~~Designation:B564–10~~ Designation: B564 – 11

Standard Specification for Nickel Alloy Forgings[1]

This standard is issued under the fixed designation B564; 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.

1. Scope*

1.1 This specification[2] ~~covers forgings of nickel alloy UNS N02200, Ni-Cu alloy UNS N04400, Ni-Cr-Fe alloys UNS N06600, UNS N06603, and UNS N06690, Ni-Cr-Mo-Nb alloy UNS N06625, Ni-Cr-Mo-Si alloy UNS N06219, low-carbon Ni-Mo-Cr alloys UNS N10276 and UNS N06022, Ni-Cr-Mo-W alloy UNS N06110, low-carbon Ni-Cr-Mo-W alloy UNS N06686, Ni-Fe-Cr-Mo-Cu alloy UNS N08825, Fe-Ni-Cr-Mo-N alloy UNS N08367, low-carbon Ni-Cr-Mo alloys UNS N06035, UNS N06058, and UNS N06059, low carbon Ni-Cr-Mo-Cu alloy UNS N06200, low-carbon Ni-Mo-Cr alloy UNS N10362, Ni-Mo-Cr-Fe alloy UNS N10242, Ni-Mo alloys UNS N10665 and UNS N10675, low-carbon Ni-Fe-Cr-Mo-Cu alloy UNS N08031, Ni-Cr-W-Mo alloy UNS N06230, Ni-Cr-Co-Mo alloy UNS N06617, Ni-Co-Cr-Si alloy UNS N12160, Ni-Fe-Cr alloys, Ni-Mo alloy UNS N10629, Ni-Cr-Fe-Al alloy UNS N06025, Ni-Cr-Fe-Si alloy UNS N06045, Low-Carbon Ni-Mo-Cr-Ta alloy UNS N06210, Ni-Mo-Cr-Fe alloy UNS N10624, and low-carbon Cr-Ni-Fe-N alloy UNS R20033*.~~

~~1.1.1The nickel-iron-chromium alloys are UNS N08120, UNS N08800, UNS N08810, and UNS N08811. Alloy UNS N08800 is normally employed in service temperatures up to and including 1100°F (593°C). Alloys UNS N08810, N08120, and UNS N08811 are normally employed in service temperatures above 1100°F where resistance to creep and rupture is required, and are annealed to develop controlled grain size for optimum properties in this temperature range.~~ covers forgings of:

Alloy Type	UNS Number(s)
Fe-Ni-Cr-Mo-N	N08367
Low-carbon Cr-Ni-Fe-N	R20033
Low-carbon Ni-Cr-Mo	N06035, N06058, N06059
Low-carbon Ni-Cr-Mo-Cu	N06200
Low-carbon Ni-Cr-Mo-W	N06686
Low-carbon Ni-Fe-Cr-Mo-Cu	N08031
Low-carbon Ni-Mo-Cr	N10276, N06022, N10362
Low-carbon Ni-Mo-Cr-Ta	N06210
Ni	N02200
Ni-Co-Cr-Si	N12160
Ni-Cr-Co-Mo	N06617
Ni-Cr-Fe	N06600, N06603, N06690
Ni-Cr-Fe-Al	N06025
Ni-Cr-Fe-Si	N06045
Ni-Cr-Mo-Nb	N06625
Ni-Cr-Mo-Si	N06219
Ni-Cr-Mo-W	N06110
Ni-Cr-W-Mo	N06230
Ni-Cu	N04400
Ni-Fe-Cr	N08120, N08800, N08810, N08811
Ni-Fe-Cr-Mo-Cu	N08825
Ni-Fe-Cr-W	N06674
Ni-Mo	N10665, N10675, N10629
Ni-Mo-Cr-Fe	N10242, N10624

1.1.1 The nickel-iron-chromium alloys are UNS N08120, UNS N08800, UNS N08810, and UNS N08811. Alloy UNS N08800 is normally employed in service temperatures up to and including 1100°F (593°C). Alloys UNS N08810, N08120, and UNS N08811 are normally employed in service temperatures above 1100°F (593°C) where resistance to creep and rupture is required, and are annealed to develop controlled grain size for optimum properties in this temperature range.

1.1.2 Nickel-iron-chromium-tungsten alloy UNS N06674 is normally employed in service temperatures above 1100°F (593°C)

[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved Oct. 1, ~~2010.~~2011. Published ~~October 2010.~~November 2011. Originally approved in 1972. Last previous edition approved in ~~2006~~2010 as ~~B564–06A.~~B564 – 10. DOI: 10.1520/B0564-~~10~~1.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-564 in Section II of that Code.

* New designations established in accordance with ASTM E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

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

where resistance to creep and rupture is required, and is annealed to develop optimum properties in this temperature range.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
E8 Test Methods for Tension Testing of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys
E112 Test Methods for Determining Average Grain Size
E350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
E1473 Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys

2.2 *Military Standards:*[4]

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-271 Nondestructive Testing Requirements for Metals

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

3.1.1 Alloy (Table 1).
3.1.2 Condition (Table 2).
3.1.3 Quantity (mass or number of pieces).
3.1.4 Forging, sketch or drawing.
3.1.5 *Certification*—State if certification or a report of test results is required (14.1).
3.1.6 *Samples for Product (Check) Analysis*—Whether samples for product (check) analysis should be furnished (see 4.2).
3.1.7 *Purchaser Inspection*—If the purchaser wishes to witness tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (12.1).

4. Chemical Composition

4.1 The material shall conform to the composition limits specified in Table 1.

4.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in accordance with Specification B880.

5. Mechanical Properties and Other Requirements

5.1 *Mechanical Properties*—The material shall conform to the mechanical properties specified in Table 2.

5.2 *Grain Size*—~~Annealed alloys (UNS N08810, N08120, and UNS N08811) shall conform to an average grain size of ASTM No. 5 or coarser.~~ —Annealed alloys UNS N08810, N08120, and UNS N08811 shall conform to an average grain size of ASTM No. 5 or coarser. Annealed alloy UNS N06674 shall conform to an average grain size of ASTM No. 7 or coarser.

6. Dimensions and Permissible Variations

6.1 Dimensions and tolerances shall be as specified on the applicable forging sketch or drawing.

7. Workmanship, Finish and Appearance

7.1 The material shall be uniform in quality and condition, sound, and free of injurious imperfections.

8. Sampling

8.1 *Lot Definition*:

8.1.1 A lot for chemical analysis shall consist of one heat.

[3] 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.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

TABLE 1 Chemical Requirements[A]

Element	Composition, %									
		Nickel-Copper Alloy	Nickel-Chromium-Iron Alloy	Nickel-Alloy	Low-Chromium-IronAlloy	Nickel-IronChromium Alloy	Nickel-Iron-Chromium Alloy	Nickel-Iron-Chromium Alloy	Nickel-Chromium-Iron-Aluminum Alloy	Nickel-Chro
Element	Nickel Alloy	Nickel-Copper Alloy	Low-Carbon Nickel-Molybdenum-Chromium Alloy	Nickel-Chromium-Iron-Aluminum Alloy	Low-Carbon Nickel-Chromium-Molybdenum Alloy	Nickel-Chromium-Iron-Silicon Alloy	Low-Carbon Nickel-Chromium-Molybdenum Alloy	Low-Carbon Nickel-Chromium-Molybdenum Alloy	Nickel-Chromium-Iron-Aluminum Alloy	Nickel-Chro
	UNS N04400	UNS N06600	UNS N06690	UNS N08120	UNS N08800	UNS N08810	UNS N06603	UNS N06025	UNS N06045	
	UNS N02200	UNS N04400	UNS N06022	UNS N06025	UNS N06035	UNS N06045	UNS N06058	UNS N06059	UNS N06045	
Nickel	63.0[A] min	72.0[A] min	58.0 min[A]	35.0–39.0	30.0–35.0	30.0–35.0	balance[A]		balance	45 min
Nickel	99.0[B] min	63.0[B] min	balance[B]	balance	30.0–35.0	30.0–35.0	balance[B]	45 min	balance	balance[B]
Copper	28.0–34.0	0.5 max	0.5 max	0.50 max	0.75 max	0.75 max	0.5 max	0.10 max	0.3 max	...
Copper	0.25	28.0–34.0	...	0.10	0.30	0.3	0.50	0.50	0.3 max	...50
Iron	2.5 max	6.0–10.0	7.0–11.0	remainder	39.5 min[A]	39.5 min[A]	8.0–11.0	8.0–11.0	21.0–25.0	1.0 max
Iron	0.40	2.5	2.0–6.0	8.0–11.0	2.00	21.0–25.0	1.5	1.5	1.0–25.0	1.0 max
Manganese	2.0 max	1.0 max	0.5 max	1.5	1.5 max	1.5 max	0.15 max	0.15	1.00.5 max	
Manganese	0.35	2.0	0.50	0.15	0.50	1.0	0.50	0.5	1.0	
Carbon	0.3 max	0.15 max	0.05 max	0.02–0.10	0.10 max	0.05–0.10	0.20–0.40	0.15–0.25	0.05–0.12	0.015 max
Carbon	0.15	0.3	0.015	0.15–0.25	0.050	0.05–0.12	0.010	0.010	0.12	0.015
Silicon	0.5 max	0.5 max	0.5 max	1.0	1.0 max	1.0 max	0.5 max	0.5	2.5–3.00.08 max	
Silicon	0.35	0.5	0.08	0.5	0.60	2.5–3.0	0.10	0.10	1.0	
Sulfur, max	0.024	0.015	0.015	0.03	0.015	0.015	0.010	0.01	0.010	0.02
Sulfur	0.01	0.024	0.02	0.01	0.015	0.010	0.010	0.01	0.010	0.015
Chromium	...	14.0–17.0	27.0–31.0	23.0–27.0	19.0–23.0	19.0–23.0	24.0–26.0	24.0–26.0	26.0–29.0	18.0-20.0
Chromium	...	...	20.0–22.5	24.0–26.0	32.25–34.25	26.0–29.0	20.0–23.0	22.0–24.0	26.0–29.0	18.0–33.0
Aluminum	...	...	...	0.40 max	0.15–0.60	0.15–0.60	2.4–3.0	1.8–2.4	...	...
Aluminum	...	...	...	1.8–2.4	0.40	...	0.40	0.1–0.4	1....	...0
Titanium	...	...	...	0.20 max	0.15–0.60	0.15–0.60	0.01–0.25	0.1–0.2	...	...
Titanium	...	...	...	0.1–0.2	...	...	...	0.1–0.2	...	1.0
Columbium (Nb) + t-antalum	...	...	...	0.4–0.9	...	...	...	...	...	...
Columbium (Nb) + Tantalum	...	...	...	0.4–0.9	...	...	...	...	...	1.0
Molybdenum	...	...	...	2.50 max	...	...	...	...	...	18.0-20.0
Molybdenum	...	...	12.5–14.5	2.50 max	...	7.60–9.00	...	19.0 - 21.0	15.0–16.5	9.0–12.0
Phosphorus	...	...	...	0.040 max	...	...	0.02 max	0.02 max	0.02 max	0.02 max
Phosphorus	...	...	0.02	0.02	0.030	0.02	0.015	0.015	0.502 max	0.02 max
Tungsten	...	...	...	2.50 max	...	...	...	...	...	...
Tungsten	...	...	2.5–3.5	2.50 max	...	0.60	...	0.3	...	1.0-4.0
Cobalt, max	...	...	...	3.0	...	...	...	...	...	1.0
Cobalt	...	...	2.5	3.0	...	1.00	...	0.3	0.3	...
Vanadium, max	...	...	...	...	...	...	...	...	...0.35	
Vanadium	...	...	0.35	...	0.20	...	...	...	...	
Nitrogen	...	...	...	0.15–0.30	...	...	...	...	...	...
Nitrogen	...	...	...	0.15–0.30	...	...	...	0.02 - 0.15	...	...
Boron	...	...	...	0.010 max	...	...	...	...	...	...
Lanthanum	...	...	...	...	...	...	...	...	...	...
Aluminum + Titanium	...	...	...	...	...	...		...	...	
Lanthanum	...	...	...	...	...	...	...	...	...	...
Aluminum + Titanium	...	...	...	...	...	...		...	...	...
Nickel + Molybdenum	...	...	...	...	...	...	...	...	.....	
Nickel + Molybdenum	...	...	...	...	...	...	...	...	...	

TABLE 1 Chemical Requirements[A] *(continued)*

Element	Nickel-Low-Carbon-Chromium Alloy	Nickel-Chromium-Molybdenum-Columbium Alloy	Low-Carbon Nickel-Molybdenum-Chromium-Tungsten Alloy	Nickel-Iron Chromium-Molybdenum-Silicon Alloy	Low-Nickel Chromium-Molybdenum-Tungsten-Molybdenum-Chromium Alloy	Nickel-Iron-Aluminum Alloy	Nickel-Chromium-Cobalt-Molybdenum-Chromium Alloy	Iron-Nickel-Chromium-Molybdenum-Columbium Nitrogen Alloy	Low-Carbon Nickel-Chromium-Molybdenum Alloy	Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy
	UNS N08811[6]200	UNS N06625[1]0	UNS N062[1]109	UNS N08862530	UNS N[1]0276603	UNS N06022617	UNS N08367625	UNS N06[6]0590	UNS N06058674	
Nickel	30.0–35.0	58.0 min[A]	51.0 min[A]	38.0–46.0	remainder[A]	remainder[A]	23.50–25.50	balance[A]	72.0[B] min	balance
Nickel	balance[B]	balance[B]	balance[B]	38.0–46.0	remainder[B]	balance[B]	44.5 min	58.0[B] min	72.0[B] min	balance[B]
Copper	0.75 max	...	0.50 max	1.5–3.0	...	...	0.75 max	0.50 max	0.50 max	
Copper	1.3–1.9	...	0.50	...	0.5	0.5	...	0.5	...	
Iron	39.5 min[A]	5.0 max	1.0 max	22.0 min[A]	4.0–7.0	2.0–6.0	remainder[A]	1.5 max	1.5 max	
Iron	3.0	1.0	2.0-4.0	3.0	8.0–11.0	3.0	5.0	6.0–10.0	20.0-27.0	
Manganese	1.5 max	0.5 max	1.0 max	1.0 max	1.0 max	0.50 max	2.00 max	0.5 max	0.50 max	
Manganese	0.50	0.5	0.50	0.30–1.00	0.15	1.0	0.5	1.0	1.50	
Carbon	0.06–0.10	0.10 max	0.15 max	0.05 max	0.010 max	0.015 max	0.030 max	0.010 max	0.010 max	
Carbon	0.010	0.015	0.05	0.05–0.15	0.20–0.40	0.05–0.15	0.10	0.15	0.10	
Silicon	1.0 max	0.5 max	1.0 max	0.5 max	0.08 max	0.08 max	1.00 max	0.10 max	0.10 max	
Silicon	0.08	0.08	0.70-1.10	0.25–0.75	0.5	1.0	0.5	0.5	1.0	
Sulfur, max	0.015	0.015	0.015	0.03	0.03	0.02	0.030	0.010	0.010	
Sulfur	0.010	0.02	0.010	0.015	0.010	0.015	0.015	0.015	0.015	
Chromium	19.0–23.0	20.0–23.0	28.0–33.0	19.5–23.5	14.5–16.5	20.0–22.5	20.0–22.0	22.0–24.0	20.0–23.0	
Chromium	22.0–24.0	18.0-20.0	18.0-22.0	20.0–24.0	24.0–26.0	20.0–24.0	20.0–23.0	14.0–17.0	21.5-24.5	
Aluminum	0.15–0.60	0.4 max	1.0 max	0.2 max	...	...	...	0.1–0.4	0.40 max	
Aluminum	0.50	...	0.50	0.50	2.4–3.0	0.8–1.5	0.4	...	...	
Titanium	0.15–0.60	0.4 max	1.0 max	0.6–1.2	...	...	...	...	...	
Titanium	...	...	0.50	...	0.01–0.25	0.6	0.4	...	0.05-0.20	
Columbium (Nb) + tantalum	...	3.15–4.15	1.0 max	...	...	...	...	...	...	
Columbium (Nb) + Tantalum	...	...	...	...	...	...	3.15–4.15	...	...	
Molybdenum	...	8.0–10.0	9.0–12.0	2.5–3.5	15.0–17.0	12.5–14.5	6.00–7.00	15.0–16.5	19.0 - 21.0	
Molybdenum	15.0–17.0	18.0-20.0	7.0-9.0	1.0–3.0	...	8.0–10.0	8.0–10.0	...	...	
Phosphorus	...	0.015 max	0.50 max	...	0.04 max	0.02 max	0.040 max	0.015 max	0.015 max	
Phosphorus	0.025	0.02	0.020	0.030	0.02	...	0.015	...	0.030	
Tungsten	...	...	1.0-4.0	...	3.0–4.5	2.5–3.5	...	...	0.3 max	
Tungsten	...	...	...	13.0–15.0	...	...	...	...	6.0-8.0	
Cobalt	...	...	...	...	2.5 max	2.5 max	...	0.3 max	0.3 max	
Cobalt	2.0	1.0	1.0	5.0	...	10.0 min–15.0	...	...	...	
Vanadium, max	...	...	...	...	0.35	0.35	...	...	...	
Vanadium	...	0.35	...	...	...	...	...	...	...	
Nitrogen	...	...	...	...	...	...	0.18–0.25	...	0.02 - 0.15	
Nitrogen	...	...	...	...	...	...	...	...	0.02	
Boron	...	...	...	...	...	...	...	...	...	
Boron	...	...	...	0.015	...	0.006	...	...	0.0005-0.006	
Lanthanum	...	...	...	...	...	...	...	...	... ...	
Aluminum + Titanium	0.85–1.20	...	...	...	...	...	...	...		
Lanthanum	...	...	...	0.005–0.050	...	...	...	...	...	
Aluminum + Titanium				...		...	...	...		
Nickel + Molybdenum	...	...	...	...	...	...	...	...	...	
Nickel + Molybdenum	...	...	...	...	...	...	...	...	...	
Columbium (Nb), max	...	...	...	...	...	...	...	...	...	
Columbium (Nb)	...	...	...	...	...	...	...	...	0.10-0.35	

TABLE 1 Chemical Requirements[A] *(continued)*

Element	Composition, %									
	Low-Carbon Nickel-Chromium-Molybdenum Alloy Low-Carbon Nickel-Chromium-Molybdenum-Copper Alloy	Low-Carbon Nickel-Molybdenum-Tungsten Alloy	Nickel-Chromium-Molybdenum-Silicon Alloy	Low-Carbon Nickel-Iron-Chromium-Molybdenum-Copper Alloy	Nickel-Iron-Chromium Alloy	Iron-Nickel-Chromium-Molybdenum-Tungsten-Nitrogen-Alloy	Nickel-Iron-Chromium Alloy	Nickel-Iron-Chromium-Alloy	Nickel-Iron-Chromium-Molybdenum Alloy	Nickel-I denChron UNS UNSN Co A
	UNS N06035686	UNS N06620690	UNS N10803621	UNS N06281920	UNS N0803167	UNS N06238800	UNS N06688170	UNS N106298811	UNS N08825	
Nickel	remainder[A]	remainder[A]	remainder[A]	balance[A]	30.0–32.0	remainder[A]	44.5 min	balance		
Nickel	remainder	58.0[B]min	30.0–32.0	35.0–39.0	23.50–25.50	30.0–35.0	30.0–35.0	30.0–35.0	30.0–35.0	38.0–46.0
Copper	0.30 max	1.3–1.9	...	0.50 max	1.0–1.4	...	0.5 max	0.5 max		
Copper	...	0.5	1.0–1.4	0.50	0.75	0.75	0.75	0.75	0.75	1.5–3.0
Iron	2.00 max	3.0 max	1.25 max	2.0-4.0	balance[A]	3.0 max	3.0 max	1.0–6.0		
Iron	5.0	7.0–11.0	balance[B]	balance	balance[B]	39.5[B] min	39.5[B] min	39.5[B] min	22.0[B] min	
Manganese	0.50 max	0.50 max	0.60 max	0.50 max	2.0 max	0.30–1.00	1.0 max	1.5		
Manganese	0.75	0.5	2.0	1.5	2.00	1.5	1.5	1.5	1.0	
Carbon	0.050 max	0.010 max	0.010 max	0.05 max	0.015 max	0.05–0.15	0.05–0.15	0.010 max		
Carbon	0.010	0.05	0.015	0.02–0.10	0.030	0.10	0.05–0.10	0.06–0.10	0.05	
Silicon	0.60 max	0.08 max	0.08 max	0.70-1.10	0.3 max	0.25–0.75	1.0 max	0.05		
Silicon	0.08	0.5	0.3	1.0	1.00	1.0	1.0	1.0	0.5	
Sulfur, max	0.015	0.010	0.010	0.010	0.010	0.015	0.015	0.01		
Sulfur	0.02	0.015	0.010	0.03	0.030	0.015	0.015	0.015	0.03	
Chromium	32.25–34.25	22.0–24.0	13.8-15.6	18.0-22.0	26.0-28.0	20.0–24.0	20.0–24.0	0.5–1.5		
Chromium	19.0–23.0	27.0–31.0	26.0-28.0	23.0–27.0	20.0–22.0	19.0–23.0	19.0–23.0	19.0–23.0	19.5–23.5	
Aluminum	0.40 max	0.50 max	0.50 max	0.50 max	...	0.50 max	0.8–1.5	0.1–0.5		
Aluminum	...	...	...	0.40	...	0.15–0.60	0.15–0.60	0.15–0.60	0.2	
Titanium	...	...	...	0.50 max	...	...	0.6 max	...		
Titanium	0.02–0.25	...	...	0.20	...	0.15–0.60	0.15–0.60	0.15–0.60	0.6–1.2	
Columbium (Nb) + Tantalum	...	...	...	...	...	...	...	...		
Columbium (Nb) + Tantalum	...	...	...	0.4–0.9	...	...	...	...	...	
Molybdenum	7.60–9.00	15.0–17.0	21.5-23.0	7.0-9.0	6.0-7.0	1.0–3.0	8.0–10.0	26.0–30.0		
Molybdenum	15.0–17.0	...	6.0-7.0	2.50	6.00–7.00	...	...	...	2.5–3.5	
Phosphorus	0.030 max	0.025 max	0.025 max	0.020 max	0.020 max	0.030 max	...	0.04 max		
Phosphorus	0.04	...	0.020	0.040	0.040	...	...	...	...	
Tungsten	0.60 max	...	...	...	...	13.0–15.0	...	...		
Tungsten	3.0–4.4	...	...	2.50	...	...	...	...	...	
Cobalt	1.00 max	2.0 max	...	1.0 max	...	5.0 max	10.0 min–15.0 max	2.5		
Cobalt	...	...	...	3.0	...	...	...	...	...	
Vanadium, max	0.20	...	...	...	...	...	...	...		
Vanadium	...	...	...	...	...	...	...	...	...	
Nitrogen	...	...	...	...	0.15-0.25	...	...	...		
Nitrogen	...	...	0.15-0.25	0.15–0.30	0.18–0.25	...	...	...	...	
Boron	...	...	...	...	...	0.015 max	0.006 max	...		
Boron	...	...	...	0.010	...	...	...	...	...	
Lanthanum	...	...	...	...	...	0.005–0.050	...	...		
Aluminum + Titanium	...	...	...	...	...	...	...	...		
Lanthanum	...	...	...	...	...	...	...	...	...	
Aluminum + Titanium	...	...		...	...	...	...	0.85–1.20	...	
Nickel + Molybdenum	...	...	...	...	...	...	...	...		
Nickel +	...	...	...	...	...	...	...	...	...	

TABLE 1 Chemical Requirements[A] *(continued)*

Element	Nickel-Molybdenum Alloy	Nickel-Chromium-Iron Alloy	Low-Carbon Nickel-Molybdenum-Chromium Alloy	Nickel-Cobalt-Chromium-Molybdenum-Iron Alloy	Nickel-Molybdenum Alloy	Nickel-Molybdenum Alloy	Nickel-Molybdenum Alloy	Nickel-Cobalt-Chromium-Silicon Alloy	Chromium Nickel-Iron-Nit Alloy
	Composition, %								
	UNS N10665	UNS N10627	UNS N10362	UNS N10668	UNS N12160	UNS N10242	UNS N10675	UNS N12160	UNS R20033	
Nickel	remainder[A]	65.0 min	remainder[A]	remainder	remainder[A]	99.0	balance[A] min	re maind	er[A]	30.0–33.0
Nickel	balance[B]	balance[B]	balance[B]	bainder	remlance[B]	balance	balance[B]	65.0 min	balance[B]	30.0–33.0
Copper	...	0.20 max	...	...	...	...	0.25 max	0.5 max	0.30–1.20	
Copper	...	...	...	0.5	0.5	...	0.20	...	0.30–1.20	
Iron	2.0 max	1.0–3.0	2.0 max	5.0 max	3.5 max	0.40 max	5.0-8.0		balance[A]	
Iron	2.0	4.0–7.0	1.25	5.0-8.0	1.0–6.0	2.0	1.0–3.0	3.5	balance[B]	
Manganese	1.0 max	3.0 max	0.80 max	0.75 max	1.5 max	0.35 max	1.0 max		2.0	
Manganese	0.80	1.0	0.60	1.0	1.5	1.0	3.0	1.5	2.0	
Carbon	0.02 max	0.01 max	0.03	0.010 max	0.15 max	0.15 max	0.01 max	0.15	015 max	
Carbon	0.03	0.010	0.010	0.01	0.010	0.02	0.01	0.15	0.015	
Silicon	0.10 max	0.10 max	0.80 max	0.08 max	2.4–3.0	0.35 max	0.10 max		0.50	
Silicon	0.80	0.08	0.08	0.10	0.05	0.10	0.10	2.4–3.0	0.50	
Sulfur, max		0.03	0.010	0.015	0.02	0.015	0.01	0.01 max	0.01	
Sulfur	0.015	0.03	0.010	0.01	0.01	0.03	0.010	0.015	0.01	
Chromium	1.0 max	1.0–3.0	7.0-9.0	19.0–23.0	26.0–30.0	...	6.0-10.0		31.0–35.0	
Chromium	7.0-9.0	14.5–16.5	13.8-15.6	6.0-10.0	0.5–1.5	1.0	1.0–3.0	26.0–30.0	31.0–35.0	
Aluminum		...	0.50 max	0.50 max	...	...	...	0.5 max	...	
Aluminum	0.50	...	0.50	0.5	0.1–0.5	...	0.50	...	...	
Titanium	...	0.20 max	...	0.02–0.25	0.20–0.80	...	...		...	
Titanium	...	...	...	...	...	...	0.20	0.20–0.80	...	
Columbium (Nb) + tantalum	...	...	...	...	...	...	...	...		
Columbium (Nb) + Tantalum	...	...	...	...	...	...	...	...	...	
Molybdenum	26.0–30.0	27.0–32.0	24.0-26.0	15.0–17.0	1.0 max	...	21.0-25.0		0.50–2.0	
Molybdenum	24.0-26.0	15.0–17.0	21.5-23.0	21.0-25.0	26.0–30.0	26.0–30.0	27.0–32.0	1.0	0.50–2.0	
Phosphorus	0.04 max	0.030 max	0.030 max	0.04 max	0.030 max	...	0.025 max	0.030	0.02 max	
Phosphorus	0.030	0.04	0.025	0.025	0.04	0.04	0.030	0.030	0.02	
Tungsten	...	3.0 max	...	3.0–4.4	1.0 max	...	...		...	
Tungsten	...	3.0–4.5	...	...	...	...	3.0	1.0	...	
Cobalt	1.00 max	3.0 max[†]	1.00 max	...	27.0–33.0†	...	1.0 max		...	
Cobalt	1.00	2.5	...	1.0	2.5	1.00	3.0†	27.0–33.0†	...	
Vanadium, max	...	0.20	...	...	...	...		...	...	
Vanadium	...	0.35	...	...	...	...	0.20	...	...	
Nitrogen	...	...	...	...	...	...	...		0.35–0.60	
Nitrogen	...	...	...	...	...	...	...	...	0.35–0.60	
Boron		...	...	0.006 max	...	...	...	...	...	
Boron	0.006	...	...	...	...	...	...	...	...	
Lanthanum	...	...	...	...	...	...	...	...	...	...
Aluminum + Titanium		...			...		...	...		...
Lanthanum	...	...	...	...	...	...	...	...	...	...
Aluminum + Titanium	...	...			...		...	...		...
Nickel + Molybdenum	...	94.0–98.0	...	...	...	...		...	...	
Nickel + Molybdenum	...	...	...	...	...	...	94.0–98.0	...	...	
Columbium (Nb), max	...	0.20	...	...	1.0	...	...		...	