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Standard Specification for Stainless Steel and Nickel Alloy Bolts, Hex Cap Screws, and Studs, for Heat Resistance and High Temperature Applications[1]

This standard is issued under the fixed designation F2281; 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 the chemical and mechanical requirements for stainless steel and nickel alloy bolts, hex cap screws, and studs, ¼ in. diameter and larger, intended for use at temperatures up to 1800°F (982°C), and in applications where resistance to heat and the effects of high temperature are to be considered. See Appendix X1 for Service Application. A wide variety of materials are covered in this specification which can be used at high temperatures as a function of the specific alloy properties, as well as environmental requirements including corrosive environments.

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 establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A276 Specification for Stainless Steel Bars and Shapes
A342/A342M Test Methods for Permeability of Feebly Magnetic Materials
A380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
A564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
A582/A582M Specification for Free-Machining Stainless Steel Bars
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B637 Specification for Precipitation-Hardening and Cold Worked Nickel Alloy Bars, Forgings, and Forging Stock for Moderate or High Temperature Service
B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
D3951 Practice for Commercial Packaging
E21 Test Methods for Elevated Temperature Tension Tests 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 (Withdrawn 2003)[3]
E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
F788/F788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

[1] This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.

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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.

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 *ASME Standards:*

B1.1 Unified Inch Screw Threads[4]

B18.2.1 Square and Hex Bolts and Screws, (Inch Series)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *heat resistance*—extent to which a material retains useful properties as measured during exposure of the material to a specified temperature and environment for a specified time.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *high temperature*—defined solely for the purpose of this document as a range in temperature from 500°F (260°C) to 1800°F (982°C). Materials listed as high temperature alloys are designed to maintain their anticipated strength and characteristics within this range.

4. Classification

4.1 Three types of material, see Appendix X1 for service application, are covered in this specification and are classified into the following:

4.1.1 *Type I*—Heat resisting alloys for continuous service applications:

4.1.1.1 *Class A*—Austenitic grades:

Alloy Grade	UNS Designation
304	S30400
304L	S30403
316	S31600
316L	S31603

4.1.1.2 *Class B*—Martensitic grades:

Alloy Grade	UNS Designation
410	S41000
416	S41600
431	S43100

4.1.1.3 *Class C*—Ferritic grades:

Alloy Grade	UNS Designation
430	S43000
430F	S43020

4.1.2 *Type II*—Heat resisting alloys for continuous and intermittent service applications:

Alloy Grade	UNS Designation
309	S30900
310	S31000
321	S32100
330	N08330
347	S34700

4.1.3 *Type III*—High temperature alloys for continuous and intermittent service applications:

4.1.3.1 *Class A*—Nickel based alloy:

Alloy Grade	UNS Designation
600	N06600
601	N06601

4.1.3.2 *Class B*—Precipitation hardened alloy:

Alloy Grade	UNS Designation
660	S66286

4.1.3.3 *Class C*—Precipitation hardened alloy:

Alloy Grade	UNS Designation
718	N07718

5. Ordering Information

5.1 Orders for bolts, hex cap screws, and studs under this specification shall include the following information:

5.1.1 ASTM designation and year date. When year date is not specified, the latest issue shall be invoked;

5.1.2 Quantity (number of pieces of each item),

5.1.3 Item name (that is, bolt, hex cap screw, or stud),

5.1.4 Size (nominal diameter, threads per inch, length),

5.1.5 Type, class, and alloy grade (see 4.1), and

5.1.6 Condition (see 6.2.3).

5.2 Orders for bolts, hex cap screws, and studs under this specification may include the following optional requirements:

5.2.1 Forming (see 6.2.1),

5.2.2 Thread type (see 6.2.2),

5.2.3 Corrosion tests (see 13.1.2.1),

5.2.4 Finish (see 11.3),

5.2.5 Test reports (see 19.2), and

5.2.6 Supplementary Requirements, if any, to be specified on the order (see S1 through S8).

6. Materials and Manufacture

6.1 *Material:*

6.1.1 Specifications A276, A484/A484M, A493, A564/A564M, A582/A582M, B637 are noted for information only as suitable sources of material for the manufacture of bolts, hex cap screws, and studs to this specification.

6.1.2 The bolts, hex cap screws, and studs shall be manufactured from material having a chemical composition conforming to the requirements listed in Table 1 and capable of developing the mechanical property requirements listed in Table 2 for the finished fastener.

6.1.3 Various grades of material having unique heat resisting or high temperature characteristics are specified in this specification. A guide to their application is listed in Appendix X1 to assist in the selection of the fastener material.

6.1.4 The form and condition of the raw material shall be at the option of the manufacturer but shall be such that the finished fastener conforms to all the specified requirements.

6.2 *Manufacture:*

6.2.1 *Forming*—Unless otherwise specified, the fasteners shall be cold formed, hot formed, or machined from suitable material, at the option of manufacturer.

6.2.2 *Threads*—Unless otherwise specified, the threads shall be rolled or cut, at the option of the manufacturer.

6.2.3 *Condition*—The fasteners shall be furnished in one of the following conditions and shall be agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

TABLE 1 Chemical Requirements

Composition, % maximum except as shown										
Alloy	Carbon	Mang.	Phos.	Sulfur	Silicon	Chromium	Nickel	Copper	Moly	Other
Type I, Class A, Heat Resisting Austenitic Grades										
304	0.08	2.00	0.045	0.030	1.00	18.0/20.0	8.0/10.5	1.00		
304L	0.03	2.00	0.045	0.030	1.00	18.0/20.0	8.0/12.0	1.00		
316	0.08	2.00	0.045	0.030	1.00	16.0/18.0	10.0/14.0		2.00/3.00	
316L	0.03	2.00	0.045	0.030	1.00	16.0/18.0	10.0/14.0		2.00/3.00	
Type I, Class B, Heat Resisting Martensitic Grades										
410	0.15	1.00	0.040	0.030	1.00	11.5/13.5				
416	0.15	1.25	0.060	0.15 min	1.00	12.0/14.0			0.60	
431	0.20	1.00	0.040	0.030	1.00	15.0/17.0	1.25/2.50			
Type1, Class C, Heat Resisting Ferritic Grades										
430	0.12	1.00	0.040	0.030	1.00	16.0/18.0				
430F	0.12	1.25	0.060	0.15 min	1.00	16.0/18.0			0.60	
Type II, Heat Resisting Austenitic Grades										
309	0.20	2.00	0.045	0.030	1.00	22.0/24.0	12.0/15.0			
310	0.25	2.00	0.045	0.030	1.50	24.0/26.0	19.0/22.0			
321	0.08	2.00	0.045	0.030	1.00	17.0/19.0	9.0/12.0			Ti5×Cmin
330	0.08	2.00	0.030	0.030	0.75/1.50	17.0/20.0	34.0/37.0			
347	0.08	2.00	0.045	0.030	1.00	17.0/19.0	9.0/13.0			Cb + Ta10 × Cmin
Type III, Class A, High Temperature, Nickel Alloy Grades										
600	0.10	1.00		0.015	0.50	14.0/17.0	72.0 min	0.50		Fe 6.0/10.0
601	0.10	1.00		0.015	0.50	21.0/25.0	58.0/63.0	1.00		Al 1.0/1.7 Fe remainder
Type III, Class B, High Temperature, Precipitation Hardened Grade										
660	0.08	2.00	0.040	0.030	1.00	13.5/16.0	24.0/27.0		1.00/1.75	Ti 1.90/2.30 V 0.10/0.50 Al 0.35 max B 0.003/0.010 Fe remainder
Type III, Class C, High Temperature, Precipitation Hardened Grade										
718	0.08	0.35	0.015	0.015	0.35	17.0/21.0	50.0/55.0	0.30	2.80/3.30	Ti 0.65/1.15 Co 1.00 max Al 0.20/0.80 B 0.006 max Cb + Ta 4.75/5.50 Fe remainder

Type	Class	Condition
I	A	A, CWA, HWA
I	B	H, HT
I	C	A, CWA, HWA
II	...	A, CWA, HWA
III	A	A, CWA, HWA
III	B	AH1, AH2 or AH3
III	C	AH4

Condition	
A	Machined from annealed or solution-annealed stock thus retaining the properties of the original material
CWA	Cold formed from annealed or solution-annealed stock and then re-annealed
HWA	Hot formed from annealed or solution-annealed stock and then re-annealed
H	Hardened and tempered at 1050°F (565°C) minimum
HT	Hardened and tempered at 525°F (274°C) minimum
AH1	Solution treated at 1850°F (1010°C) and precipitation hardened (aging)
AH2	Solution treated at 1700°F (927°C) and precipitation hardened (aging)
AH3	Solution treated at 1850°F (1010°C) and double aged
AH4	Solution treated at 1725°F (941°C) to 1850°F (1010°C) and precipitation hardened (aging)

6.2.4 *Heat Treatment:*

6.2.4.1 *Condition A—(Austenitic Alloys Type I Class A and Type II),* shall be heated to 1850 to 1950°F (1010 to 1066°C), held for a sufficient time, then cooled at a rate sufficient to prevent the precipitation of carbides and to provide the specified properties.

6.2.4.2 *Condition A—(Ferritic Alloys Type I Class C),* shall be heated to 1400 to 1500°F (760 to 816°C), held for a sufficient time, and then air cooled to provide the specified properties.

6.2.4.3 *Condition A—(Nickel Alloy Type III Class A),* shall be heated to 1600° to 1800°F (871 to 982°C), held for 10 to 15 min, and either water quenched or air cooled.

6.2.4.4 *Condition CWA—(Austenitic Alloys Type I Class A and Type II),* shall be cold formed from annealed or solution annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.1 after all cold working (including heading and threading) has been completed.

6.2.4.5 *Condition CWA—(Ferritic Alloys Type I Class C),* shall be cold formed from annealed or solution annealed stock and then re-annealed or re-solution annealed in accordance

TABLE 2 Mechanical Property Requirements at Room Temperature

Alloy Grades	Condition	Marking	Nominal Diameter, in.	Full-Size Tests		Rockwell Hardness	Machined Specimen Tests		
				Tensile Strength, min, ksi	Yield Strength, min, ksi		Tensile Strength, min, ksi	Yield Strength, min, ksi	Elongation 4D, min %
Type I, Class A, Heat Resisting Austenitic Grades									
304, 304L	A	F1A	All diameters	75	30	65 to 95 HRB	75	30	30
	CWA	F1B	All diameters	75	30	65 to 95 HRB	75	30	30
	HWA	F1C	All diameters	75	30	65 to 95 HRB	75	30	30
316, 316L	A	F1D	All diameters	75	30	65 to 95 HRB	75	30	30
	CWA	F1E	All diameters	75	30	65 to 95 HRB	75	30	30
	HWA	F1F	All diameters	75	30	65 to 95 HRB	75	30	30
Type I, Class B, Heat Resisting Martensitic Grades									
410, 416	H	F1G	Up to 4 diameter	110	85	20 to 30 HRC	110	85	15
	HT	F1H	Up to 4 diameter	160	120	34 to 45 HRC	160	120	12
431	H	F1I	All diameters	125	100	25 to 32 HRC	125	100	15
	HT	F1J	All diameters	180	140	40 to 48 HRC	180	140	10
Type I, Class C, Heat Resisting Ferritic Grades									
430, 430F	A	F1K	All diameters	55	30	65 to 95 HRB	50	25	...
	CWA	F1L	All diameters	55	30	65 to 95 HRB	50	25	...
	HWA	F1M	All diameters	55	30	65 to 95 HRB	50	25	...
Type II, Class A Heat Resisting Austenitic Grades									
309, 310	A	F2A	All diameters	75	30	85 to 95 HRB	75	30	30
	CWA	F2B	All diameters	75	30	65 to 95 HRB	75	30	30
	HWA	F2C	All diameters	75	30	65 to 95 HRB	75	30	30
321, 347	A	F2D	All diameters	75	30	85 to 95 HRB	75	30	30
	CWA	F2E	All diameters	75	30	65 to 95 HRB	75	30	20
	HWA	F2F	All diameters	75	30	65 to 95 HRB	75	30	30
330	A	F2G	All diameters	75	30	85 to 95 HRB	75	30	30
	CWA	F2H	All diameters	75	30	65 to 95 HRB	75	30	20
	HWA	F2I	All diameters	75	30	65 to 95 HRB	75	30	30
Type III, Class A, High Temperature, Nickel Alloy Grades									
600, 601	A	F3A	All diameters	80	25	65 to 85 HRB	75	25	35
	CWA	F3B	All diameters	80	25	65 to 85 HRB	75	25	35
	HWA	F3C	All diameters	80	25	65 to 85 HRB	75	25	35
Type III, Class B, High Temperature, Precipitation Hardened Grade									
660	AH1	F3D	All diameters	130	85	22 to 37 HRC	130	85	15
	AH2	F3E	All diameters	130	85	22 to 37 HRC	130	85	15
	AH3	F3F	All diameters	130	85	22 to 37 HRC	130	85	15
Note: Condition AH1 results in increased rupture strength after aging, while Condition AH2 results in better ductility and higher hardness.									
Type III, Class C High Temperature, Precipitation Hardened Grade									
718	AH4	F3G	All diameters	185	150	36 to 48 HRC	180	150	12

with 6.2.4.2 after all cold working (including heading and threading) has been completed.

6.2.4.6 *Condition CWA—(Nickel Alloy Type III Class A),* shall be cold formed from annealed stock and then re-annealed in accordance with 6.2.4.3 after all cold working (including heading and threading) has been completed.

6.2.4.7 *Condition HWA—(Austenitic Alloys Type I Class A and Type II),* shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.1 after all hot forming has been completed.

6.2.4.8 *Condition HWA—(Ferritic Alloys Type I Class C),* shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.2 after all hot forming has been completed.

6.2.4.9 *Condition HWA—(Nickel Alloy Type III Class A),* shall be hot formed from annealed or solution-annealed stock and then re-annealed or re-solution annealed in accordance with 6.2.4.3 after all hot forming has been completed.

6.2.4.10 *Condition H—(Martensitic Alloys Type I Class B),* shall be hardened by heating to 1800 to 1900°F (982 to 1038°C), held for at least ½ h and rapid air or oil quenched, then reheated to 1050°F (565°C) minimum for at least 1 h and air cooled to provide the specified properties.

6.2.4.11 *Condition HT—(Martensitic Alloys Type 1 Class B),* shall be hardened by heating to 1800 to 1900°F (982 to 1038°C), held for at least ½ h and rapid air or oil quenched, then reheated to 525°F (274°C) minimum for at least 1 h and air cooled to provide the specified properties.

6.2.4.12 *Condition AH1—(Precipitation Hardened Alloy Type III Class B),* shall be solution treated at 1800 to 1900°F (982 to 1038°C), held for 1 h at heat, then cooled rapidly. Precipitation hardening (aging) shall be performed by heating to 1300 to 1400°F (704 to 760°C), holding for 12 to 16 h at heat then air cooled. See Note 1.

6.2.4.13 *Condition AH2—(Precipitation Hardened Alloy Type III Class B),* shall be solution treated at 1650 to 1750°F (899 to 954°C), held for 2 h at heat, then cooled rapidly. Precipitation hardening (aging) shall be performed by heating to 1300 to 1400°F (704 to 760°C), holding for 12 to 16 h at heat then air cooled. See Note 1.

NOTE 1—Condition AH1 results in increased rupture strength after aging, while Condition AH2 results in better ductility and higher hardness.

6.2.4.14 *Condition AH3—(Precipitation Hardened Alloy Type III Class B),* shall be solution treated at 1800 to 1900°F (982 to 1038°C), held for 1 h at heat, then cooled rapidly. Precipitation hardening (aging) shall be performed by heating

to 1425 ± 25°F (775 ± 14°C) holding for 16 h at heat then air cooled. Heated again to 1200 ± 25°F (650 ± 14°C) holding for 16 h at heat then air cooled.

6.2.4.15 *Condition AH4—(Precipitation Hardened Alloy Type III Class C),* shall be solution treated at 1725°F (941°C) to 1850°F (1010°C), held at the selected temperature for a time commensurate with cross-sectional thickness, and cooled at a rate equivalent to an air cool or faster. Solution treating temperatures shall be controlled in a range of ±25°F (±14°C). Precipitation hardening (aging) shall be performed by heating to 1325°F (718°C) held at heat for 8 h, cooled to 1150°F (621°C) at a rate of 100°F (56°C)/h, held for 8 h at heat and air cooled. Alternatively, parts may be furnace cooled to 1150°F (621°C) at any rate provided the time at 1150°F (621°C) is adjusted so the total heat treat time is 18 h minimum. Precipitation treatment temperatures and cooling rates shall be controlled in the range of ±15°F (±8°C).

7. Chemical Composition

7.1 *Chemical Composition*—Bolts, hex cap screws, and studs shall conform to the chemical composition requirements prescribed in Table 1 for the specified alloy grade.

7.2 *Product Analysis:*

7.2.1 When a product analysis is made by the purchaser from finished fasteners representing each lot, the chemical composition thus determined shall conform to the requirements listed in Table 1 for the specified alloy grade, subject to the product analysis tolerance listed in Specifications A484/A484M and B880.

7.2.2 In the event of a discrepancy, a referee chemical analysis of samples, taken from each lot, shall be made in accordance with 14.1 and 15.1.

8. Mechanical Properties

8.1 Bolts, hex cap screws, and studs shall meet the applicable mechanical properties listed in Table 2 for the specified alloy grade and condition when tested at room temperature, in accordance with the mechanical properties requirements specified herein for the type, grade, diameter, and length.

8.2 *Mechanical Test Requirements :*

8.2.1 Bolts and hex cap screws which meet the minimum requirements for length, and have a maximum 160 000 lb tensile load, shall have a full size wedge tensile strength and yield strength test performed as outlined in Section 15. For bolts and hex cap screws which exceed the 160 000 lb limit, a machined specimen tensile strength, yield strength, and elongation test performed as outlined in Section 15 may be substituted for the full size wedge test. In addition, for bolts and hex cap screws that are less than the minimum length requiring tension tests, either a full size wedge tensile strength test, full size axial tensile strength test or a Rockwell hardness test shall be required as outlined in Section 15. In all cases, full size wedge tensile strength testing shall be performed whenever possible.

8.2.2 Studs which meet the minimum requirements for length and have a maximum 160 000 lb tensile load, shall have a full size axial tensile strength test and yield strength test performed as outlined in Section 15. For studs which exceed the 160 000 lb limit, a machined specimen tensile strength, yield strength, and elongation test performed as outlined in Section 15 may be substituted for the full size axial test. In addition, for studs that are less than the minimum length requiring tension tests, either a full size axial tensile strength test or a Rockwell hardness test shall be required as outlined in Section 15. In all cases, full size axial tensile strength testing shall be performed whenever possible.

TABLE 3 Elevated Temperature Mechanical Property Requirements for Type III High Temperature Alloys

Temperature		Tensile Strength, ksi, min	Yield 0.2 % Strength, ksi, min	Elongation in 2 in., %, min
°F	°C			
Class A—Nickel Based Alloys				
Alloy Grade 600 Annealed at 1600°F (871°C)				
600	316	89.0	34.0	45.0
1000	538	82.0	33.0	42.0
1400	760	37.0	26.0	70.0
1800	982	11.0	5.0	115.0
Alloy Grade 601 Annealed at 1800°F (982°C)				
800	427	104.0	54.5	36.0
1000	538	94.8	51.5	34.0
1200	649	73.5	46.5	32.0
1400	760	37.3	36.6	88.0
1800	982	8.7	7.5	173.0
Class B—Precipitation Hardened Alloys				
Alloy Grade 660				
800	427	138.0	93.0	18.0
1000	538	131.0	87.5	18.0
1100	593	122.0	90.0	21.0
1200	649	104.0	88.0	13.0
1300	704	86.5	86.0	11.0
1400	760	64.0	62.0	18.0
1500	816	36.5	33.0	68.0
Class C—Precipitation Hardened Alloys				
Alloy Grade 718				
600	316	184.0	156.0	20.0
1000	538	173.0	148.0	16.0
1200	649	145.0	125.0	12.0
1400	760	124.0	116.0	5.0

8.3 In the event of a discrepancy between full size wedge test, full size axial test, machined specimen test, and Rockwell hardness test results, the precedence sequence shall be the same as the sequence listed in this section for acceptance purposes. That is, if parts pass axial tensile but fail Rockwell hardness they are acceptable; however, if they fail axial tensile and pass Rockwell hardness they are not acceptable.

8.4 If tests to determine high temperature properties are required on Type III high temperature alloys, Supplementary Requirement S8 shall be specified in the inquiry and order and high temperature testing shall be performed and meet the applicable mechanical properties listed in Table 3.

9. Corrosion Resistance

9.1 *Carbide Precipitation:*

9.1.1 The type I, class A austenitic alloys listed in 4.1.1.1 and all type II austenitic alloys listed in 4.1.2 shall be capable of passing the test for susceptibility to intergranular corrosion in accordance with Practice E of Practices A262.

9.1.2 As stated in Practices A262, samples may be subjected to the faster and more severe screening test in accordance with Practice A. Failing Practice A, specimens may be tested in accordance with Practice E and be considered satisfactory if passing Practice E.

10. Dimensions

10.1 *Bolts and Hex Cap Screws:*

10.1.1 Unless otherwise specified, the dimensions shall be in accordance with the requirements of ASME B18.2.1 for hex cap screws.

10.1.2 When specified, the dimensions of bolts shall be in accordance with the requirements of ASME B18.2.1 (type as specified), or such other dimensions as shall be specified.

10.2 *Studs:*

10.2.1 Dimensions of studs shall be specified by the purchaser.

10.2.2 *Stud Type:*

10.2.2.1 Continuous thread.

10.2.2.2 Double end clamping (also known as stud bolt or bolt stud).

10.2.2.3 Double end interference (also known as tap-end stud).

10.2.2.4 Other studs as shall be specified by the purchaser.

10.2.3 *Threads*—Unless otherwise specified, studs shall have Class 2A threads in accordance with ASME B1.1.

10.2.4 *Points*—Unless otherwise specified, the points shall be flat and chamfered or rounded at the option of the manufacturer.

11. Workmanship, Finish, and Appearance

11.1 *Surface Discontinuities*—For fasteners with specified minimum tensile strengths of 90 000 psi and higher the requirements in Specification F788/F788M shall apply.

11.2 *Cleaning and Descaling*—The fasteners shall be descaled, or cleaned, or both, in accordance with Practice A380.

11.3 *Protective Finishes*—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

12. Sampling

12.1 A lot, for the purposes of selecting test specimens and inspection, shall be as defined in Guide F1470.

13. Number of Tests and Retests

13.1 *Number of Tests:*

13.1.1 *Mechanical Tests*—The mechanical property requirements listed in Table 2 shall be met for all lots produced and submitted for testing. The manufacturer shall make sample inspections in accordance with Guide F1470 detection process, to ensure the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S1 shall be specified in the inquiry and order.

13.1.2 *Corrosion Resistance Tests:*

13.1.2.1 Unless otherwise specified, inspection for corrosion resistance shall be in accordance with the manufacturer's standard quality control practices. No one specific method of inspection is required, but the fasteners shall be produced from suitable raw material and manufactured, by properly controlled practices, to maintain resistance to corrosion. When corrosion tests are required, Supplementary Requirement S6 shall be specified in the inquiry and order, except as noted in 13.1.2.2.

13.1.2.2 Products that have been hot worked shall be solution annealed. Sampling for determination of freedom from precipitated carbides shall be in accordance with Guide F1470 detection process.

13.1.3 Sampling for determination of freedom from surface discontinuities shall be in accordance with Guide F1470 detection process.

14. Specimen Preparation

14.1 *Chemical Tests*—When required, samples for chemical analysis shall be taken by drilling, sawing, milling, turning, clipping, or other such methods capable of producing representative samples.

14.2 *Mechanical Tests:*

14.2.1 When required, machined tension specimens shall be machined from the fastener in accordance with Test Methods F606. The largest test specimen that can be machined from the bolt, hex cap screw, or stud shall be used.

14.2.2 When required, the hardness shall be determined on the finished fastener in accordance with Test Methods F606.

14.3 *Corrosion Resistance*—When required, test specimens shall be prepared in accordance with Practices A262.

15. Test Methods

15.1 *Chemical Analysis:*

15.1.1 The fastener manufacturer may accept the chemical analysis of each heat of raw material purchased and reported on the raw material certification furnished by the raw material producer. The fastener manufacturer is not required to do any further chemical analysis testing provided that precise heat lot traceability has been maintained throughout the manufacturing process on each lot of fasteners produced and delivered.

15.1.2 The chemical composition of stainless steel fasteners shall be determined in accordance with Test Methods, Practices, and Terminology A751.

15.1.3 The chemical composition of nickel alloy fasteners shall be determined in accordance with Test Methods E76, E353, E354, or other equivalent method.

15.2 *Mechanical Tests:*

15.2.1 When full-size tests are to be performed, the yield strength, wedge tensile strength, or axial tensile strength, as required by Section 8 above, shall be determined on each sample in accordance with the appropriate methods of Test Methods F606.

15.2.2 Full-size bolts and hex cap screws subject to tension tests shall be tested using a wedge under the head. The wedge shall be 10° for bolts 0.750-in. nominal diameter and less and 6° for bolts over 0.750-in. diameter.

15.2.3 When machined specimen tests are necessary (see Section 8), the yield strength, tensile strength, and elongation shall be determined on each sample in accordance with Test Methods F606.

15.2.4 Bolts, hex cap screws, and studs that are less than the minimum length requiring tension tests shall be tested in accordance with Test Method F606.

15.2.5 The hardness shall be determined in accordance with Test Methods F606. A minimum of two readings shall be made on each sample, each of which shall conform to the specified requirements.

15.3 *Corrosion Resistance*—When required or when specified on the purchase order or inquiry, corrosion tests to determine freedom from precipitated carbides shall be performed in accordance with Practices A262, Practice A or E, as applicable.

16. Significance of Numerical Limits

16.1 For the purpose of determining compliance with the specified limits for properties listed in this specification, an observed value or calculated value shall be rounded, in accordance with Practice E29.

17. Inspection

17.1 If source inspection is required by the purchaser, Supplementary Requirement S3 shall be specified in the inquiry, order, or contract.

17.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's facility that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspection required by the specification, that are requested by the purchaser's representative and purchase order, shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operations of the manufacturer.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification shall be rejected. If rejection is made by the purchaser, it shall be reported to the supplier promptly in writing. In case of disagreement with the results of the tests or inspection performed or authorized by the purchaser, the supplier may make claim for a retesting or re-inspection.

19. Certification and Test Reports

19.1 *Certificate of Compliance*—Unless otherwise specified in the purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and the customer's order and conforms to all specified requirements.

19.2 *Test Reports*—When specified on the purchase order, the manufacturer shall furnish a test report showing the chemical analysis of the material used to produce the fasteners and the results of the last completed set of mechanical tests, for each lot of fasteners in the shipment. Corrosion test results shall be reported when corrosion testing has been performed.

20. Product Marking

20.1 *Individual Products*—All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking in accordance with Table 2. The manufacturer may at its option add the specific alloy designation from Table 1. The marking shall be raised or depressed at the option of the manufacturer.

21. Packaging and Package Marking

21.1 *Packaging:*

21.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D3951.

21.1.2 When special packaging requirements are required by the purchaser, they shall be defined at the time of inquiry and order.

21.2 *Package Marking*—Each shipping unit shall include or be plainly marked with the following:

21.2.1 ASTM designation,

21.2.2 Alloy number,

21.2.3 Name of item (that is, bolt, hex cap screw, or stud),

21.2.4 Size,

21.2.5 Name and brand or trademark of the manufacturer,

21.2.6 Number of pieces,

21.2.7 Purchase order number, and

21.2.8 Lot number, if applicable.

22. Keywords

22.1 bolts; heat resistant; hex cap screws; high temperature; stainless steel; studs

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry and order (see 5.2.6). Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Shipment Lot Testing

S1.1 When Supplementary Requirement S1 is specified on the order, the manufacturer shall make sample tests on the individual lots for shipment, to ensure that the product conforms to the specified requirements.

S1.2 The manufacturer shall make an analysis of a randomly selected finished fastener from each lot of product to be shipped. Heat or lot control shall be maintained. The analysis of the starting material from which the fasteners have been manufactured may be reported in place of the product analysis.

S1.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F1470 on the individual lots for shipment.

S1.4 The manufacturer shall furnish a test report, for each lot in the shipment, showing the actual results of the chemical analysis, mechanical property tests performed, and if required corrosion testing results, in accordance with Supplementary Requirement S1.

S2. Additional Tests

S2.1 When additional tests of mechanical properties are desired by the purchaser, Supplementary Requirement S2 shall be specified on the inquiry and order. The additional test(s) shall be made, as agreed upon between the manufacturer and the purchaser, at the time of the inquiry or order.

S3. Source Inspection

S3.1 When Supplementary Requirement S3 is specified on the inquiry and order, the product shall be subject to inspection by the purchaser, at the place of manufacturer, prior to shipment.

S4. Heat Control

S4.1 When Supplementary Requirement S4 is specified on the inquiry and order, the manufacturer shall control the product by heat analysis and identify the finished product in each shipment by the actual heat number.

S4.2 When Supplementary Requirement S4 is specified on the inquiry and order, Supplementary Requirement S1 shall be considered automatically invoked, with the addition that the heat analysis shall be reported to the purchaser on the test reports.

S5. Permeability

S5.1 When Supplementary Requirement S5 is specified on the inquiry and order, the permeability of bolts, hex cap screws and studs of Type I Class A, Type II, and Type III Class A and B, in Condition A, Condition CWA, and Condition HWA, shall not exceed 1.5 at 100 oersteds when determined in accordance with Test Methods A342/A342M.

S6. Corrosion Resistance Tests

S6.1 When Supplementary Requirement S6 is specified on the inquiry and order, corrosion test(s) shall be performed, as agreed upon between the manufacturer and the purchaser, at the time of the inquiry or order.

S7. Passivation

S7.1 When supplementary Requirement S7 is specified on the inquiry and order, the finished product shall be passivated, in accordance with Practice A380.

S8. High Temperature Tests

S8.1 When Supplementary Requirement S8 is specified on the inquiry and order, tests to determine high temperature properties shall be performed, in accordance with Test Methods E21, E139, and E292, or other equivalent method. One high temperature test shall be performed on each lot at a test temperature agreed upon between the buyer and the seller and selected from one of the test temperatures listed in Table 3.

APPENDIX

(Nonmandatory Information)

X1. GUIDE TO SERVICE APPLICATION

X1.1 This Guide should not be used as the sole criteria for selecting high temperature and heat resisting materials for fasteners. Corrosion, stress corrosion cracking, embrittlement, and deterioration are the ultimate responsibility of the user. (**Warning—**Prolonged exposure of Heat Resisting Alloys to temperatures from 700 to 1500°F (temperature sensitivity varies with the different grades) can result in chromium carbide precipitation, reduced corrosion resistance, reduced impact strength, or other embrittling phenomena.)

TABLE X1.1 Guide to Service Application

Type I, Class A Heat Resisting Alloys at Continuous Service		
Alloy Grade	Safe Scaling Temperature at Continuous Service	
304/304L	1600°F (871°C)	
316/316L		
Type I, Class B Heat Resisting Alloys at Continuous Service		
Alloy Grade	Safe Scaling Temperature at Continuous Service	
410/416	1200°F (649°C)	
431	1300°F (704°C)	
Type I, Class C Heat Resisting Alloys at Continuous Service		
Alloy Grade	Safe Scaling Temperature at Continuous Service	
430/430F	1500°F (816°C)	
Type II, Heat Resisting Alloys at Continuous Service and Intermittent Service		
Alloy Grade	Safe Scaling Temperature at Continuous Service	Safe Scaling Temperature at Intermittent Service
309	2000°F (1093°C)	1850°F (1010°C)
310	2100°F (1149°C)	2000°F (1093°C)
321	1600°F (871°C)	1650°F (899°C)
330	2200°F (1204°C)	2200°F (1204°C)
347	1600°F (871°C)	1650°F (871°C)
Type III, Class A Nickel Alloys for High Temperature Service		
Alloy Grade	Resistant to Oxidation and Scaling up to	
600	1800°F (980°C)	
601	2000°F (1095°C)	
Type III, Class B Precipitation Hardened Alloys for High Temperature Service		
Alloy Grade	High Strength and Resistant to Corrosion up to	
660	1300°F (704°C)	