



Designation: **A990/A990M—20 A990/A990M – 21**

# Standard Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service<sup>1</sup>

This standard is issued under the fixed designation A990/A990M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers iron-nickel-chromium and nickel alloy castings specially processed with restricted melt practices, weldability testing, and nondestructive examination (NDE) requirements.

1.2 A number of grades of iron-nickel-chromium and nickel alloy castings are included in this specification. Since these grades possess varying degrees of suitability for service in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and corrosion-resistant characteristics.

1.3 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.

1.3.1 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable M-specification designation (SI units), the inch-pound units shall apply. Within the text, the SI units are shown in brackets.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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>

[A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts](#)

[A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel](#)

[A494/A494M Specification for Castings, Nickel and Nickel Alloy](#)

<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.

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



A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts  
A743/A743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application  
A744/A744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service  
A802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination  
A903/A903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection

A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts  
E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film  
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  
E272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy 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

2.2 AWS Standards:<sup>3</sup>

AWS A5.4 Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding  
AWS A5.9 Specification for Bare Stainless Steel Welding Electrodes and Rods  
AWS A5.11/A5.11M Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding  
AWS A5.14/A5.14M Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

2.3 ASME/ANSI Standard:<sup>4</sup>

ASME/ANSI B16.34 Valves—Flanged, Threaded, and Welding End

### 3. Terminology

3.1 Definitions of Terms Specific to This Standard:

- 3.1.1 *accessible surface, n*—surface that can be welded on without cutting access holes in the casting.
- 3.1.2 *refined ingot, n*—metal processed by argon-oxygen-decarburization (AOD) or vacuum-oxygen-decarburization (VOD) and cast to a size and shape suitable for remelting.
- 3.1.3 *revert, n*—gates, risers, and castings. Also includes scrapped machinery and fabricated items, chips, and turnings.

### 4. General Conditions for Delivery

4.1 Other than investment castings, material furnished to this specification shall conform to the requirements of Specification A703/A703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

4.2 *Investment Castings*—Material furnished to this specification shall conform to the requirements of Specification A985/A985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A985/A985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A985/A985M, Specification A985/A985M shall prevail.

### 5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered to this specification. Such requirements may include, but are not limited to, the following:

- 5.1.1 Quantity.
- 5.1.2 Grade designation (Table 1).
- 5.1.3 Description of the casting by pattern number or drawing. Dimensional tolerances should be included on the casting drawing.

<sup>3</sup> Available from American Welding Society (AWS), 8669 NW 36 Street, #130, Miami, FL 33166-6672, <http://www.aws.org>.  
<sup>4</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.



TABLE 1 Chemical Requirements

Element, % (max, except where range is given)	Grade						
	CK3MCuN	CW-2M	CN3MCu	M35-1	CW2MG	N2M	
C	0.025	0.020	0.030		0.35	0.020	0.020
Mn	1.20	1.00	1.50		1.50	1.00	1.00
Si	0.75	0.80	1.00	1.25	0.45	0.80	
P	0.020	0.030	0.030	0.030	0.015	0.030	
S	0.010	0.015	0.015	0.015	0.015	0.015	
Mo	6.0–7.0	15.0–17.5	2.0–3.0		...	8.0–10.0	30.0–33.0
Fe	balance	2.00	balance		3.5	5.0	3.00
Ni	17.5–19.5	balance	27.5–30.5	Balance	Balance	Balance	
Cr	19.5–20.5	15.0–17.5	19.0–22.0		...	20.0–23.0	1.00
N	0.18–0.24						
Cu	0.50–1.00	...	3.0–3.5		26.0–33.0	0.50	0.20
W		1.00	...	...	0.50	0.20	
V		...	...	...	0.20	0.20	
Cb		...	...	...	3.1–4.5	...	

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

Element, %	Grade						
	CK3MCuN	CN3MCu	CW2M	CW2MC	M35-1	N2M	
Carbon	0.025	0.030	0.020	0.020	0.35	0.020	
Manganese	1.20	1.50	1.00	1.00	1.50	1.00	
Silicon	0.75	1.00	0.80	0.45	1.25	0.80	
Phosphorus	0.020	0.030	0.030	0.015	0.030	0.030	
Sulfur	0.010	0.015	0.015	0.015	0.015	0.015	
Molybdenum	6.0–7.0	2.0–3.0	15.0–17.5	8.0–10.0	...	30.0–33.0	
Iron	Balance	Balance	2.00	5.0	3.5	3.00	
Nickel	17.5–19.5	27.5–30.5	Balance	Balance	Balance	Balance	
Chromium	19.5–20.5	19.0–22.0	15.0–17.5	20.0–23.0	...	1.00	
Nitrogen	0.18–0.24	...	...	...	...	...	
Copper	0.50–1.00	3.0–3.5	...	0.50	26.0–33.0	0.20	
Tungsten		...	...	1.00	0.50	0.20	
Vanadium		...	...	...	0.20	...	0.20
Niobium <sup>C</sup>		...	...	...	3.1–4.5	...	...

<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> Columbium (Cb) and niobium (Nb) are interchangeable names for the same element 41.

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5.1.4 Nondestructive inspection class required (Table 2). Class D will be supplied unless otherwise specified.

5.1.5 Wetted surfaces (Table 2).

5.2 The purchaser shall specify any supplementary requirements desired, including standards of acceptance, required to adequately describe the desired material.

## 6. Process and Manufacture

6.1 Alloys, except for nickel base, 25 to 35 % Cu alloys, shall be made by one of the two following processes:

6.1.1 Electric arc or induction furnace melting followed by AOD or VOD refining, or

6.1.2 Electric induction furnace melting of refined ingot.

6.2 Nickel base alloys with 25 to 35 % Cu shall be made by 6.1.1 or 6.1.2 or by electric furnace.

6.3 Additions of up to 5 % are permitted for compositional adjustments and deoxidation.

6.4 Revert shall not be used.



TABLE 2 Nondestructive Examination Requirements

Maximum Casting Thickness	Class	Visual Examination, Practice A802/A802M Minimum Acceptance Level	Radiographic Examination, Guide E94/E94M Number of Castings Severity Level per Table 6	Liquid Penetrant Examination, Practice E165/E165M	
				Coverage	Minimum Acceptance Level per Specification A903/A903M
Less than 5/8 in. [15.9 mm]	A	Level I	100 %	All accessible surfaces	Level II
	B	Level II	100 %	All accessible wetted surfaces	Level II
	C	Level II	Initial casting off pattern	Weld repairs	Level II
	D	Level II	Initial casting off pattern	NA	NA
5/8 to 1 in. [15.9 to 25.4 mm]	A	Level I	100 %	All accessible surfaces	Level III
	B	Level II	100 %	All accessible wetted surfaces	Level III
	C	Level II	Initial casting off pattern	Weld repairs	Level III
	D	Level II	Initial casting off pattern	NA	NA
Over 1 to 2 in. [25.4 to 50.8 mm]	A	Level I	100 %	All accessible surfaces	Level IV
	B	Level II	100 %	All accessible wetted surfaces	Level IV
	C	Level II	Initial casting off pattern	Weld repairs	Level IV
	D	Level II	Initial casting off pattern	NA	NA
Over 2 to 4 1/2 in. [50.8 to 114 mm]	A	Level II	100 %	All accessible surfaces	Level IV
	B	Level II	100 %	All accessible wetted surfaces	Level IV
	C	Level III	Initial casting off pattern	Weld repairs	Level V
	D	Level III	Initial casting off pattern	NA	NA
Over 4 1/2 in. [114 mm]	A	Level III	100 %	All accessible surfaces	Level V
	B	Level III	100 %	All accessible wetted surfaces	Level V
	C	Level IV	Initial casting off pattern	Weld repairs	Level V
	D	Level IV	Initial casting off pattern	NA	NA

## 7. Chemical Composition

7.1 These alloys shall conform to the chemical composition requirements prescribed in Table 1. An analysis of every heat is required.

## 8. Tensile Properties

8.1 One tension test shall be made from each heat. Test results shall conform to the tensile requirements specified in Table 3. The bar shall be solution heat treated per the requirements of Table 4 in production furnaces to the same procedure as the castings it represents. If the casting grade does not require heat treatment, the bar used for the test specimen shall not be heat treated.

## 9. Weldability Qualification

9.1 Each heat shall be qualified by weldability testing.

### 9.2 Sampling:

9.2.1 The weldability test plate shall be cast in accordance with Fig. 1.

9.2.2 For heats produced under 6.1.1, at least one weldability test plate shall be cast from each heat.

9.2.3 For heats produced under 6.1.2, at least one weldability test plate shall be cast from the first heat in an uninterrupted series of heats, made in the same furnace from the same heat of refined ingot using the same melting procedure, and shall qualify all of the subsequent heats in that series made in the same shift.

TABLE 3 Tensile Requirements

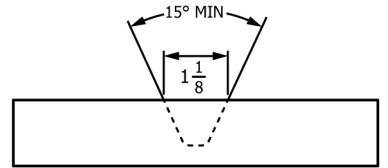
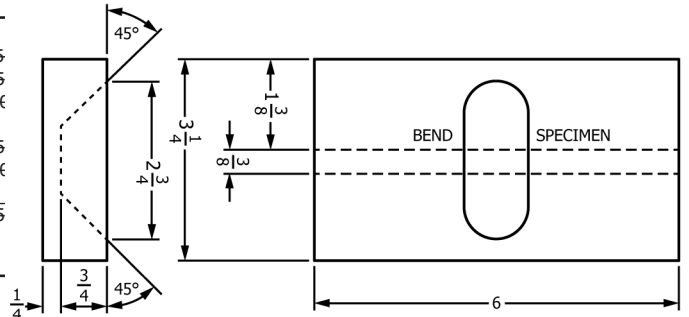
	Grade			
	CK3MCuN	CW-2M	CN3MCu	M35
Tensile strength, min, ksi [MPa]	80 [550]	72 [495]	62 [425]	65 [450]
0.2 % offset yield strength, min, ksi [MPa]	38 [260]	40 [275]	25 [170]	25 [170]
Elongation in 2 in. [50 mm], min, % <sup>A</sup>	35	20	35	25

TABLE 3 Tensile Requirements<sup>A</sup>

Grade	Tensile Strength, ksi [MPa]	0.2 % Offset Yield Strength, ksi [MPa]	Elongation in 2 in. [50 mm], % <sup>B</sup>
CK3MCuN	80 [550]	38 [260]	35
CN3MCu	62 [425]	25 [170]	35
CW2M	72 [495]	40 [275]	20
CW2MC	70 [485]	40 [275]	25
M35-1	65 [450]	25 [170]	25
N2M	76 [525]	40 [275]	20

<sup>A</sup> All values are minimums unless a range is provided.

<sup>B</sup> When—When ICI test bars are used in tensile testing as provided for in Specification A985/A985M, the gage length to reduced section diameter ratio shall be 4 to 1.



(a)

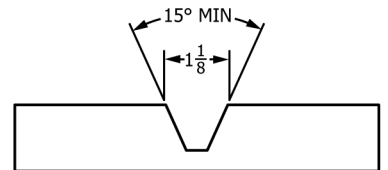
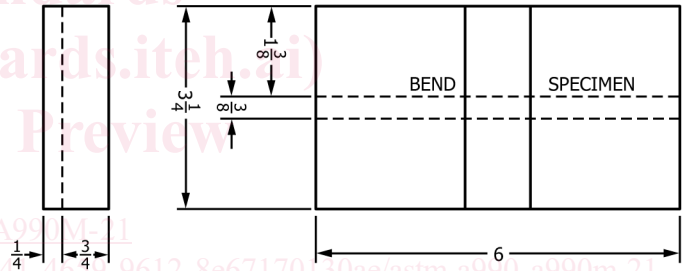
Metric Equivalents

in.	1/4	3/8	3/4	1 1/8	2 3/4	3 1/4	6
[mm]	[5]	[10]	[20]	[30]	[70]	[85]	[155]

TABLE 4 Heat Treat Requirements

Grade	Heat Treatment
CK3MCuN	Heat to 2200 to 2265 °F [1205 to 1240 °C] for 1 h at temperature per 1 in. [25 mm] of thickness with a minimum of 4 h. Quench in water. <sup>A</sup>
CW-2M	Heat to 2225 to 2300 °F [1220 to 1260 °C] for a minimum of 1 h at temperature per 1 in. [25 mm] of thickness. Quench in water. <sup>A</sup>
CN3MCu	Heat to 2050 °F [1120 °C] min for a min of 1 h at temperature per 1 in. [25 mm] of thickness. Quench in water. <sup>A</sup>
CN3MCu	Heat to 2050 °F [1120 °C] min for a min of 1 h at temperature per 1 in. [25 mm] of thickness. Quench in water. <sup>A</sup>
CW2M	Heat to 2225 to 2300 °F [1220 to 1260 °C] for a minimum of 1 h at temperature per 1 in. [25 mm] of thickness. Quench in water. <sup>A</sup>
M35-1	As-cast
CW2MC	Heat to 2175 °F [1190 °C] min for a min of 2 h at temperature or a min of 1 h per 1 in. [25 mm] of thickness, whichever is greater. Quench in water. <sup>A</sup>
M35-1	As-cast
N2M	Heat to 2080 °F [1140 °C] min for a min of 2 h at temperature + 1 h per 1 in. [25 mm] of thickness. Quench in water. <sup>A</sup>

<sup>A</sup> Quench in water or rapid cool by other means as agreed upon by the manufacturer and purchaser.



(b)

NOTE—May be used with the purchaser's approval when the molding process makes it impractical to cast the cavity into the test plate.

Metric Equivalents

in.	1/4	3/8	3/4	1 1/8	3 1/4	6
[mm]	[5]	[10]	[20]	[30]	[85]	[155]

FIG. 1 (a) Weldability Test Plate; (b) Optional Weldability Test Plate with a Machined Groove

### 9.3 ~~Procedure:~~ Procedure:

9.3.1 The test plates required under 9.2 shall be processed and tested as follows:

9.3.1.1 Prior to welding, the test plate shall be solution heat treated according to the requirements of Table 4 in production furnaces to the same procedure as the castings it represents.

9.3.1.2 All forms of cold working, mechanical deformation, hammering, or peening in excess of that required for normal cleaning is prohibited.

9.3.1.3 Fill the groove in the plate with weld deposit according to the procedure used in Section 11 and the filler material grade specified in Table 5.

9.3.1.4 For the purposes of the weldability test only, post-weld heat treatment of the test plate is prohibited even if part of the procedure. Remove one 3/8-in. [10-mm] min thick bend coupon longitudinally from the center of the welded plate by machining, sawing, or abrasive cutting. Make a transverse side bend test of the welded joint in accordance with Practice A488/A488M.

### 9.4 ~~Acceptance:~~ Acceptance:

9.4.1 On the bent specimen, cracks or other open defects exceeding 1/8 in. [3.2 mm] measured in any direction on the convex surface shall be cause for rejection, except that cracks occurring on and limited to the corners while testing shall not be considered.

## 10. Nondestructive Examination

10.1 One of four different classes of nondestructive examination shall be imposed on castings ordered to this specification. Classes A, B, C, and D are defined in Table 2. Each class imposes specific requirements for three different NDE methods. Class D will be supplied unless otherwise specified.

10.2 *Visual Examination*—Each casting shall be examined visually in accordance with Practice A802/A802M. Fusion discontinuities, expansion discontinuities, and inserts are unacceptable. All other surface features must meet the acceptance criteria class in Table 2.

### 10.3 *Radiographic Examination:*

10.3.1 The number of castings to be examined radiographically and the acceptance criteria shall be in accordance with the specified class in Table 2 and Table 6.

10.3.2 The extent of coverage shall be agreed upon between the manufacturer and purchaser. Where applicable, the minimum coverage shall comply with ASME/ANSI B 16.34.

10.3.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

10.3.4 All castings that are radiographed and found acceptable shall be permanently marked “RT.”

10.3.5 For Classes C and D, if a rejectable indication is found, that first casting shall be scrapped or repaired and the second casting

**TABLE 5 Weld Filler Materials**

Cast Grade	AWS A5.11/A5.11M and AWS A5.14/A5.14M Weld Filler Material
CK3MCuN	AWS A5.4 and AWS A5.9 NiCrMo-3
GW2M	NiCrMo-7 or NiCrMo-10
CN3MCu	AWS A5.4 and AWS A5.9 320LR
M35-1	NiCu-7
CW2M	NiCrMo-7 or NiCrMo-10
CW2MC	NiCrMo-3
M35-1	NiCu-7
N2M	NiMo-7 or NiMo-10



TABLE 6 Radiographic Severity Level Requirements

Nickel Copper		Severity Level, Min Acceptance Level										Reference Radiographs E186 Chaplets	
		Shrinkage		Dross		Porosity		Inclusions					
Casting Thick-ness in Area of interest	Class	Type	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source	
1 in. [25 mm] and less	Class A	Feathery Spongy	Cd 2	X-ray	Bb 1	X-ray	A3	X-ray	Ba 3	X-ray	None	Acceptable	
	Class B, C and D	Linear	Cd 2	Gamma	Bb 2	X-ray	A4	X-ray	Ba 4	X-ray	None	Acceptable	
Over 1 in. [25 mm]	Class A	Feathery Spongy	Cd 3	X-ray	Bb 2	Gamma	A3	Gamma	Ba 3	Gamma	None	Acceptable	
	Class B, C and D	Linear	Cd 3	Gamma	Bb 3	Gamma	A4	Gamma	Ba 4	Gamma	None	Acceptable	
Iron-Nickel-Chromium and Nickel-Chromium													
Casting Thickness	Class	ASTM Standard	Shrinkage	Porosity	Inclusion	Hot Tear, Crack	Insert, Chaplet						
Less than 1 in. [25 mm]	Class A	E446	CA 2, CB 2, CC 2, CD 2	A2	B2	None	None						
	Class B, C and D	E446	CA 3, CB 3, CC 3, CD 3	A3	B3	None	None						
1 to 2 in. [25 to 51 mm]	Class A	E446	CA 2, CB 2, CC 2, CD 2	A2	B2	None	None						
	Class B, C and D	E446	CA 3, CB 3, CC 3, CD 3	A3	B3	None	None						
Over 2 to 4½ in. [251 to 114 mm]	Class A	E186	CA 3, CB 3, CC 3	A3	B3	None	None						
	Class B, C and D	E186	CA 4, CB 4, CC 4	A4	B4	None	None						
Over 4½ in. [114 mm]	Class A	E280	CA 3, CB 3, CC 3	A3	B3	None	None						
	Class B, C and D	E280	CA 4, CB 4, CC 4	A4	B4	None	None						

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radiographed. If the second casting passes, then no additional radiography beyond the normal amount is required. If that second casting fails, all remaining castings shall be radiographed in only the rejectable areas found on the first and second castings. After changes are made to the gating or risering of a pattern, and the subsequent castings produce no rejectable radiographic indications, then no additional radiography beyond the sampling rate agreed upon by the purchaser and the producer shall be required.

10.4 Liquid Penetrant Examination:

10.4.1 All Class A, B, and C castings shall be liquid penetrant (LP) tested in accordance with Table 2 after the final specified heat treatment.

10.4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

10.4.3 When welding is performed after the liquid penetrant examination, the repair weld and at least ¼ in. [6 mm] of the surrounding material shall be LP tested in accordance with Table 2.

11. Repair by Welding

11.1 All weld repairs shall be made with welders and procedures qualified in accordance with Practice A488/A488M. Only the filler material grades specified in Table 5 shall be used.

11.2 Major weld repairs are repairs required when a casting has leaked on hydrostatic test or when the depth of the cavity after