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Standard Specification for Castings, Nickel and Nickel Alloy[1]

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 U.S. Department of Defense.

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 nonconformance with the standard.

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:*[2]

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
A957/A957M Specification for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use
E8/E8M 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E30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron (Withdrawn 1995)[3]
E38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys (Withdrawn 1989)[3]
E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)[3]
E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

3. Terminology

3.1 *Definitions:*

[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.

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[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] The last approved version of this historical standard is referenced on www.astm.org.

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

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 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A781/A781M, including any supplementary requirements that are indicated on 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.

4.2 Investment castings furnished to this specification shall conform to the requirements of Specification A957/A957M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A957/A957M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A957/A957M, Specification A957/A957M shall prevail.

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 adequately describe 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 heat-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:

TABLE 1 Composition Requirements[A,B]

Grade Type UNS	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	Molybdenum	Element, % Iron	Nickel	Chromium	Niobium[C]	Tungsten	Vanadium	Bismuth	Tin
~~Element, %~~	~~CZ100 Ni N02100~~	~~M25S Ni-Cu N24025~~	~~M30C[C] Ni-Cu N24130~~	~~M30H Ni-Cu N24030~~	~~M35-1[C] Ni-Cu N24135~~	~~M35-2 Ni-Cu N04020~~	~~N3M Ni-Mo N30003~~	~~N7M Ni-Mo N30007~~	~~N12MV Ni-Mo N30012~~	~~Material Grade, Type, UNS~~					
~~Carbon~~	~~1.00~~	~~0.25~~	~~0.30~~	~~0.30~~	~~0.35~~	~~0.35~~	~~0.03~~	~~0.07~~	~~0.12~~						
~~Manganese~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.00~~	~~1.00~~	~~1.00~~						
~~Phosphorus~~	~~0.03~~	~~0.03~~	~~0.03~~	~~0.03~~	~~0.03~~	~~0.03~~	~~0.030~~	~~0.030~~	~~0.030~~						
~~Sulfur~~	~~0.02~~	~~0.02~~	~~0.02~~	~~0.02~~	~~0.02~~	~~0.02~~	~~0.020~~	~~0.020~~	~~0.020~~						
CU5MCuC Ni-Cr N08826	0.050	1.0	0.030	0.020	1.0	1.50–3.50	2.5–3.5	Balance	38.00–44.0	19.5–23.5	0.60–1.20	[E]	[E]	. . .	. . .
~~Silicon~~	~~2.00~~	~~3.5 – 4.5~~	~~1.0 – 2.0~~	~~2.7 – 3.7~~	~~1.25~~	~~2.00~~	~~0.50~~	~~1.00~~	~~1.00~~						
~~Copper~~	~~1.25~~	~~27.0 – 33.0~~	~~26.0 – 33.0~~	~~27.0 – 33.0~~	~~26.0 – 33.0~~	~~26.0 – 33.0~~	~~. . .~~	~~. . .~~	~~. . .~~						
CW2M Ni-Cr N26455	0.02	1.00	0.03	0.02	0.80	[E]	15.0–17.5	2.0	Balance	15.0–17.5	[E]	1.0	[E]	. . .	. . .
CW6M Ni-Cr N30107	0.07	1.00	0.030	0.020	1.00	[E]	17.0–20.0	3.0	Balance	17.0–20.0	[E]	[E]	[E]	. . .	. . .
~~Molybdenum~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~30.0 – 33.0~~	~~30.0 – 33.0~~	~~26.0 – 30.0~~						
CW6MC Ni-Cr N26625	0.06	1.00	0.015	0.015	1.00	[E]	8.0–10.0	5.0	Balance	20.0–23.0	3.15–4.50	[E]	[E]	. . .	. . .
~~Iron~~	~~3.00~~	~~3.50~~	~~3.50~~	~~3.50~~	~~3.50~~	~~3.50~~	~~3.00~~	~~3.00~~	~~4.0 – 6.0~~						
~~Nickel~~	~~95.00 (min)~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~						
CW12MW Ni-Cr N30002	0.12	1.00	0.030	0.020	1.00	[E]	16.0–18.0	4.5–7.5	Balance	15.5–17.5	[E]	3.75–5.25	0.20–0.40	. . .	. . .
~~Chromium~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~1.0~~	~~1.0~~	~~1.00~~						
CX2M Ni-Cr N26059	0.02	1.00	0.020	0.020	0.50	[E]	15.0–16.5	1.50	Balance	22.0–24.0	[E]	[E]	[E]	. . .	. . .
~~Columbium (Niobium)[D]~~	~~. . .~~	~~[E]~~	~~1.0 – 3.0~~	~~[E]~~	~~0.5~~	~~0.5~~	~~. . .~~	~~. . .~~	~~. . .~~						
CX2MW Ni-Cr N26022	0.02	1.00	0.025	0.020	0.80	[E]	12.5–14.5	2.0–6.0	Balance	20.0–22.5	[E]	2.5–3.5	0.35	. . .	. . .
~~Tungsten~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~						
~~Vanadium~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~[E]~~	~~[E]~~	~~0.20 – 0.60~~						

TABLE 1 *Continued*

Grade Type UNS	Element, % Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	Molybdenum	Iron	Nickel	Chromium	Niobium[C]	Tungsten	Vanadium	Bismuth	Tin
CY40 Ni-Cr N06040	0.40	1.50	0.03	0.02	3.00	[E]	[E]	11.0	Balance	14.0–17.0	[E]	[E]	[E]	. . .	. . .
~~Bismuth~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~						
CY5SnBiM Other N26055	0.05	1.5	0.03	0.02	0.5	. . .	2.0–3.5	2.0	Balance	11.0–14.0	. . .	. . .	. . .	3.0–5.0	3.0–5.0
~~Tin~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~						
CZ100 Ni N02100	1.00	1.50	0.03	0.02	2.00	1.25	. . .	3.00	95.00 min	. . .	. . .	. . .	. . .	. . .	. . .

~~Element, %~~	~~CU5MCuC Ni-Cr N08826~~	~~CW2M Ni-Cr N26455~~	~~CW6M Ni-Cr N30107~~	~~CW6MC Ni-Cr N26625~~	~~CW12MW Ni-Cr N30002~~	~~CX2M Ni-Cr N26059~~	~~CX2MW Ni-Cr N26022~~	~~CY40 Ni-Cr N06040~~	~~CY5SNBiM Other N26055~~	~~Material Grade, Type, UNS~~
~~Carbon~~	~~0.050~~	~~0.02~~	~~0.07~~	~~0.06~~	~~0.12~~	~~0.02~~	~~0.02~~	~~0.40~~	~~0.05~~	
~~Manganese~~	~~1.0~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.50~~	~~1.5~~	
~~Phosphorus~~	~~0.030~~	~~0.03~~	~~0.030~~	~~0.015~~	~~0.030~~	~~0.020~~	~~0.025~~	~~0.03~~	~~0.03~~	
~~Sulfur~~	~~0.020~~	~~0.02~~	~~0.020~~	~~0.015~~	~~0.020~~	~~0.020~~	~~0.020~~	~~0.02~~	~~0.02~~	
~~Silicon~~	~~1.0~~	~~0.80~~	~~1.00~~	~~1.00~~	~~1.00~~	~~0.50~~	~~0.80~~	~~3.00~~	~~0.5~~	
~~Copper~~	~~1.50—3.50~~	~~E~~	~~E~~	~~E~~	~~E~~	~~E~~	~~E~~	~~E~~	~~. . .~~	
M25S Ni-Cu N24025	0.25	1.50	0.03	0.02	3.5–4.5	27.0–33.0	. . .	3.50	Balance	. . .	[E]	. . .	. . .	. . .	. . .
~~Molybdenum~~	~~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~~	~~E~~	~~2.0—3.5~~						
~~Iron~~	~~Balance~~	~~2.0~~	~~3.0~~	~~5.0~~	~~4.5—7.5~~	~~1.50~~	~~2.0—6.0~~	~~11.0~~	~~2.0~~						
M30C[D] Ni-Cu N24130	0.30	1.50	0.03	0.02	1.0–2.0	26.0–33.0	. . .	3.50	Balance	. . .	1.0–3.0	. . .	. . .	. . .	. . .
~~Nickel~~	~~38.00—44.0~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~	~~Balance~~						
~~Chromium~~	~~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~~						
~~Columbium (Niobium)[D]~~	~~0.60—1.20~~	~~E~~	~~E~~	~~3.15—4.50~~	~~E~~	~~E~~	~~E~~	~~E~~	~~. . .~~						
M30H Ni-Cu N24030	0.30	1.50	0.03	0.02	2.7–3.7	27.0–33.0	. . .	3.50	Balance	. . .	[E]	. . .	. . .	. . .	. . .
~~Tungsten~~	~~E~~	~~1.0~~	~~E~~	~~E~~	~~3.75—5.25~~	~~E~~	~~2.5—3.5~~	~~E~~	~~. . .~~						
M35-1[D] Ni-Cu N24135	0.35	1.50	0.03	0.02	1.25	26.0–33.0	. . .	3.50	Balance	. . .	0.5	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

Grade Type UNS	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	Molybdenum	Element, % Iron	Nickel	Chromium	Niobium[C]	Tungsten	Vanadium	Bismuth	Tin
~~Vanadium~~	[E]	[E]	[E]	[E]	~~0.20–0.40~~	[E]	~~0.35~~	[E]	...						
~~Bismuth~~	...	...	...	...	...	...	...	...	~~3.0 – 5.0~~						
M35-2 Ni-Cu N04020	0.35	1.50	0.03	0.02	2.00	26.0–33.0	...	3.50	Balance	...	0.5	...	...	...	...
N3M Ni-Mo N30003	0.03	1.00	0.030	0.020	0.50	...	30.0–33.0	3.00	Balance	1.0	...	...	[E]	...	...
~~Tin~~	...	...	...	...	...	...	...	...	~~3.0 – 5.0~~						
N7M Ni-Mo N30007	0.07	1.00	0.030	0.020	1.00	...	30.0–33.0	3.00	Balance	1.0	...	...	[E]	...	...
N12MV Ni-Mo N30012	0.12	1.00	0.030	0.020	1.00	...	26.0–30.0	4.0–6.0	Balance	1.00	...	...	0.20–0.60	...	...

[A] Where ellipses (...) appear in this table, there is no requirement, and the element need not be analyzed for or reported.
[B] All values are maximum unless ~~a~~ specified as a minimum or a range is provided.
~~[C] Order M35-1 or M30C when weldability is required.~~
[C] Columbium (Cb) and niobium (Nb) are interchangeable names for the same element 41.
[D] Order M35-1 or M30C when weldability is required.
[E] Element to be analyzed and reported for information only. See paragraph 5.5 (Grade Substitution) of Specification A781/A781M or for investment castings, Specification A957/A957M.

TABLE 2 Heat-Treat Requirements

Grade	Heat Treatment
CZ100, M35-1, M35-2, CY40 Class 1, M30H, M30C, M25S Class 1, CY5SnBiM	As cast
M25S, Class 2[A]	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.[B] Cool to 1300 °F [705 °C][C] 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.~~
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.

[A] M25S, while machinable in the "as-cast" condition, is capable of being solution heat treated for improved machinability. It may be subsequently age hardened to the hardness specified in Table 3 and finished machined or ground.
[B] For cross sections over 6 in. [125 mm], it may be necessary to increase the hold time if maximum softness is desired.
[C] 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].

(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 their representative.

7.4 Test Methods E76 or E354 shall be used for referee purposes. Test Methods E30 or E38 shall be used if Test Methods E76 or 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/E8M.

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.

TABLE 3 Mechanical Properties

Alloy Family	Ni	Ni-Cu				Ni-Mo		
	CZ100	M25S	M30C	M30H	M35-1	M35-2	N3M	N
Tensile strength, min, ksi [MPa]	50 [345]	...	65 [450]	100 [690]	65 [450]	65 [450]	76 [525]	[
Yield strength, min, ksi [MPa]	18 [125]	...	32.5 [225]	60 [415]	25 [170]	30 [205]	40 [275]	[
Elongation in 2 in. [50 mm],[A] min, %	10	...	25	10	25	25	20.0	
Hardness HBW	...	[B]	...	...	...	...	...	

TABLE 3 Mechanical Properties[A,B]

Type	Grade	Tensile Strength, ksi [MPa]	Yield Strength, ksi [MPa][C]	Elongation in 2 in. [50 mm], %[D]	Hardness, HBW
Ni	CZ100	50 [345]	18 [125]	10	...
Ni-Cr	CU5MCuC	75 [520]	35 [240]	20	...
	CW2M	72 [495]	40 [275]	20	...
	CW6M	72 [495]	40 [275]	25	...
	CW6MC	70 [485]	40 [275]	25	...
	CW12MW	72 [495]	40 [275]	4	...
	CX2M	72 [495]	39 [270]	40	...
	CX2MW	80 [550]	45 [310]	30	...
	CY40	70 [485]	28 [195]	30	...
Other	CY5SnBiM	...	...	...	...
Ni-Cu	M25S	...	...	...	[E]
	M30C	65 [450]	32.5 [225]	25	...
	M30H	100 [690]	60 [415]	10	...
	M35-1	65 [450]	25 [170]	25	...
	M35-2	65 [450]	30 [205]	25	...
Ni-Mo	N3M	76 [525]	40 [275]	20.0	...
	N7M	76 [525]	40 [275]	20	...
	N12MV	76 [525]	40 [275]	6	...

[A] All values are a minimum.
[B] Where ellipses (...) appear in this table, there is no requirement.
[C] Determine by the 0.2 % offset method.
[D] When 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.
[E] 300 300 HBW minimum for the age hardened age-hardened condition.

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 the "Rounding Method" of Practice E29 to the nearest 0.5 ksi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area. In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification limits if following Practice E29 would cause rejection of material.

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.