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## Standard Specification for Castings, Nickel and Nickel Alloy<sup>1</sup>

This standard is issued under the fixed designation A494/A494M; 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.

*This standard has been approved for use by agencies of the Department of Defense.*

<sup>1</sup> NOTE—Table 1 was editorially corrected in February 2010.

### 1. Scope\*

1.1 This specification covers nickel, nickel-copper, nickel-copper-silicon, nickel-molybdenum, nickel-chromium, and nickel-molybdenum-chromium alloy castings for corrosion-resistant service.

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 non-conformance with the standard.

### 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](#)

[A732/A732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures](#)

[A781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use](#)

[E8 Test Methods for Tension Testing of Metallic Materials](#)

[E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)

[E30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron \(Withdrawn 1995\)<sup>3</sup>](#)

[E38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys \(Withdrawn 1989\)<sup>3</sup>](#)

[E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys \(Withdrawn 2003\)<sup>3</sup>](#)

[E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys](#)

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *master heat*—a single furnace charge of refined alloy, which may either be poured directly into castings or into remelt alloy for individual melts.

3.1.2 *melts*—a single furnace charge poured into castings. When master heats are used to prepare melts, a melt analysis shall be reported.

### 4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the requirements of Specification [A781/A781M](#), including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification [A781/A781M](#) constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification [A781/A781M](#), this specification shall prevail.

<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](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

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



## 5. Ordering Information

5.1 Orders for castings to this specification should include the following information:

5.1.1 Quantity, in pieces, and

5.1.2 Grade designation (Table 1) and class (Table 2).

5.2 The purchaser shall specify any of the following information required to describe adequately the desired material:

5.2.1 Heat-treat condition (see 6.1 and 6.2),

5.2.2 Repair welding (see Section 11)

5.2.3 Source inspection requirements, if any (see Specification A781/A781M),

5.2.4 Marking-for-identification requirements, if any (see 13.1), and

5.2.5 Supplementary requirements desired, including the standards of acceptance.

## 6. Heat Treatment

6.1 Castings shall be heat treated in accordance with the requirements in Table 2.

NOTE 1—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and, in some cases, to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature, and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6.2 When Class 1 is specified, grades CY40 and M25S shall be supplied in the as-cast condition. When Class 2 is specified, grades CY40 and M25S shall be supplied in the solution-treated condition. When Class 3 is specified, grade M25S shall be supplied in the age-hardened condition.

## 7. Chemical Composition

7.1 These alloys shall conform to the chemical composition requirements prescribed in Table 1.

7.2 The grades that pertain to this specification are placed into the five general categories given below. The producer shall report for information all elements in Table 1 for which a limit is given for any alloy in the same alloy family. The alloy families are:

(1) Nickel – CZ100

(2) Nickel-copper – M35-1, M35-2, M30C, M30H, M25S

(3) Nickel-molybdenum – N12MV, N7M, N3M

(4) Nickel-chromium – CY40, CW6M, CW2M, CW6MC, CX2MW, CU5MCuC, CX2M

(5) Other – CY5SnBiM

7.3 An analysis of each master heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a representative sample taken during the pouring of the master heat. Chemical composition shall be reported to the purchaser or his representative.

7.4 Test Methods E76 or Test Methods E354 shall be used for referee purposes. Test Methods E30 or Methods E38 shall be used if Test Methods E76 or Test Methods E354 do not include a method for some element present in the material.

## 8. Tensile Properties

8.1 One tension test shall be made from each master heat except for grades M25S and CY5SnBiM when the master heat is used to pour the castings. One tension test shall be made from each melt except for grades M25S and CY5SnBiM. Test results shall conform to the tensile requirements specified in Table 3. Test bars shall be poured in special blocks from the same heat as the castings represented.

8.2 The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. If the castings are not heat treated, the bar used for the test specimen must not be heat treated.

8.3 Test specimens may be cut from castings, at the producer's option, instead of from test bars.

8.4 When castings are produced by methods other than investment process, tension test coupons shall be machined to the form and dimension shown in Fig. 8 of, and tested in accordance with, Test Methods E8.

8.4.1 When castings are produced by the investment process, test specimens in accordance with Specification A732/A732M shall be used for measurement of tensile properties.

8.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heats.

8.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded in accordance with Practice E29 to the nearest 500 psi [3.5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

TABLE 1 Chemical Requirements

NOTE 1—Values are maximum unless otherwise indicated.

Alloy Family	Ni	Ni-Cu					Ni-Mo			Ni-Cr							Other	
		Grade	M25S	M30C <sup>A</sup>	M30H	M35-1 <sup>A</sup>	M35-2	N3M	N7M	N12MV	CU5MCuC	CW2M	CW6M	CW6MC	CW12MW	CX2M		CX2MW
UNS Numbers	N02100	N24025	N24130	N24030	N24135	N24020	J30003	J30007	N30012	N08826	N26455	N30107	N26625	N30002	N26059	N26022	N06040	N26055
Composition, %																		
C†	1.00	0.25	0.30	0.30	0.35	0.35	0.03	0.07	0.12	0.050†	0.02	0.07	0.06	0.12	0.02	0.02	0.40	0.05
C	1.00	0.25	0.30	0.30	0.35	0.35	0.03	0.07	0.12	0.050	0.02	0.07	0.06	0.12	0.02	0.02	0.40	0.05
Mn†	1.50	1.50	1.50	1.50	1.50	1.50	1.00	1.00	1.00	1.0†	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.5
Mn	1.50	1.50	1.50	1.50	1.50	1.50	1.00	1.00	1.00	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.5
Si†	2.00	3.5-4.5	1.0-2.0	2.7-3.7	1.25	2.00	0.50	1.00	1.00	1.0†	0.80	1.00	1.00	1.00	0.50	0.80	3.00	0.5
Si	2.00	3.5-4.5	1.0-2.0	2.7-3.7	1.25	2.00	0.50	1.00	1.00	1.0	0.80	1.00	1.00	1.00	0.50	0.80	3.00	0.5
P†	0.03	0.03	0.03	0.03	0.03	0.03	0.040	0.040	0.040	0.030†	0.03	0.040	0.015	0.040	0.020	0.025	0.03	0.03
P	0.03	0.03	0.03	0.03	0.03	0.03	0.030	0.030	0.030	0.030†	0.03	0.030	0.015	0.030	0.020	0.025	0.03	0.03
S	0.02	0.02	0.02	0.02	0.02	0.02	0.020	0.020	0.020	0.020	0.02	0.020	0.015	0.020	0.020	0.020	0.02	0.02
Cu	1.25†	27.0-33.0	26.0-33.0	27.0-33.0	26.0-33.0	26.0-33.0	...	...	...	1.50-3.50	B	B	B	B	B	B	B	...
Cu	1.25	27.0-33.0	26.0-33.0	27.0-33.0	26.0-33.0	26.0-33.0	...	...	...	1.50-3.50	B	B	B	B	B	B	B	...
Mo	...	...	...	...	...	...	30.0-33.0	30.0-33.0	26.0-30.0	2.5-3.5	15.0-17.5	17.0-20.0	8.0-10.0	16.0-18.0	15.0-16.5	12.5-14.5	B	2.0-3.5
Fe	3.00†	3.50†	3.50†	3.50†	3.50†	3.50†	3.00†	3.00†	4.0-6.0	balance	2.0†	3.0†	5.0†	4.5-7.5	1.50†	2.0-6.0	11.0†	2.0†
Fe	3.00	3.50	3.50	3.50	3.50	3.50	3.00	3.00	4.0-6.0	balance	2.0	3.0	5.0	4.5-7.5	1.50	2.0-6.0	11.0	2.0
Ni	95.00 min	balance	balance	balance	balance	balance	balance	balance	balance	38.0-44.0	balance	balance	balance	balance	balance	balance	balance	balance
Cr	...	...	...	...	...	...	1.0	1.0	1.00	19.5-23.5	15.0-17.5	17.0-20.0	20.0-23.0	15.5-17.5	22.0-24.0	20.0-22.5	14.0-17.0	11.0-14.0
Gb (Nb)	...	B	1.0-3.0	B	0.5†	0.5†	...	...	...	0.60-1.20	B	B	3.15-4.50	B	B	B	B	...
Cb (Nb)	...	B	1.0-3.0	B	0.5	0.5	...	...	...	0.60-1.20	B	B	3.15-4.50	B	B	B	B	...
W	...	...	...	...	...	...	...	...	...	B	1.0†	B	B	3.75-5.25	B	2.5-3.5	B	...
W	...	...	...	...	...	...	...	...	...	B	1.0	B	B	3.75-5.25	B	2.5-3.5	B	...
V	...	...	...	...	...	...	B	B	0.20-0.60	B	B	B	B	0.40	B	0.35†	B	...
V	...	...	...	...	...	...	B	B	0.20-0.60	B	B	B	B	0.40	B	0.35	B	...
Bi	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.0-5.0
Sn	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.0-5.0

<sup>A</sup> Order M35-1 or M30C when weldability is required.

<sup>B</sup> Element to be analyzed and reported for information only.

†Editorially corrected.



TABLE 2 Heat Treat Requirements

Grade	Heat Treatment
CZ100, M35-1, M35-2, CY40 Class 1, M30H, M30C, M25S Class 1, CY5SnBiM M25S, Class 2 <sup>A</sup>	As cast  Load into furnace at 600°F [315°C] maximum. Heat to 1600°F [870°C] and hold for 1 h plus an additional 30 min for each ½ in. [13 mm] of cross section over 1 in. <sup>B</sup> Cool to 1300°F [705°C] <sup>C</sup> and hold at temperature for 30 min then quench in oil to room temperature.
M25S, Class 3	Load into furnace at 600°F [315°C] maximum. Heat slowly to 1100°F [605°C] and hold to develop maximum hardness. Furnace or air cool to room temperature.
N12MV, N7M, N3M	Heat to 2000°F [1095°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CW12MW, CW6M, CW6MC, CW2M	Heat to 2150°F [1175°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CY40, Class 2	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2MW	Heat to 2200°F [1205°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.
CU5MCuC	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water. Stabilize at 1725-1815°F [940-990°C], hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2M	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.

<sup>A</sup> M25S, while machinable in the “as-cast” condition, is capable of being solution treated for improved machinability. It may be subsequently age hardened to the hardness specified in Table 3 and finished machined or ground.

<sup>B</sup> For cross sections over 6 in. [125 mm], it may be necessary to increase the hold time if maximum softness is desired.

<sup>C</sup> For maximum softness and the least variation in hardness levels, castings should be transferred from an oven at 1600°F [870°C] to a second oven at 1300°F [705°C].

TABLE 3 Mechanical Properties

Alloy Family	Ni	Ni-Cu					Ni-Mo			Ni-Cr							Other		
		CZ100	M25S	M30C	M35-1	M35-2	M35-1	M35-2	N3M	N7M	N12MV	CU5-MCuC	CW2M	CW6M	CW6MC	CW-12MW		CX2M	CX2MW
Tensile strength, min, ksi [MPa]	50 [345]	...	65 [450]	100 [690]	65 [450]	65 [450]	76 [525]	76 [525]	76 [525]	75 [520]	72 [495]	72 [495]	70 [485]	72 [495]	72 [495]	72 [495]	80 [550]	70 [485]	...
Yield strength, min, ksi [MPa]	18 [125]	...	32.5 [225]	60 [415]	25 [170]	30 [205]	40 [275]	40 [275]	40 [275]	35 [240]	40 [275]	40 [275]	40 [275]	40 [275]	39 [270]	45 [310]	28 [195]	...	
Elongation in 2 in. [50 mm], <sup>A</sup> min, %	10	...	25	10	25	25	20.0	20	6	20	20	25	25	4	40	30	30	...	
Elongation in 2 in. [50 mm], <sup>A</sup> min, %	10	...	25	10	25	25	20.0	20	6	20	20	25	25	4	40	30	30	...	
Hardness HB	...	<sup>B</sup>	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

<sup>A</sup> When ICI test bars are used in tensile testing as provided for in Specification A732/A732M, the gage length to reduced section diameter ratio shall be 4 to 1.

<sup>B</sup> 300 HB minimum for the age hardened condition.

## 9. Workmanship, Finish, and Appearance

9.1 Critical surfaces of all castings intended for corrosion-resistant service shall be cleaned. Cleaning may be accomplished by blasting with clean sand or metallic corrosion-resistant shot or by other approved methods.

## 10. Quality

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

10.2 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets and affected cast material must be completely removed.

## 11. Repair by Welding

11.1 Repairs shall be made by using a welding procedure and operators capable of producing sound welds. The composition of deposited weld metal shall be similar to that of the castings.

11.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the