Designation: F2281 – 04 (Reapproved 2017)

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

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 Weakly 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

[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.

Current edition approved Dec. 1, 2017. Published December 2017. Originally approved in 2003. Last previous edition approved in 2012 as F2281 – 04(2012). DOI: 10.1520/F2281-04R17.

[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.

F606/F606M 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
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

Alloy	Carbon	Mang.	Phos.	Sulfur	Silicon	Chromium	Nickel	Copper	Moly	Other
				Composition, % maximum except as shown						
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