Designation: F 468 – 98

Standard Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use[1]

This standard is issued under the fixed designation F 468; 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 covers the requirements for commercial wrought nonferrous bolts, hex cap screws, and studs 0.250 to 1.500 in. inclusive in diameter manufactured from a number of alloys in common use and intended for general service applications.

1.2 Applicable nuts for use with bolts, cap screws, and studs covered by this specification are covered by Specification F 467.

NOTE 1—A complete metric companion to Specification F 468 has been developed—F 468M; therefore no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys[2]

B 193 Test Method for Resistivity of Electrical Conductor Materials[3]

B 211 Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire[4]

B 565 Test Method for Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-Heading Wire and Rods[4]

D 3951 Practice for Commercial Packaging[5]

E 8 Test Methods of Tension Testing of Metallic Materials[6]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[6]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[7]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys[8]

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[9]

E 53 Test Methods for Chemical Analysis of Copper[8]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[8]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[8]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[8]

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[8]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[8]

E 92 Test Method for Vickers Hardness of Metallic Materials[6]

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[10]

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys[8]

E 165 Test Method for Liquid Penetrant Examination[11]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[8]

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys[8]

E 478 Test Methods for Chemical Analysis of Copper Alloys[8]

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique[8]

F 467 Specification for Nonferrous Nuts for General Use[12]

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets[12]

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection[12]

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[1] This specification is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.04 on Nonferrous Fasteners.

Current edition approved Dec. 10, 1998. Published February 1999. Originally published as F 468 – 76 T. Last previous edition F 468 – 97.

[2] *Annual Book of ASTM Standards,* Vol 02.01.

[3] *Annual Book of ASTM Standards,* Vol 02.03.

[4] *Annual Book of ASTM Standards,* Vol 02.02.

[5] *Annual Book of ASTM Standards,* Vol 15.09.

[6] *Annual Book of ASTM Standards,* Vol 03.01.

[7] *Annual Book of ASTM Standards,* Vol 14.02.

[8] *Annual Book of ASTM Standards,* Vol 03.05.

[9] Discontinued 1989; *Replaced by E 350.*

[10] Discontinued; see *1995 Annual Book of ASTM Standards,* Vol 03.05.

[11] *Annual Book of ASTM Standards,* Vol 03.03.

[12] *Annual Book of ASTM Standards,* Vol 01.08.

2.2 *American National Standards:*

ANSI B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)[13]

ANSI B18.2.1 Square and Hex Bolts and Screws, Including Hex Cap Screws[13]

ANSI H35.1 Alloy and Temper Designation Systems for Aluminum[13]

3. Ordering Information

3.1 Orders for fasteners under this specification shall include the following information:

3.1.1 Quantity (number of pieces of each item and size),

3.1.2 Name of item. For silicon bronze alloy 651, state if hex cap screw dimensions or roll thread body diameter are required (see 7.1.2),

3.1.3 Size (diameter, threads per inch, length),

3.1.4 Alloy number (Table 1). For Ti5, state Class A or Class B (Table 11, 6.5, and 6.5.1),

3.1.5 Stress relieving, if required (see 4.2.3),

3.1.6 Shipment lot testing, as required (see Section 10),

3.1.7 Source inspection, if required (see Section 14),

3.1.8 Certificate of compliance or test report, if required (see Section 16),

3.1.9 Additional requirements, if any, to be specified on the purchase order (see 4.2.1, 4.2.4, 7.3.1, 8.2, 11.1, and 12.1),

3.1.10 Supplementary Requirements, if any, and

3.1.11 ASTM designation and date of issue.

NOTE 2— *Example*

10 000 pieces, Hex Cap Screw, 0.250 in.-20 × 3.00 in., Alloy 270. Furnish Certificate of Compliance, Supplementary Requirement S1, ASTM F 468 dated —.

4. Materials and Manufacture

4.1 *Materials*:

4.1.1 The bolts, cap screws, and studs shall be manufactured from material having a chemical composition conforming to the requirements in Table 1 and capable of developing the required mechanical properties for the specified alloy in the finished fastener.

4.1.2 The starting condition of the raw material shall be at the discretion of the fastener manufacturer but shall be such that the finished products conform to all of the specified requirements.

4.2 *Manufacture*:

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

4.2.2 *Condition*—Except as provided in 4.2.3, the fasteners shall be furnished in the following conditions:

Alloy	Condition
Copper (all alloys)	As formed or stress relieved at manufacturer's option
Nickel alloys:	
400 and 405	As formed or stress relieved at manufacturer's option
500	Solution annealed and aged
Aluminum alloys:	
2024-T4	Solution treated and naturally aged
6061-T6	Solution treated and artificially aged
7075-T73	Solution treated and stabilized
Titanium	As formed

4.2.3 *Stress Relieving*—When required, stress relieving shall be specified by the purchaser for nickel alloys 400 and 405 and all copper alloys.

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

5. Chemical Composition

5.1 *Chemical Composition*—The fasteners shall conform to the requirements as to chemical composition prescribed in Table 1 for the specified alloy.

5.2 *Manufacturer's Analysis*:

5.2.1 When test reports are required on the inquiry or purchase order (see 3.1.8), the manufacturer shall make individual analyses of randomly selected finished fasteners from the product to be shipped and report the results to the purchaser, except as provided in 5.2.2. Alternatively, if heat and lot identities have been maintained, the analysis of the raw material from which the fasteners have been manufactured may be reported instead of product analysis.

5.2.2 For aluminum fasteners, the manufacturer may furnish instead a certificate of conformance certifying compliance with the chemical composition specified in Table 1.

5.3 *Product Analysis*:

5.3.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements in Table 1.

5.3.2 In the event of disagreement, a referee chemical analysis of samples from each lot shall be made in accordance with 11.1 and 12.1.

[13] Available from American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

TABLE 1 Chemical Requirements

UNS Designation Number	Composition, %												
	Copper and Copper-Base Alloys												
	Alloy	General Name	Aluminum	Copper, min	Iron, max	Manganese, max	Nickel, max	Phosphorus	Silicon	Zinc, max[A]	Lead, max	Tin	Arsenic, max
C11000	110	ETP copper		99.9									
C27000	270	brass		63.0–68.5	0.07					balance	0.10		
C46200	462	naval brass		62.0–65.0	0.10					balance	0.20	0.5–1.0	
C46400	464	naval brass		59.0–62.0	0.10					balance	0.20	0.5–1.0	
C51000	510	phosphor bronze		balance[A]	0.10			0.03–0.35		0.30	0.05	4.2–5.8	
C61300	613	aluminum bronze	6.0–7.5	[B]	2.0–3.0	0.10	0.15[C]	0.015	0.10	0.05	0.01	0.20–0.50	
C61400	614	aluminum bronze	6.0–8.0	88.0[D]	1.5–3.5	1.0							
C63000	630	aluminum bronze	9.0–11.0	78.0[D]	2.0–4.0	1.5	4.0–5.5		0.25 max			0.20 max	
C64200	642	aluminum silicon bronze	6.3–7.6	88.65[D]	0.30	0.10	0.25		1.5–2.2[E]	0.50	0.05	0.20 max	0.15
C65100	651	silicon bronze		96.0[D]	0.8	0.7			0.8–2.0	1.5	0.05		
C65500	655	silicon bronze		94.8[D]	0.8	1.5	0.6		2.8–3.8	1.5	0.05		
C66100	661	silicon bronze	0.25 max	94.0[D]	0.25	1.5			2.8–3.5	1.5	0.20–0.8		
C67500	675	manganese bronze		57.0–60.0	0.8–2.0	0.05–0.5				balance	0.20	0.5–1.5	
C71000	710	cupro-nickel		74.0[D]	0.60	1.00	19.0–23.0[C]			1.00	0.05		
C71500	715	cupro-nickel		65.0[D]	0.40–0.7	1.00	29.0–33.0[C]			1.00	0.05		

[A] Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.
[B] Copper plus specified elements = 99.8 min; copper plus silver = 88.5–91.5.
[C] Cobalt is to be counted as nickel.
[D] Minimum content of copper plus all other elements with specified limits shall be 99.5 %.
[E] An alloy containing as high as 2.6 % silicon is acceptable provided the sum of all the elements other than copper, silicon, and iron does not exceed 0.30 %.

TABLE 1 *Continued*

Nickel and Nickel-Base Alloys																	
UNS Designation Number	Alloy	General Name	Aluminum	Carbon, max	Chromium	Copper[A]	Iron, max	Manganese, max	Nickel[A]	Phosphorus, max	Silicon, max	Titanium	Cobalt, max	Molybdenum	Sulfur, max	Vanadium	Tungsten
N10001	335	Ni-Mo		0.05	1.0 max		4.0–6.0	1.0	balance	0.025	1.00		2.50	26.0–30.0	0.030	0.2–0.4	
N10276	276	Ni-Mo-Cr		0.02	14.5–16.5		4.0–7.0	1.00	balance	0.040	0.08		2.50	15.0–17.0	0.030	0.35 max	3.0–4.5
N04400	400	Ni-Cu Class A		0.3		balance	2.5	2.0	63.0–70.0		0.5		[B]		0.024		
N04405	405	Ni-Cu Class B		0.3		balance	2.5	2.0	63.0–70.0		0.5		[B]		0.025–0.060		
N05500	500	Ni-Cu-Al	2.30–3.15	0.25		balance	2.0	1.5	63.0–70.0		0.5	0.35–0.85	[B]		0.01		

[A] Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.
[B] Cobalt is to be counted as nickel.

TABLE 1 *Continued*

Composition, %													
Aluminum-Base Alloys[A]													
UNS Designation Number	Alloy	General Name	Aluminum[B]	Chromium	Copper	Iron, max	Manganese, max	Silicon, max	Titanium, max	Zinc, max	Magnesium	Other Elements, max	
												Each	Total
A92024	2024	Aluminum 2024	balance	0.10 max	3.8–4.9	0.50	0.30–0.9	0.50	0.15[C]	0.25	1.2–1.8	0.05	0.15
A96061	6061	Aluminum 6061	balance	0.04–0.35	0.15–0.40	0.7	0.15	0.40–0.8	0.15	0.25	0.8–1.2	0.05	0.15
A97075	7075	Aluminum 7075	balance	0.18–0.35	1.2–2.0	0.50	0.30	0.40	0.20[D]	5.1–6.1	2.1–2.9	0.05	0.15

[A] Analysis shall regularly be made only for the elements specified in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.

[B] Elements shown as balance shall be arithmetically computed by deducting the sum of the other named elements from 100.

[C] Titanium + zirconium 0.20 %, max.

[D] Titanium + zirconium 0.25 %, max.

TABLE 1 *Continued*

Titanium and Titanium-Base Alloys[A]

UNS Designation Number	Alloy	General Name	Aluminum, Al	Carbon, C	Iron, Fe	Titanium, Ti	Hydrogen, H	Nitrogen, N	Oxygen, O	Palladium, Pd	Vanadium, V	Chromium, Cr	Molybdenum, Mo	Zirconium, Zr	Tin, Sn	Silicon, Si	Ruthenium, Ru	Residuals[B]	
																		each, max	total, max
R50250	1	Titanium Gr 1		0.10	0.20	balance	0.0125	0.05	0.18									0.1	0.4
R50400	2	Titanium Gr 2		0.10	0.30	balance	0.0125	0.05	0.25									0.1	0.4
R50700	4	Titanium Gr 4		0.10	0.50	balance	0.0125	0.07	0.40									0.1	0.4
R56400	5[C]	Titanium Gr 5[C]	5.5–6.75	0.10	0.40	balance	0.0125	0.05	0.20		3.5–4.5							0.1	0.4
R56401	23	Titanium Ti-6Al-4V ELI	5.5–6.5	0.08	0.25	balance	0.0125	0.05	0.13		3.5–4.5							0.1	0.4
R52400	7	Titanium Gr 7		0.10	0.30	balance	0.0125	0.05	0.25	0.12–0.25								0.1	0.4
R58640	19	Titanium Ti-38-6-44	3.0–4.0	0.05	0.30	balance	0.0200	0.03	0.12	0.10[D]	7.5–8.5	5.5–6.5	3.5–4.5	3.5–4.5			0.10[D]	0.15	0.4
R55111	32	Titanium Ti-5-1-1-1	4.5–5.5	0.08	0.25	balance	0.0125	0.03	0.11		0.6–1.4		0.6–1.2	0.6–1.4	0.6–1.40	06–0.14		0.1	0.4

[A] All reported values are maximums, unless a range is specified.

[B] A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. Residual elements need not be reported unless a report is specifically required by the purchaser.

[C] Identical chemical requirements apply to both Class A and B as defined in Table 2 and 6.5.

[D] Ruthenium and Palladium, or both, may be added to Grade 19 for enhanced corrosion resistance as negotiated between purchaser and vendor. Chemical analysis is not required unless specifically required by the purchaser.

6. Mechanical Properties

6.1 The fasteners shall be tested in accordance with the mechanical testing requirements for the applicable type, length of product, and minimum tensile strength and shall meet the mechanical properties in Table 2 and Table 3 for the specified alloy.

6.2 Fasteners having a length equal to or longer than the "minimum length of product requiring tension testing" as specified in Test Methods F 606 and a breaking load of 120 000 lbf or less shall be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2 for the specified alloy.

6.3 Fasteners having a length equal to or longer than the "minimum length of product requiring tension testing" as specified in Test Methods F 606 and a breaking load exceeding 120 000 lbf shall preferably be tested full size and shall meet the full-size tensile (minimum and maximum) and yield strength properties in Table 2. When equipment of sufficient capacity for such tests is not available, or if excessive length of the bolts or stud makes full-size testing impractical, standard

TABLE 2 Mechanical Property Requirements

Alloy	Mechanical Property Marking	Nominal Thread Diameter, in.	Hardness[A]	Full-Size Tests[B]		Machined Specimen Tests		
				Tensile Strength, ksi	Yield Strength, min, ksi[C]	Tensile Strength, min, ksi	Yield Strength min,ksi[C]	Elongation in 4*D*, min, %[D]
Copper								
Cu 110	F 468A	all	65–90 HRF	30–50	10	30	10	15
Cu 270	F 468B	all	55–80 HRF	60–90	50	55	50	35
Cu 462	F 468C	all	65–90 HRB	50–80	25	50	25	20
Cu 464	F 468D	all	55–75 HRB	50–80	15	50	15	25
Cu 510	F 468E	all	60–95 HRB	60–90	35	55	30	15
Cu 613	F 468F	0.250–0.500	70–95 HRB	80–110	50	80	50	30
		0.625–1.500	70–95 HRB	75–105	45	75	45	30
Cu 614	F 468G	all	70–95 HRB	75–110	35	75	35	30
Cu 630	F 468H	all	85–100 HRB	100–130	50	100	50	5
Cu 642	F 468J	all	75–95 HRB	75–110	35	75	35	10
Cu 651	F 468K	0.250 to 0.750	75–95 HRB	70–100	55	70	53	8
		0.875–1.500	70–95 HRB	55–90	40	54	38	8
Cu 655	F 468L	all	60–80 HRB	50–80	20	50	15	20
Cu 661	F 468M	all	75–95 HRB	70–100	35	70	35	15
Cu 675	F 468N	all	60–90 HRB	55–85	25	55	25	20
Cu 710	F 468P	all	50–85 HRB	45–75	15	45	15	40
Cu 715	F 468R	all	60–95 HRB	55–85	20	55	20	45
Nickel								
Ni 335	F 468S	all	20–32 HRC	115–145	45	115	45	35
Ni 276	F 468T	all	20–32 HRC	110–140	45	110	45	25
Ni 400	F 468U	0.250 to 0.750	75 HRB–25 HRC	80–130	40	80	40	20
		0.875 to 1.500	60 HRB–25 HRC	70–130	30	70	30	20
Ni 400 HF[E]	F 468HF	all	60–95 HRB	70–120	30	70	30	20
Ni 405	F 468V	all	60 HRB–20 HRC	70–125	30	70	30	20
Ni 500	F 468W	0.250 to 0.875	24–37 HRC	130–180	90	130	90	20
		1.000 to 1.500	24–37 HRC	130–180	85	130	85	20
Aluminum								
Al 2024–T4[F]	F 468X	all	70–85 HRB	55–70	36	62	40	10
Al 6061–T6[F]	F 468Y	all	40–50 HRB	37–52	31	42	35	10
Al 7075–T73[F]	F 468Z	all	80–90 HRB	61–76	50	68	56	10
Titanium[G]								
Ti 1	F 468AT	all	140–160 HV	35–70	30	35	25	24
Ti 2	F 468BT	all	160–180 HV	50–85	45	50	40	20
Ti 4	F 468CT	all	200–220 HV	80–115	75	80	70	15
Ti 5 Class A[H]	F 468DT	all	30–39 HRC	130–165	125	130	120	10
Ti 5 Class B[H]	F 468HT	all	30–39 HRC	130–165	125	130	120	10
Ti 7	F 468ET	all	160–180 HV	50–85	45	50	40	20
Ti 19	F 468FT	all	24–38 HRC	115–150	115	120	115	15
Ti 23	F 468GT	all	25–36 HRC	120–165	110	120	110	10
Ti-5-1-1-1	F 468HT	all	24–38 HRC	105–150	90	100	85	10

[A] Where both tension and hardness tests are performed, the tension tests shall take precedence for acceptance purposes. For aluminum and titanium alloys, hardness tests are for information only. See 6.5.

[B] The yield and tensile strength values for full-size products shall be computed by dividing the yield and maximum tensile load by the stress area for the product diameter and thread pitch as given in table on tensile stress areas.

[C] Yield strength is the stress at which an offset of 0.2 % gage length occurs.

[D] Elongation is determined using a gage length of 4 diameters of test specimen in accordance with Test Methods E 8.

[E] "HF" denotes a hot-formed product.

[F] Aluminum alloy temper designations are in accordance with ANSI H35.1.

[G] Full-size test mechanical properties apply to fasteners with a maximum diameter of 76 mm. Mechanical properties of larger sections shall be negotiated between the material manufacturer and the fastener producer.

[H] Ti 5 Class A requires wedge tensile testing in accordance with 6.6. Ti 5 Class B requires wedge tensile testing in accordance with 6.5.1.

TABLE 3 Tensile Stress Areas and Threads per Inch

Nominal Size, in.	Coarse Threads-UNC		Fine Threads-UNF		8 Thread Series-8UN	
	Threads/ in.	Stress Area[A], in.^{2}	Threads/ in.	Stress Area[A], in.^{2}	Threads/ in.	Stress Area[A], in.^{2}
¼	20	0.0318	28	0.0364	...	...
5⁄16	18	0.0524	24	0.0580	...	...
3⁄18	16	0.0775	24	0.0878	...	...
7⁄16	14	0.1063	20	0.1187	...	...
½	13	0.1419	20	0.1599	...	...
9⁄16	12	0.1820	18	0.2030	...	...
5⁄8	11	0.2260	18	0.2560	...	...
¾	10	0.3340	16	0.3730	...	...
7⁄8	9	0.4620	14	0.5090	...	...
1	8	0.6060	12	0.6630	...	...
1 1⁄8	7	0.7630	12	0.8560	8	0.790
1 ¼	7	0.9690	12	1.0730	8	1.000
1 3⁄8	6	1.1550	12	1.3150	8	1.233
1 ½	6	1.4050	12	1.5810	8	1.492

[A] Tensile stress areas are computed using the following formula:

$$As = 0.7854\ [D - (0.9743/n)]^{2}$$

where:
As = tensile stress area, in.^{2},
D = nominal size (basic major diameter), in., and
n = number of threads per inch.

round specimens shall be used which shall meet the "machined specimen tests" tensile properties in Table 2. In the event of a discrepancy between full-size and machined specimen tension tests, full-size tests shall be used as the referee method to determine acceptance.

6.4 For all alloys except aluminum and titanium, fasteners that are too short (lengths less than that specified in Test Methods F 606 as the "minimum length of product requiring tension testing"), that have insufficient threads for tension testing (see 11.2), or that have drilled or undersized heads weaker than the thread section, are not subject to tension tests but shall conform to the minimum and maximum hardness in Table 2. Hardness tests are not applicable to aluminum and titanium alloys. When required for aluminum alloys, a shear test shall be performed in accordance with 11.2.2 and 12.2.2. Test results shall conform to the following minimum shear strength requirements: 37 ksi for 2024-T4; 25 ksi for 6061-T6; and 41 ksi for 7075-T73.

6.5 Full-size bolts and cap screws subject to tension tests shall be tested using a wedge under the head. Wedge angles shall be as follows, except for Ti5 Class B which shall use wedge angles as defined in 6.5.1. The wedge shall be 10° for bolts and cap screws of 0.750-in. nominal diameter and less, and 6° for bolts and cap screws over 0.750 in. in diameter. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 6° for sizes 0.750 in. in nominal diameter and less, and 4° for sizes over 0.750 in. in diameter.

6.5.1 Ti5 Class B wedge angles shall be 6° for bolts and cap screws of 0.750 in. nominal diameter and less, and 4° for bolts and cap screws over 0.750 in. in diameter. For bolts and cap screws threaded essentially to the head, the wedge angle shall be 4° for bolts and cap screws of 0.750 in. nominal diameter and less, and 2° for bolts and cap screws over 0.750 in. in diameter.

6.6 Where both tension and hardness tests are performed, the tension test results shall take precedence for acceptance purposes.

7. Dimensions

7.1 *Bolts and Hex Cap Screws*:

7.1.1 Unless otherwise specified, the dimensions of hex cap screws (finished hex bolts), excluding silicon bronze alloy 651, shall be in accordance with the requirements of ANSI B18.2.1.

7.1.2 Unless otherwise specified, the dimensions of silicon bronze alloy 651 hex cap screws [finished hex bolt] shall be in accordance with the requirements of ANSI B18.2.1; or, the bolts and cap screws shall have a roll thread body diameter (that is, body with minimum diameter equal to the pitch diameter), with all other dimensions in accordance with ANSI B18.2.1, as specified by the purchaser.

7.1.3 When specified, the dimensions of bolts shall be in accordance with the requirements of ANSI B18.2.1, or such other dimensions as specified.

7.2 *Studs*—The dimensions of studs shall be as specified by the purchaser. Studs shall be of the continuous thread; double-end clamping (also known as stud bolt and bolt stud); or double-end interference (also known as tap-end stud) types as specified by the purchaser.

7.3 *Threads*:

7.3.1 Unless otherwise specified, the bolts, cap screws, and studs shall have Class 2A threads in accordance with ANSI B1.1.

7.3.2 For silicon bronze alloy 651, the thread length for bolts ordered with roll thread body diameter shall conform to the following:

Bolt Length, in.	Thread Length
2.00 and less	within 2 threads of the head
Over 2.00 to 6.00, incl	2.00 in. min + 2 threads
Over 6.00	3.00 in. min + 2 threads

8. Workmanship, Finish, and Appearance

8.1 *Workmanship*—The fasteners shall have a workmanlike finish free of injurious burrs, seams, laps, irregular surfaces, and other imperfections affecting serviceability.

8.2 *Finish*—Unless otherwise specified, the fasteners shall be furnished without an additive chemical or metallic finish.

9. Sampling

9.1 A lot, for the purposes of selecting test specimens, shall consist of not more than 100 000 pieces offered for inspection at one time having the following common characteristics:

9.1.1 One type of item (that is, bolts, hex cap screws, studs, etc.),

9.1.2 Same alloy and temper,

9.1.3 One nominal diameter and thread series, and

9.1.4 One nominal length.

10. Number of Tests and Retests

10.1 *Number of Tests*—The requirements of this specification shall be met in continuous mass production for stock. The manufacturer shall make sample inspections as specified below to ensure that the product conforms to the specified requirements. When tests of individual shipments are required, Supplementary Requirement S2 shall be specified.

		Acceptance Criteria	
Number of Pieces in Lot	Number of Tests	Acceptance Number	Rejection Number
50 and under	2	0	1
51 to 500	3	0	1
501 to 35 000	5	0	1
35 001 to 100 000	8	0	1

10.2 *Retests*:

10.2.1 When tested in accordance with the required sampling plan, a lot shall be subject to rejection if any of the test specimens fails to meet the applicable test requirements.

10.2.2 If the failure of a test specimen is due to improper preparation of the specimen or to incorrect testing technique, the specimen shall be discarded and another specimen substituted.

11. Test Preparation

11.1 *Chemical Tests*—When required, samples for chemical analysis shall be taken in accordance with Practice E 55 by drilling, sawing, milling, turning, clipping, or such other methods capable of producing representative samples.

11.2 *Mechanical Tests*:

11.2.1 Machined tension specimens, when required, shall be taken in accordance with Test Methods F 606. The largest test specimen that can be machined from the bolt or stud shall be used.

11.2.2 Machined shear test specimens, when required and applicable to aluminum alloys only, shall be taken in accordance with Test Method B 565.

12. Test Methods

12.1 *Chemical Analysis*—The chemical composition may be determined by any recognized commercial test method. In the event of disagreement, the following test methods shall be used for referee purposes:

Alloy	Test Method
Copper	E 53, E 54, E 62, E 75, E 478
Aluminum	E 34, E 101, E 227
Nickel	E 38, E 76, E 354
Titanium	E 120, E 1409

12.2 *Mechanical*:

12.2.1 When full-size tests are to be performed, determine the yield strength, wedge tensile strength, and axial tensile strength, as required by Section 6, on each sample in accordance with the appropriate methods of Test Methods F 606.

12.2.2 When machined specimen tests are necessary (see Section 6), determine the yield strength, tensile strength, and elongation on each sample in accordance with Test Methods E 8; and the shear strength (applicable to aluminum alloys only) in accordance with Test Method B 565.

12.2.3 Determine the hardness in accordance with Test Methods E 18 or E 92 at mid-radius on the bottom of the threaded end after suitable preparation. Make a minimum of two readings, each of which shall conform to the specified requirements.

13. Significance of Numerical Limits

13.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or calculated value shall be rounded in accordance with Practice E 29.

14. Inspection

14.1 When specified on the inquiry or purchase order, the product shall be subject to inspection by the purchaser at the place of manufacture prior to shipment. The inspector representing the purchaser shall have controlled entry only to those parts of the manufacturer's operations that concern the manufacture of the ordered product and only when and where work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the product is being furnished in accordance with this specification. All inspections and tests shall be conducted so as not to interfere unnecessarily with the operations of the manufacturer.

15. Rejection and Rehearing

15.1 Unless otherwise specified, any rejection based on tests specified herein and made by the purchaser shall be reported to the manufacturer as soon as practical after receipt of the product by the purchaser.

16. Certification and Test Reports

16.1 *Certificate of Compliance*—When specified in the contract or purchase order, the manufacturer shall furnish certification that the product was manufactured and tested in accordance with this specification and conforms to all specified requirements.

16.2 *Test Reports*—When shipment lot testing in accordance with Supplementary Requirement S3 is specified in the contract or purchase order, the manufacturer shall furnish a test report showing the results of the mechanical tests for each lot shipped.

17. Product, Packaging and Package Marking

17.1 *Individual Fasteners*—All products shall be marked

with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking specified in Table 2. The marking shall be raised or depressed at the option of the manufacturer.

17.2 *Packaging:*

17.2.1 Unless otherwise specified packaging shall be in accordance with Practice D 3951.

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

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

17.3.1 ASTM designation,
17.3.2 Alloy number,
17.3.3 Alloy/mechanical property marking,
17.3.4 Size,
17.3.5 Name and brand or trademark of the manufacturer,
17.3.6 Number of pieces,
17.3.7 Country of origin, and
17.3.8 Purchase order number.

18. Keywords

18.1 bolts; cap screws; general use; nonferrous; studs

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Stress Corrosion Requirements

S1.1 *Copper Alloys*—Copper alloy fasteners shall exhibit no evidence of cracking after immersion for 30 min in an aqueous solution of mercurous nitrate when tested in accordance with Test Method B 154.

S1.1.1 **Caution**—Mercury is a definite health hazard and equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

S1.2 *7075-T73 Aluminum Alloy*—For aluminum alloy 7075-T73 fasteners, the resistance to stress corrosion cracking shall be established by testing the previously selected tension test specimens to the electrical conductivity-yield strength criteria listed in 12.2 of Specification B 211. When the fasteners are too short to permit tension testing, suitable lengths of the stock used to produce the fasteners shall be heat treated with the fasteners and tested to the electrical conductivity-yield strength criteria. The conductivity shall be determined in accordance with Test Method B 193.

S2. Shipment Lot Testing

S2.1 When Supplementary Requirement S2 is specified on the order (see 3.1.6), the manufacturer shall make sample tests on the individual lots for shipment to ensure that the product conforms to the specified requirements.

S2.2 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.

S2.3 The manufacturer shall perform mechanical property tests in accordance with this specification and Guide F 1470 on the individual lots for shipment.

S2.4 The manufacturer shall furnish a test report for each lot in the shipment showing the actual results of the chemical analysis and mechanical property tests performed in accordance with Supplementary Requirement S2.

S3. Dye Penetrant Inspection

S3.1 When dye penetrant inspection is specified on the purchase order, the fasteners shall be tested in accordance with Practice E 165 or other mutually acceptable procedures, and shall conform to acceptance criteria as mutually agreed upon by the purchaser and manufacturer.

S4. Heat Control (Alloys 400, 405, and 500 Only)

S4.1 When Supplementary Requirement S5 is specified on the inquiry or 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 S5 is specified on the inquiry and order, Supplementary Requirement S2 shall be considered automatically invoked with the addition that the heat analysis shall be reported to the purchaser on the test reports.