621]	10	Qt
4A	90	[621]	50	[345]	20	A
4Q	125	[862]	100	[689]	5	Qt
5N	85	[586]	55	[379]	22	Nt[C]
6N	90	[621]	60	[414]	20	Nt
7Q	150	[1030]	115	[793]	7	Qt
8Q	180	[1241]	145	[1000]	5	Qt
9Q	150	[1030]	115	[793]	7	Qt
10Q	180	[1241]	145	[1000]	5	Qt
11	120	[827]	100	[689]	10	Qt
12Q	190	[1310]	170	[1172]	4	Qt
13Q	105	[724]	85	[586]	10	Qt
14Q	150	[1030]	115	[793]	7	Qt
15A[D]	...	...	...	...	...	A

[A] Annealed.
[B] Quenched and tempered.
[C] Normalized and tempered.
[D] Hardness Rockwell B, 100 max.

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Copyright by ASTM Int'l (all rights reserved);
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005
Not for Resale

TABLE S26 Elevated-Temperature Tensile Requirements

Grade	21	31
Condition	as cast	as cast
Test temperature:		
°F	1500	1500
°C	820	820
Tensile strength, min:		
ksi	52.0	55.0
MPa	360	380
Elongation in 4*D*, min , %	10	10

representative and shall conform to the requirements prescribed in Table S27. The stress rupture test shall be performed in accordance with Practice E 139.

TABLE S27 Stress Rupture Requirements

Grade	21	31
Condition	as cast	as cast
Test temperature:		
°F	1500	1500
°C	820	820
Stress:		
ksi	23.0	30.0
MPa	160	205
Rupture life, min, h	15	15
Elongation in 4*D*, min, %	5	5

APPENDIX

(Nonmandatory Information)

X1. GUIDE TO CLASSIFICATION OF COBALT ALLOY CASTINGS

X1.1 This guide is appended to the specification as a source of information; it is not mandatory and does not form a part of the specification.

X1.1.1 This specification itself is intended to provide both the manufacturer and the purchaser of alloy castings with a means of production control on the basis of acceptance through mutually acceptable, sound, standard requirements.

X1.1.2 This guide has been prepared as an aid to prospective users of alloy castings covered by the specification in determining the classification best suited for a particular application with due consideration to the particular requirements for that application.

X1.2 *Stress for Design*—The old method of basing design calculations on 50 % of the limiting creep stress is conservative, but it is relatively crude and has the disadvantage that the resulting stress values do not have a consistent relation to life expectancy. Design with the stress that should produce rupture in 100 000 h is frequently satisfactory, though it should be recognized that this is an extrapolated value and provides no assurance that the installation will actually endure for this time. Among the factors that can result in shorter life are reduction of the effective cross-sectional area by hot-gas corrosion, thermal stresses superimposed on the normal working stresses, and overheating. Usually overheating is the most serious of these, since in general a 200°F [110°C] increase in temperature will cut the rupture strength in half.

X1.3 *Grade 21 (Cobalt-base—27 % Cr, 5.5 % Mo, 2.8 % Ni):*

X1.3.1 This grade is resistant to oxidizing and reducing atmospheres at temperatures up to 2100°F [1150°C]. The alloy has good strength at elevated temperatures and is used in many applications where resistance to thermal shock is important. The alloy can be produced as sand, shell, or investment castings.

X1.3.2 *Composition*—This grade is of the austenitic, solid solutioning type and possesses its basic strength characteristics without the need of heat treatment. However, the alloy is so designed that aging occurs in the 1300 to 2100°F [700 to 1150°C] range by the formation of carbides, thus strengthening the alloy in service. The high chromium imparts the excellent oxidation resistance of the alloy and contributes, along with the molybdenum, to the strength of the alloy.

X1.3.3 *Mechanical Properties*—This grade can be used for applications of high stress up to 1500°F [815°C] and moderate strength requirements to 2100°F [1150°C]. The average as-cast tensile strength at 1500°F is 62 000 psi [430 MPa] with 16 % elongation. The alloy exhibits good impact strength even in the age-strengthened condition. The average charpy *V*-notch impact strength after aging is above 20 ft·lb [27 J] in the 1200 to 1800°F [650 to 980°C] range. Table X1.1 contains typical stress-rupture data for this alloy.

X1.3.4 *Applications*—This grade can be used for applications of high stress up to 1500°F and for moderate strength requirements up to 2100°F. In the past, it has been used

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Copyright by ASTM Int'l (all rights reserved);
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005
Not for Resale

TABLE X1.1 Typical Stress-Rupture Data for Grade 21

Test Temperature		Average Initial Stress for Rupture							
°F	°C	10 h		100 h		500 h		1000 h	
		Psi	MPa	Psi	MPa	Psi	MP[a	Psi	MPa
1400	760	42 000	290	24 000	165	18 000	124	15 000	103
1500	815	27 500	189	19 000	131	15 000	103	13 500	93
1700	925	17 000	117	13 000	90	10 800	74	10 000	69
1800	980	12 500	86	9 400	65	7 700	53	7 000	48

TABLE X1.2 Typical Stress-Rupture Data for Grade 31

Test Temperature		Average Initial Stress for Rupture							
°F	°C	10 h		100 h		500 h		1000 h	
		Psi	MPa	Psi	MPa	Psi	MPa	Psi	MPa
1350	730	49 000	338	44 000	303	40 000	276	39 000	269
1500	815	33 000	228	27 000	159	23 000	159	22 000	152
1700	925	20 000	138	17 000	117	15 400	106	14 500	100
1800	980	13 000	90	11 300	78	10 200	70	9 800	68

successfully for gas turbine blades and vanes, as well as for turbosupercharger blading applications.

X1.4 *Grade 31 (Cobalt-base—25.5 % Cr, 10.5 % Ni, 7.5 % W):*

X1.4.1 This grade has been one of the most useful high-temperature alloys in the past. The alloy is used for high-strength applications to about 1500°F [815°C] and moderate-strength applications to 1800°F [980°C]. It has excellent oxidation resistance, thermal shock resistance, and fatigue life. The alloy can be produced as a sand, shell, or investment casting.

X1.4.2 *Composition*—This grade is the austenitic, solid solutioning type and possesses its basic strength characteristics without the need of heat treatment. However, the alloy is so designed that aging and strengthening occur in service through the precipitation of carbides. Also, it is sometimes necessary to employ a solution heat-treatment for heavy sections of castings to develop optimum strength.

X1.4.3 *Mechanical Properties*—Until the introduction of the vacuum-melted nickel-base, precipitation-hardening alloys, the solid solution cobalt-base alloys were considered the stronger of the available engineering materials for high temperature applications. At 1500°F [815°C] this grade has an average as-cast tensile strength of 63 200 psi [43.5 MPa] and an elongation of 15 %. The combination of strength with high ductility is an advantage over other alloys which exhibit ductilities in the order of 5 % or less. Table X1.2 contains typical stress-rupture data for this alloy.

X1.4.4 *Applications*—This grade can be used for applications of high stress up to 1500°F [816°C] and for moderate strength requirements up to 2100°F [1149°C]. In the past, it has been used extensively for blading and vanes for gas turbine and turbosuperchargers.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 732/A 732M - 02) that may impact the use of this standard. (Approved Jan. 1, 2005.)

(1) This specification has been completely revised and updated to meet the requirements of Form and Style of Guide A 994, to incorporate the requirements of Investment Casting Common Requirements of Specification A 957, and to incorporate the requirements of Investment Casting Visual Examine of Practice A 997. Other than minor additions from the visual specification, the technical requirements of this specification have not changed.

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005
Not for Resale

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
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Copyright by ASTM Int'l (all rights reserved);
Reproduction authorized per License Agreement with Kathe Hooper (ASTMIHS Account); Mon Jan 24 15:25:41 EST 2005
Not for Resale