The Nuts and Bolts of Industrial Fasteners

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Fasteners have been successfully utilized in industry for many years and continue to be widely utilized today. Almost everything you touch or utilize today is held together in some manner by a fastener. Computers, printers, televisions, automobiles, lawn mowers, coffee makers, vacuum cleaners, etc. In the industrial sector, our profession, they are utilized in valves, pumps, flanges, heat exchangers, mechanical seals, hydraulic cylinders, etc. Let's explore the nuts and bolts of industrial fasteners.

The most common and widely utilized fasteners in the industrial setting are nuts, bolts, and studs. Their use is spelled out in the parts list for each piece of equipment. The parts list is usually found on the assembly drawing for the equipment. The parts list indicates the fastener type, specification, material grade, size, length, and thread quantity. The material selection depends on many factors including design and operating temperature and pressure, operating atmosphere, and strength required. Why such attention to detail when specifying the fasteners to be utilized? **The answer is simple: to avoid joint failure.** Socket head cap screws and set screws commonly found in mechanical seals are a subject for another day.

One of the most commonly referenced bolting specification is ASTM A193/A193M – 14a, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications. The M indicates SI Units or International System of Units (SI); no designation, in the US, indicates Inch-Pound Units. The 14 indicates the year of original adoption or last revision and "a" indicates subsequent revision in the same year. The most commonly referenced nut specification is ASTM A194/A 194M – 15, Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.

These specifications cover alloy steel and stainless steel bolting materials for use in valves, flanges and fittings, and pressure vessels for high temperature or high pressure service, and for special applications. Many grades are covered including ferritic stainless steels and austenitic stainless steels.

An ASTM A193, Grade B7 stud with an ASTM A194, Grade 2H Nut. The stud end is stamped B7 and the top surface of the nut is labeled 2H (raised letter and number)

Ferritic steels are high chromium, stainless steels (contain iron, magnetic), and are nickel free. They have low carbon content, and cannot be hardened or strengthened by heat treatment. Specialty grades often include molybdenum. Typically classified as 400 series.

Austenitic stainless steels contain high chromium and nickel (2% to 20%) for increased corrosion and wear resistance. Austenitic stainless steels are all non-magnetic in the annealed condition and become slightly magnetic when cold worked. Typically classified as 200 and 300 series.

Stress Relaxation High Temperature Service Limit:

Material (from BS 4882)	Temp Limit °F	Temp Limit °C
B7	752	400
B16	968	520
B8	1067	575
B8M	1112	600

Source: British Standard BS 4882: 1973

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Ferritic Steels include: Grade: B5, B6 and B6X, B7 and B7M (Chromium –Molybdenum), B16 (Chromium Molybdenum-Vanadium). The most common grade is B7. B7 is an alloy steel; AISI 4140/4142 quenched and tempered.

Austenitic Steels include: B8, B8A, B8C, B8CA, B8M, B8MA, B8M2, B8M3, B8P, B8PA, B8N, B8NA, B8MN, B8MNA, B8MLCuN, B8MLCuNA, B8T, B8TA, B8R, B8RA, B8S, B8SA, B8LN, B8LNA, B8MLN, and B8MLNA.

There are two classes, Class 1 and Class 2. Class 1 has lower tensile strength and yield strength. Class 2 has higher tensile strength and yield strength.

The most common Austenitic Steels or stainless steels are: B8 Class 1 (UNS S30400, AISI 304, carbide solution treated), B8M Class 1 (UNS31600, ANSI 316, carbide solution treated), B8 Class 2 (UNS S30400, ANSI 304, carbide solution treated and strain hardened), and B8M Class 2 (UNS S31600, ANSI 316, carbide solution treated and strain hardened).

The above nut, bolt, and stud information is very useful when working with pipe flanges and heat exchangers.

How do I determine what flange I have? How do I determine the size and pressure class of the flange?

This is fairly easy to do; survey the flange. If the flange is uninsulated, read the flange marking. The flange is typically marked with the ASTM specification and grade identification symbol, NPS or nominal pipe size and pressure class designation. The designation B16 or B16.5 shall be applied and indicates conformance to the standard; the use of the prefix ASME is optional.

An ASTM A193, Grade B16 stud with an ASTM A194, Grade 7L nut. The stud end is stamped B16 and the top surface of the nut is labeled 7L (raised letter and number). The letter "L" indicates for low temperature service (minimum impact energy absorption at test temperature).

An ASME B16.5, 4" 300# Class Flange, Material: A105

A.W. Chesterton Company Anti-Seize Compounds	
710 Copper Based Anti-Seize	K, nut factor: .20
725 Nickel Anti-Seize	K, nut factor: .18
772 Premium Nickel Anti-Seize	K, nut factor: .16
783 ACR Corrosion Resistant Anti-Seize	K, nut factor: .16
785 Parting Lubricant	K, nut factor: .17
787 Sliding Paste Anti-Seize	K, nut factor: .16

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I have determined I have ASME B16.5, 4" 300# flanges. The flanges have 8 each, 3/4" studs. The studs are ASTM A193 Grade B7; the end of the stud was stamped B7. The nuts are ASTM A194 Grade 2H; the top surface of the nut has 2H in raised letters and numbers. ASME B16.5 flanges with B7 studs and 2H nuts can handle a 60,000 psi bolt stress.

How do I determine the correct torque to apply for my flange ?

Calc. Torque (ft-lbs) = M x D x Sy x As x K x C

M = Percent of yield strength to which fasteners are to be tightened (as a decimal). (Typical: 55 - 60% of yield)

D = Nominal Diameter of Bolt or Stud in inches

Sy = Yield Strength of Bolt Material, psi (See Table on Page 4)

As = Tensile Stress Area of Threads in inch^2 For 3/4" - 10 UNC, As = .334 inch^2 (see table below)

K = Nut Factor From 772 Premium Nickel Anti-seize Product Data Sheet, K = .16

C = Conversion Factor (inch-lbs to ft-lbs), 0.0833

Torque 210 ft-lbs = (.60) x (.750") x (105,000 psi) x (0.334) x (.16) x (0.0833)

Which nut do I use ?
ASTM A193, Grade B7 - Use ASTM A194, Grade 2H, 4,7, or 8
ASTM A193, Grade B8, CL 1 - Use ASTM A194, Grade 8
ASTM A193, Grade B8, CL 2 - Use ASTM A194, Grade 8
ASTM A193, Grade B16 - Use ASTM A 194, Grade 4, 7, or 8
Above are the most popular A193 material grades. Contact MP Application Engineering if you have a different grade.

Picture of a heavy hex nut. The left side shows the bottom flat surface of the nut which will contact the flat washer surface. The right side shows the top surface of the nut and identifies it as an ASTM A194 Grade 2H nut.

Tensile Stress Area (As)

Thread	Series	As in.^{2}
1/4 - 20	UNC	0.0318
5/16 - 18	UNC	0.0524
3/8 - 16	UNC	0.0775
7/16 - 14	UNC	0.1063
1/2 - 13	UNC	0.1419
9/16 - 12	UNC	0.182
5/8 - 11	UNC	0.226
3/4 - 10	UNC	0.334
7/8 - 9	UNC	0.462
1 - 8	UNC	0.606
1-1/8 - 8	UN	0.790
1-1/4 - 8	UN	1.000
1-3/8 - 8	UN	1.233
1-1/2 - 8	UN	1.492
1-5/8 - 8	UN	1.78
1-3/4 - 8	UN	2.08
1-7/8 - 8	UN	2.41
2 - 8	UN	2.77
2-1/4 - 8	UN	3.56
2-1/2 - 8	UN	4.44
2-3/4 - 8	UN	5.43

Mechanical Requirements, Inch Products

Ferritic Steels

Grade	Description	UNS Designation	Diameter, inch	Tensile Strength, min	Yield Strength, min, 0.2% offset
B5	5% Chromium		up to 4, incl	100,000 psi	80,000 psi
B6	12% Chromium	S41000 (410)	up to 4, incl	110,000 psi	85,000 psi
B6X	12% Chromium	S41000 (410)	up to 4, incl	90,000 psi	70,000 psi
B7	Chromium-Molybdenum	*	2-1/2 and under	125,000 psi	105,000 psi
B7	Chromium-Molybdenum	*	over 2-1/2 to 4	115,000 psi	95,000 psi
B7	Chromium-Molybdenum	*	over 4 to 7	100,000 psi	75,000 psi
B7M	Chromium-Molybdenum	*	4 and under	100,000 psi	80,000 psi
B7M	Chromium-Molybdenum	*	over 4 to 7	100,000 psi	75,000 psi
B16	Chromium- Molybdenum-Vanadium		2-1/2 and under	125,000 psi	105,000 psi
B16	Chromium- Molybdenum-Vanadium		over 2-1/2 to 4	110,000 psi	95,000 psi
B16	Chromium- Molybdenum-Vanadium		over 4 to 8	100,000 psi	85,000 psi

* Typical steel compositions for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H

Austenitic Steels, Classes 1, 1A, 1D, and 2

Grade	Heat Treatment	UNS Designation	Diameter, inch	Tensile Strength, min	Yield Strength, min, 0.2% offset
B8 Class 1 & 1D	Carbide solution treated	S30400 (304)	all diameters	75,000 psi	30,000 psi
B8M Class 1 & 1D	Carbide solution treated	S31600 (316)	all diameters	75,000 psi	30,000 psi
B8 Class 2	Carbide solution treated and strain hardened	S30400 (304)	¾ and under	125,000 psi	100,000 psi
B8 Class 2	"	S30400 (304)	over ¾ to 1, incl	115,000 psi	80,000 psi
B8 Class 2	"	S30400 (304)	over 1 to 1-1/4, incl	105,000 psi	65,000 psi
B8 Class 2	"	S30400 (304)	over 1-1/4 to 1-1/2, incl	100,000 psi	50,000 psi
B8M Class 2	"	S31600 (316)	¾ and under	110,000 psi	95,000 psi
B8M Class 2	"	S31600 (316)	over ¾ to 1, incl	100,000 psi	80,000 psi
B8M Class 2	"	S31600 (316)	over 1 to 1-1/4, incl	95,000 psi	65,000 psi
B8M Class 2	"	S31600 (316)	over 1-1/4 to 1-1/2, incl	90,000 psi	50,000 psi

Note: There are many other grades of Austenitic Steel materials available; too many to list here.
Refer to ASTM A 193/A 19M Specification for grades not listed above.

Mechanical Requirements, Metric Products

Ferritic Steels

Grade	Description	UNS Designation	Diameter, inch	Tensile Strength, min	Yield Strength, min, 0.2% offset
B5	5% Chromium		up to M100, incl	690 MPa	550 MPa
B6	12% Chromium	S41000 (410)	up to M100, incl	760 MPa	585 MPa
B6X	12% Chromium	S41000 (410)	up to M100, incl	620 MPa	485 MPa
B7	Chromium-Molybdenum	*	M64 and under	860 MPa	720 MPa
B7	Chromium-Molybdenum	*	over M64 to M100	795 MPa	655 MPa
B7	Chromium-Molybdenum	*	over M100 to M180	690 MPa	515 MPa
B7M	Chromium-Molybdenum	*	M100 and under	690 MPa	550 MPa
B7M	Chromium-Molybdenum	*	over M100 to M180	690 MPa	515 MPa
B16	Chromium- Molybdenum-Vanadium		M64 and under	860 MPa	725 MPa
B16	Chromium- Molybdenum-Vanadium		over M64 to M100	760 MPa	655 MPa
B16	Chromium- Molybdenum-Vanadium		over M100 to M180	690 MPa	585 MPa

* Typical steel compositions for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H

Austenitic Steels, Classes 1, 1A, 1D, and 2

Grade	Heat Treatment	UNS Designation	Diameter, inch	Tensile Strength, min	Yield Strength, min, 0.2% offset
B8 Class 1 & 1D	Carbide solution treated	S30400 (304)	all diameters	515 MPa	205 MPa
B8M Class 1 & 1D	Carbide solution treated	S31600 (316)	all diameters	515 MPa	205 MPa
B8 Class 2	Carbide solution treated and strain hardened	S30400 (304)	M20 and under	860 MPa	690 MPa
B8 Class 2	"	S30400 (304)	over M20 to M24, incl	795 MPa	550 MPa
B8 Class 2	"	S30400 (304)	over M24 to M30, incl	725 MPa	450 MPa
B8 Class 2	"	S30400 (304)	over M30 to M36, incl	690 MPa	345 MPa
B8M Class 2	"	S31600 (316)	M20 and under	760 MPa	655 MPa
B8M Class 2	"	S31600 (316)	over M20 to M24, incl	690 MPa	550 MPa
B8M Class 2	"	S31600 (316)	over M24 to M30, incl	655 MPa	450 MPa
B8M Class 2	"	S31600 (316)	over M30 to M36, incl	620 MPa	345 MPa

Note: There are many other grades of Austenitic Steel materials available, however too numerous to list here.
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Metric Page 3

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How do I determine the correct torque to apply for my flange ?

Calc. Torque (Nm) = [M x D x Sy x As x K] / C

M = Percent of yield strength to which fasteners are to be tightened (as a decimal). (Typical: 55 - 60% of yield)

D = Nominal Diameter of Bolt or Stud in millimeters

Sy = Yield Strength of Bolt Material, MPa (See Table on Page 4)

As = Tensile Stress Area of Threads in mm^2 For 3/4” - 10 UNC, As = .216 mm^2 (see table below)

K = Nut Factor From 772 Premium Nickel Anti-seize Product Data Sheet, K = .16

C = Conversion Factor (mm to meter), 1000

Torque 284 Nm = [(.60) x (19.05mm) x (720 MPa) x (216) x (.16)] / (1000)

Tensile Stress Area (As)			Tensile Stress Area (As)		
Thread	**Series**	**As (mm^2)**	**Thread**	**Series**	**As (mm^2)**
1/4” - 20	UNC	20.5	1-1/4” - 8	UN	645
5/16” - 18	UNC	33.8	1-3/8” - 8	UN	796
3/8” - 16	UNC	50.0	1-1/2” - 8	UN	963
7/16” - 14	UNC	68.6	1-5/8” - 8	UN	1148
1/2” - 13	UNC	92	1-3/4” - 8	UN	1342
9/16” - 12	UNC	117	1-7/8” - 8	UN	1555
5/8” - 11	UNC	146	2” - 8	UN	1787
3/4” - 10	UNC	216	2-1/4” - 8	UN	2297
7/8” - 9	UNC	298	2-1/2” - 8	UN	2865
1” - 8	UNC	391	2-3/4” - 8	UN	3503
1-1/8” - 8	UN	510			

A.W. Chesterton Company Anti-Seize Compounds

Product	K, nut factor	Temperature Limit
710 Copper Based Anti-Seize	K, nut factor: .20	up to 1100°C (2000°F)
725 Nickel Anti-Seize	K, nut factor: .18	up to 1425°C (2600°F)
772 Premium Nickel Anti-Seize	K, nut factor: .16	up to 1425°C (2600°F)
783 ACR Corrosion Resistant Anti-Seize	K, nut factor: .16	-34 to 900°C (-30 to 1650°F)
785 Parting Lubricant	K, nut factor: .17	-34 to 1204°C (-30 to 2200°F)
787 Sliding Paste Anti-Seize	K, nut factor: .16	up to 538°C (1000°F)