

1.7 STANDARD MANUFACTURING REFERENCES

1.7.1 Mechanical Fasteners

Mechanical fasteners, such as bolts and nuts, are manufactured from many different materials with significantly different fastener strength. Two fastener materials used by Solar Turbines are carbon steel and stainless steel.

The most common types of bolt used at Solar Turbines is carbon steel, often called Zinc or Zinc-Dichromate (Gold) because of their Zinc-based corrosion resistant coatings. Steel bolts are manufactured in three common strength ranges: Grade 2, Grade 5, and Grade 8. Grade 2 bolts and studs are not used at Solar Turbines.

Stainless steel bolts are alloyed with chromium to make them more corrosion resistant. Chromium and other alloying elements increases corrosion resistance but reduce strength which prevents most stainless steel bolts from being used as direct replacements for zinc-coated carbon steel bolts. Torque values for stainless steel bolts are usually lower than those for zinc bolts and must be read from the appropriate torque tables.

While many bolts look nearly identical, their strengths vary significantly. It is important to know how to identify the bolt types used at Solar Turbines to ensure the correct bolt is used for a particular application.

1.7.2 Head Markings

Bolts are identified by head marking, which consist of letters, numbers, radial lines, or a combination of all three. Grade levels of studs are stamped on one end of the stud. The following describe specific carbon steel and stainless steel bolt head markings and bolt applications.

CARBON STEEL BOLTS

Carbon steel bolts are commonly identified by radial lines on the bolt heads. Carbon steel-alloy bolts may be identified by a combination of letters and numbers on the bolt heads.

Grade 5 Carbon Steel Bolt

Grade 5 carbon steel bolts (Figure [1.7.1](#)) are identified by three radial lines on the head and are acceptable for most structural applications.

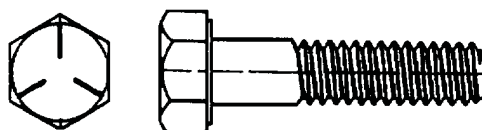


Figure 1.7.1 Grade 5 Carbon Steel Bolt

Grade B7 Carbon Steel Bolt/Stud

Grade B7 carbon steel bolts/studs (Figure [1.7.2](#)) are identified by B7 on the head and are used in pressure and temperature applications.

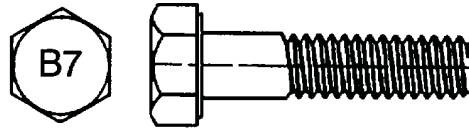


Figure 1.7.2 Grade B7 Carbon Steel Bolt/Stud

Grade B7M Steel Bolt/Stud

Grade B7M steel bolts/studs (Figure [1.7.3](#)) are identified by B7M on the head and are used in National Association of Corrosion Engineers (NACE) (sour-gas) pressure and temperature applications.

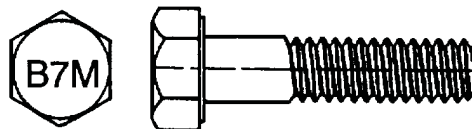


Figure 1.7.3 Grade B7M Steel Bolt/Stud

Grade 8 Carbon Steel Bolt

Grade 8 carbon steel bolts (Figure [1.7.4](#)) are identified by six radial lines on the head and are used in applications that demand extra strength.

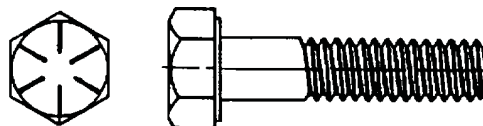


Figure 1.7.4 Grade 8 Steel Bolt

STAINLESS STEEL BOLTS

Stainless steel bolts are commonly identified by letters and numbers on the bolt heads.

Grade B6 Stainless Steel Bolt

Grade B6 stainless steel bolts (Figure [1.7.5](#)) are identified by B6 on the head and are used in temperature and pressure applications.

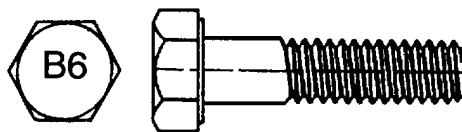


Figure 1.7.5 Grade B6 Stainless Steel Bolt

Grade B8 Stainless Steel Bolt

Grade B8 stainless steel bolts (Figure [1.7.6](#)) are identified by B8 on the head and are used in pressure and temperature applications.

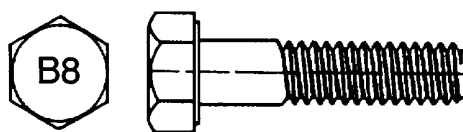


Figure 1.7.6 Grade B8 Stainless Steel Bolt

Grade B8M (Type 316) Stainless Steel Bolt/Stud

Grade B8M (Type 316) stainless steel bolts/studs (Figure [1.7.7](#)) are identified by B8M on the head and are used in NACE (sour-gas) or non-NACE pressure and temperature applications.

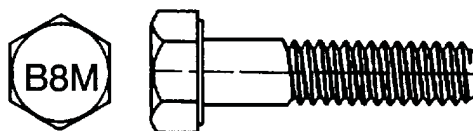


Figure 1.7.7 Grade B8M Stainless Steel Bolt/Stud

Grade 17-4PH, 17-4N, B8M, and B8M2 Stainless Steel Bolts/Studs

Grade 17-4PH stainless steel bolts/studs (Figure [1.7.8](#)) are identified by 17-4 on the head and are used in pressure and temperature applications. Grade 17-4PH steel bolts and studs are a direct replacement for SAE Grade 5 carbon steel bolts and studs.

Bolts identified by 17-4N (Figure [1.7.8](#)) on the head are used in NACE pressure and temperature applications, and are a direct replacement for SAE Grade 5 carbon steel bolts.

Bolts identified by B8M or B8M2 (Figure [1.7.8](#)) on the head are similar to B8M (Type 316) stainless steel bolts except B8M or B8M2 bolts are stronger.

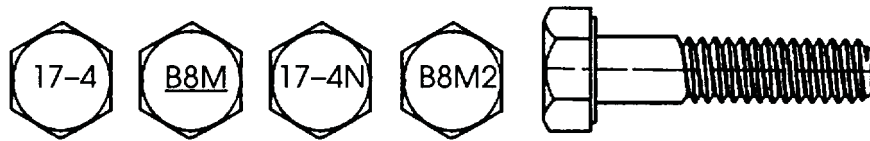


Figure 1.7.8 Grade 17-4PH Steel Bolt/Stud

WELD STUDS

Weld studs (Figure 1.7.9) have no head. They are welded directly to the base.

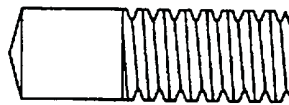
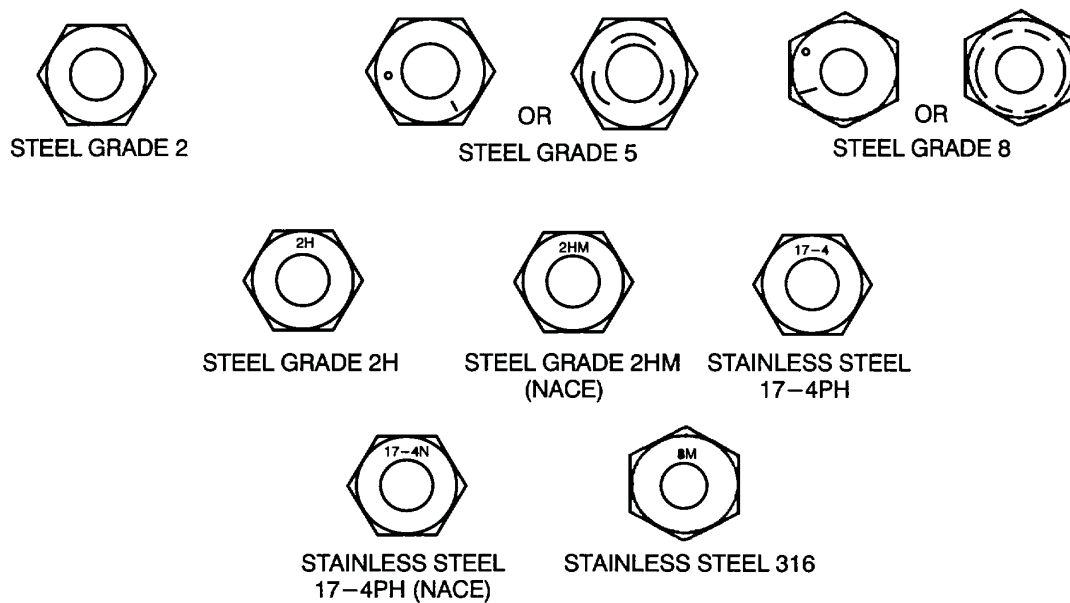


Figure 1.7.9 Weld Stud

1.7.3 Hex Nuts

Hex nuts are manufactured from materials with significant strength differences. Hex nut materials and their response to heat treatment influence fastener strength significantly.

Hex nuts should be selected for material strength comparable to that of the mating bolts. A Grade 5 steel bolt, for example, should be mated with at least a Grade 5 steel nut. It is permissible to substitute stronger fasteners, such as a Grade 8 steel nut on a Grade 5 steel bolt, although the torque applied is limited to the torque specified for the weaker fastener in the joint. Hex nuts are identified by their head markings. See Figure 1.7.10 for hex nut head markings.

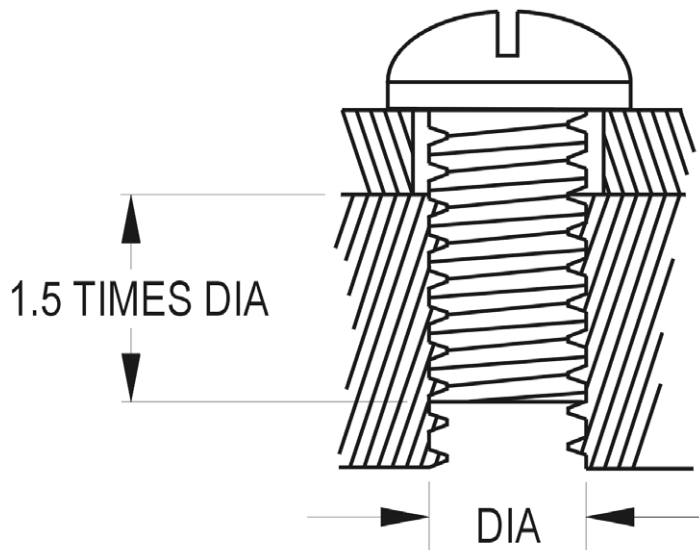


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Figure 1.7.10 Hex Nut Head Markings

1.7.4 Thread Engagement

Steel, stainless steel, brass, and aluminum fasteners require thread engagement of at least one and one-half times the diameter of the fastener (Figure [1.7.11](#)).



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Figure 1.7.11 Metal Fastener Thread Engagement

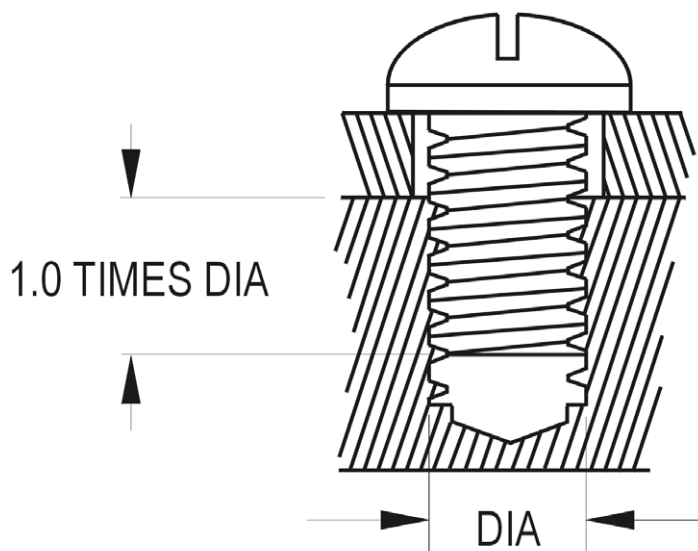
Nonmetals, such as plastics, require thread engagement of at least the diameter of the fastener or three threads, whichever is greater (Figure [1.7.12](#)).

Self-locking nuts must have at least three complete threads extending through the nut.

NOTE

Self-locking nuts are to be installed one time only. Once the assembly has been disassembled, discard locknuts and replace with new ones. Locknuts with nylon inserts are limited to 250°F (121°C).

Fasteners secured with lockwashers are torqued according to the fasteners' grade and size.



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Figure 1.7.12 Nonmetal Fastener Thread Engagement

1.7.5 Thread Lubricants

Thread lubricants and anti-seize compounds are used to facilitate proper installation and future removal of bolts. The relationship between applied torque and the resulting clamp load is dramatically affected by lubrication.



CAUTION

Failure to lubricate threads can result in improper torque, substandard assembly, and seizure (cold welding) of bolts.

NOTE

All bolts 1/2 in. (12.7 mm) in diameter and larger must be lubricated per Solar Engineering Specification ES 9-54. Do not lubricate bolts smaller than 1/2 in. (12.7 mm) in diameter.

Acceptable thread lubricants for bolts and nuts and other threaded fasteners are listed in Table [1.7.1](#).

Table 1.7.1 Thread Lubricants

Name	Solar Part Number	Operating Temperature
Fel-Pro Nickel Anti-Seize Lubricant	917427C1	-95°F to 2400°F (-70.6°C to 1315.6°C)
Dow Corning 321 Dry Film Lubricant Spray	980376C1	-325°F to 600°F (-198°C to 315.6°C)
Fougera White Petrolatum	915793C1	Benign (not extreme) Temperatures Only

1.7.6 Critical Torque Areas and Assembly Hardware

Critical torque areas are identified as areas where fastener failure could cause harm to a system or operator. Fasteners used in critical torque areas are identified as assembly hardware. All assembly hardware is to be torqued to specifications with a torque wrench. The following indicates critical torque areas where assembly hardware must be used:

- Trunnions and engine mounts
- Pressure vessels, such as oil and fuel filters
- Driver and driven interfaces, such as couplings and guards
- Major components, such as start motor and all pumps and motors
- All vendor-supplied driven equipment, such as frame interface hardware, interface pipe assembly, hold-down hardware.
- All pipe assembly flanges, ASME/ANSI flanges, SAE/Caterpillar 4-bolt flanges
- Lubricating oil tank lids and other components with sealing surfaces
- Air inlet and exhaust collector ducting
- All base-to-base structural interfaces, all baseplate lifting members

1.7.7 Noncritical Torque Areas and Attaching Hardware

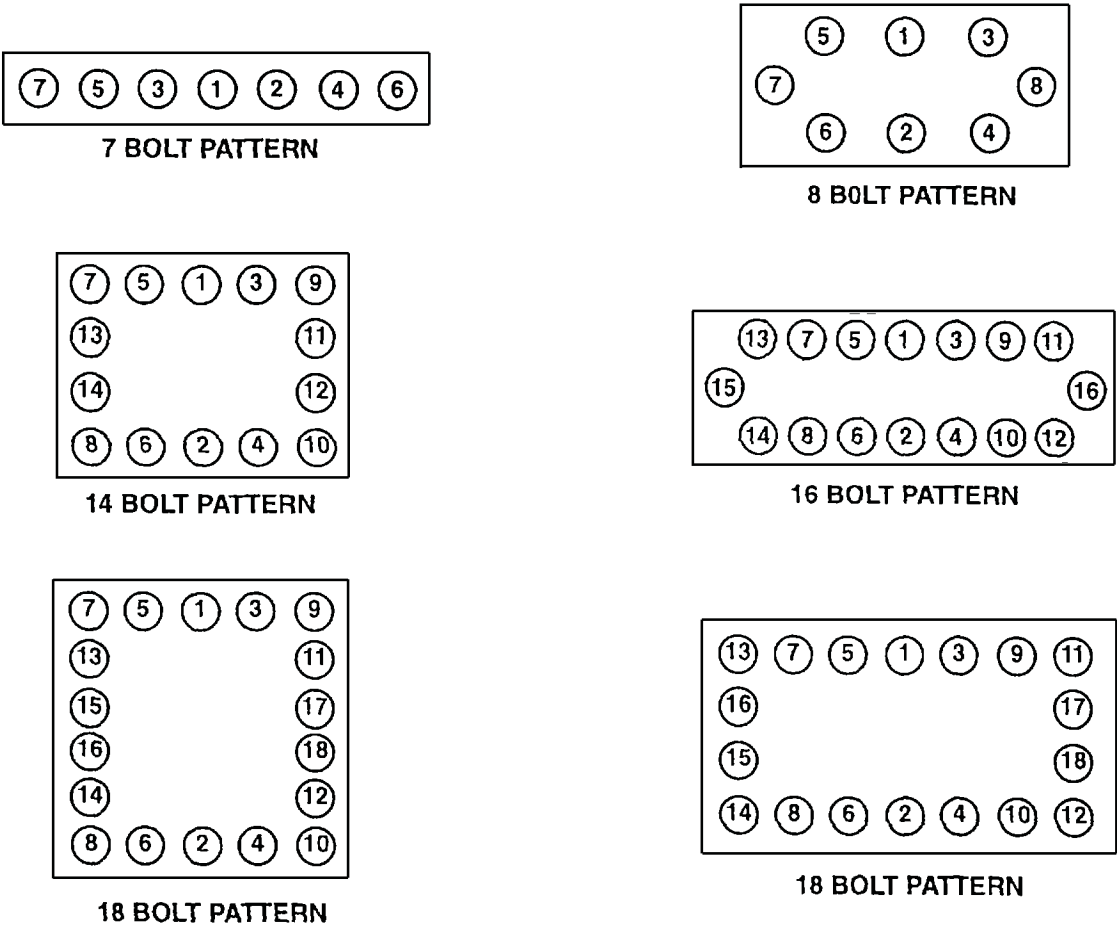
Noncritical torque areas are identified as areas where fasteners are used in noncritical applications and are nonstructural in their design intent. Fasteners used in noncritical torque areas are identified as attaching hardware. Attaching hardware, as a rule, must be firmly secured and wrench tight. The following indicates noncritical torque areas and applications where attaching hardware may be used:

- Mounting unistrut for conduit, tubing, and manifolds

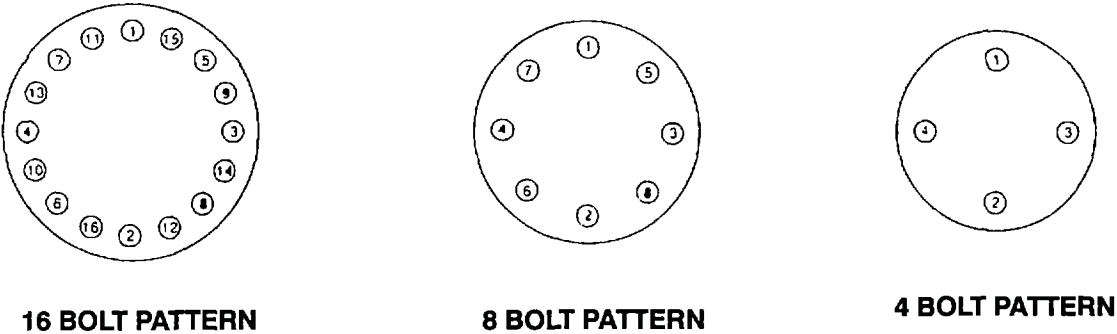
- Mounting hardware for functional components such as switches, transmitters, gages, and solenoids
- The use of spring nuts
- Fine threaded or miniature fasteners, as used in control boxes
- Cushion clamps
- Serviceable hardware, that is, hardware that has to be removed to service or replace package components for maintenance in the field

1.7.8 Torque Sequences for Bolt Patterns

If one or more screws, bolts, or nuts of a series are tightened, as in a series of bolts around a flange or a half-shell, all of that series must be tightened equally to prevent distortion, damage, or leakage. See Figure [1.7.13](#) for torque sequences for bolt patterns.



Round /ANSI Flange Patterns



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Figure 1.7.13 Torque Sequences for Bolt Patterns

1.7.9 Torque Sequences for Split Flange Clamps

See Figure 1.7.14 for torque sequences for low/high pressure, SAE 4-bolt, centerline split flanges. See Figure 1.7.15 for torque sequences for high pressure XT-5/6 4-bolt diagonal split flanges. Use SAE Steel Grade 8 or higher carbon steel bolts or Grade 17-4PH stainless steel bolts with according lengths and sizes on all 4-bolt, split-flange clamps. Refer to QAS 821 for hardware information.

NOTE

The maximum gap permitted after final tightening is cumulative, that is, 0.08 in. (2 mm) each side or 0.16 in. (4 mm) on one side with zero on opposite side or any combination equaling the 0.16 in. (4 mm) maximum gap.

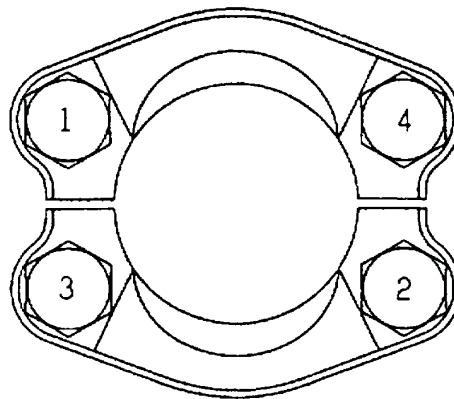


Figure 1.7.14 Torque Sequence for 4-Bolt Centerline Split Flange

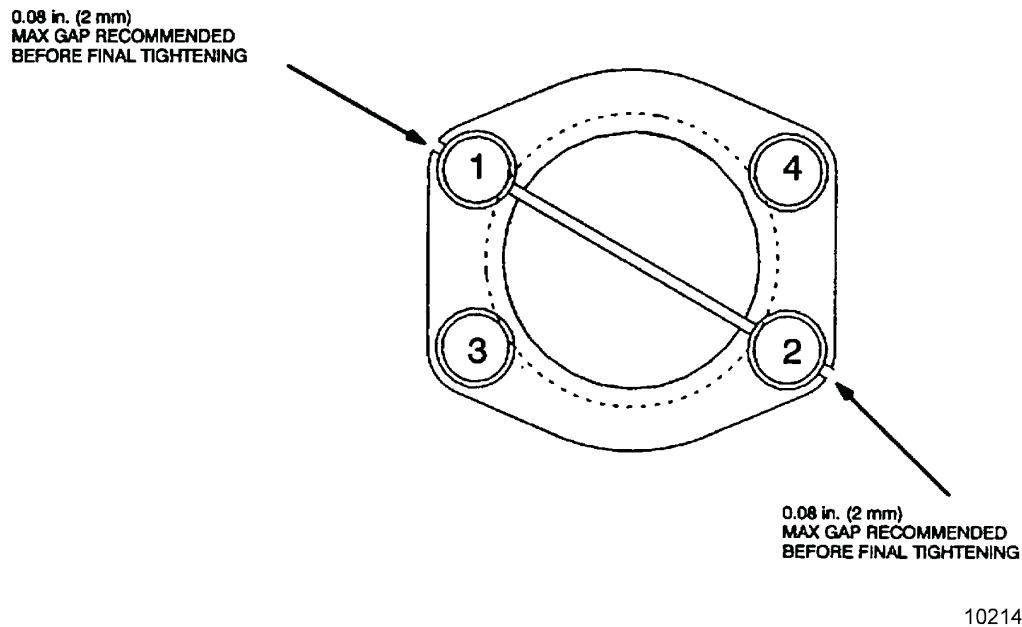
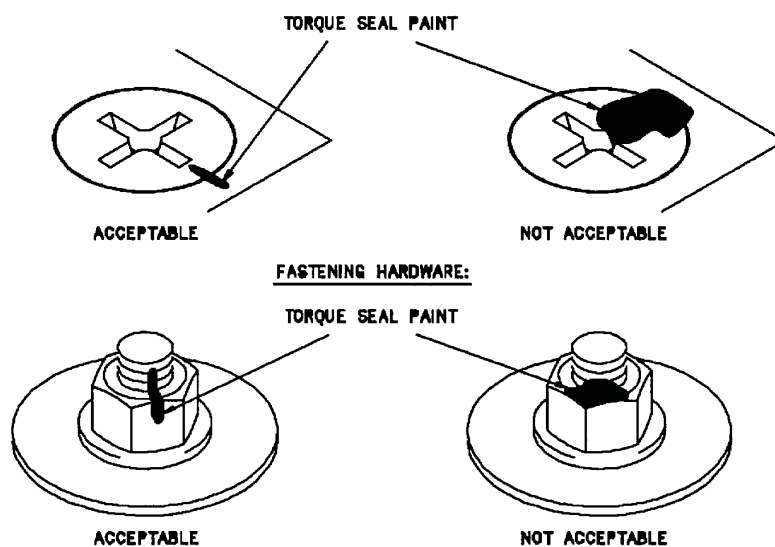


Figure 1.7.15 Torque Sequence for 4-Bolt Diagonal Split Flange

1.7.10 Torque Paint

Torque paint shall be applied such that breaks or unsealing may be readily identified. When torque paint is applied for the second time, all evidence of the first application must be removed. See Figure [1.7.16](#) for examples of torque paint acceptance standards.



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Figure 1.7.16 Torque Seal Paint Acceptance Standards

1.7.11 Torque Values



CAUTION

Use standard torque values only when torque values are not specified for an application.

When tightening any screws, bolts, or nuts during inspection or during parts replacement or repair, tighten the item to the applicable torque listed in the following tables.

NOTE

Values in torque tables are based on bolts with thread sizes greater than or equal to 1/2 in. (12.7 mm) in diameter being lubricated with lubricants listed in Table [1.7.1](#). Bolts less than 1/2 in. (12.7 mm) in diameter are not to be lubricated.

Values in torque tables are given for UNF (Unified National Fine) and UNC (Unified National Coarse) bolt threads.

If one or more screw, bolt, or nut of a series is tightened, as in a series of bolts around a flange or a half-shell, all of that series must be tightened equally to prevent distortion, damage, or leakage.

INLET AND EXHAUST DUCTS

Torque values for inlet duct assembly hardware are 600 to 660 in-lb (68 to 75 N·m) or 50 to 55 ft-lb (68 to 75 N·m). Torque values for exhaust duct assembly hardware are 696 to 960 in-lb (79 to 109 N·m) or 58 to 80 ft-lb (79 to 109 N·m). Torque values apply to ducts in any orientation.

NOTE

A properly tightened fastener must be within ± 5 percent of the prescribed or calculated torque value.

Torque values noted on mechanical installation drawing shall take precedence over torque values in this section, QAS 821, and ES 9-54.

All bolts 1/2 in. (12.7 mm) in diameter and larger must be lubricated per ES 9-54. Do not lubricate bolts smaller than 1/2 in. (12.7 mm) in diameter.

GRADE 5 CARBON STEEL BOLTS

Table 1.7.2 provides torque values for Society of Automotive Engineers (SAE) Specification J429, Grade 5 carbon steel bolts.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.2 Torque Values for Grade 5 Carbon Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	133 (15)	-	1/4-20	121 (14)	-
5/16-24	237 (27)	-	5/16-18	222 (25)	-
3/8-24	414 (47)	35 (47)	3/8-16	384 (43)	32 (43)
7/16-20	647 (73)	54 (73)	7/16-14	605 (68)	50 (68)
1/2-20	655 (74)	55 (74)	1/2-13	629 (71)	52 (71)
9/16-18	960 (109)	80 (109)	9/16-12	924 (104)	77 (104)
5/8-18	1340 (151)	112 (151)	5/8-11	1283 (145)	107 (145)
3/4-16	2325 (263)	194 (263)	3/4-10	2240 (253)	187 (253)
7/8-14	3696 (418)	308 (418)	7/8-9	3577 (404)	298 (404)
1-12	5042 (570)	420 (570)	1-8	4880 (551)	407 (551)
1 1/8 - 12	7226 (816)	602 (816)	1 1/8 - 7	6939 (784)	578 (784)

Table 1.7.2 Torque Values for Grade 5 Carbon Steel Bolts, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1 1/4 - 12	9960 (1125)	830 (1125)	1 1/4 - 7	9622 (1087)	802 (1087)
1 3/8 - 12	13 306 (1503)	1109 (1503)	1 3/8 - 6	12 733 (1439)	1061(1439)
1 1/2 - 12	17 330 (1958)	1444 (1958)	1 1/2 - 6	16 674 (1884)	1390 (1884)

GRADE B7 NICKEL-PLATED STEEL BOLTS/STUDS

Table 1.7.3 provides torque values for American Society for Testing Materials (ASTM) Specification A193, Grade B7 (Nickel-Plated) steel bolts/studs.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.3 Torque Values for Grade B7 Nickel-Plated Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4 - 28	253 (29)	21 (29)	1/4 - 20	225 (25)	-
5/16 - 24	488 (55)	41 (55)	5/16 - 18	448 (51)	37 (51)
3/8 - 24	862 (97)	72 (97)	3/8 - 16	776 (88)	65 (88)
7/16 - 20	1343 (152)	112 (152)	7/16 - 14	1225 (138)	102 (138)
1/2 - 20	826 (93)	69 (93)	1/2 - 13	786 (89)	66 (89)
9/16 - 18	1165 (132)	97 (132)	9/16 - 12	1115 (126)	93 (126)
5/8 - 18	1628 (184)	136 (184)	5/8 - 11	1549 (175)	129 (175)
3/4 - 16	2825 (319)	235 (319)	3/4 - 10	2709 (306)	226 (306)
7/8 - 14	4492 (507)	374 (507)	7/8 - 9	4327 (489)	361 (489)
1 - 12	6699 (757)	558 (757)	1 - 8	6473 (731)	539 (731)
1 1/8 - 12	9604 (1085)	800 (1085)	1 1/8 - 7	9203 (1040)	767 (1040)
1 1/4 - 12	13 242 (1496)	1104 (1496)	1 1/4 - 7	12 786 (1445)	1066 (1445)
1 3/8 - 12	17 696 (1999)	1475 (1999)	1 3/8 - 6	16 892 (1909)	1408 (1909)
1 1/2 - 12	23 053 (2605)	1921 (2605)	1 1/2 - 6	22 128 (2500)	1844 (2500)
1 3/4 - 12	36 327 (4104)	3027 (4104)	1 3/4 - 5	35 050 (3960)	2921 (3960)
2 - 12	55 127 (6228)	4594 (6228)	2 - 4 1/2	52 470 (5928)	4373 (5928)

Table 1.7.3 Torque Values for Grade B7 Nickel-Plated Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
2 1/4 - 12	78 705 (8892)	6559 (8892)	2 1/4 - 4 1/2	75 481 (8528)	6290 (8528)
2 1/2 - 12	108 188 (12 223)	9016 (12 223)	2 1/2 - 4	103 447 (11 687)	8621 (11 687)

GRADE B7 ZINC-PLATED STEEL BOLTS/STUDS

Table 1.7.4 provides torque values for ASTM Specification A193, Grade B7 (Zinc-Plated) zinc-plated steel bolts/studs.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.4 Torque Values for Grade B7 Zinc-Plated Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	163 (18)	-	1/4-20	149 (17)	-
5/16-24	315 (36)	26 (36)	5/16-18	294 (33)	25 (33)
3/8-24	553 (63)	46 (63)	3/8-16	508 (57)	42 (57)
7/16-20	863 (98)	72 (98)	7/16-14	800 (90)	67 (90)
1/2-20	894 (101)	75 (101)	1/2-13	846 (96)	71 (96)
9/16-18	1082 (122)	90 (122)	9/16-12	1042 (118)	87 (118)
5/8-18	1510 (171)	126 (171)	5/8-11	1447 (164)	121 (164)
3/4-16	2619 (296)	218 (296)	3/4-10	2527 (286)	211 (286)
7/8-14	4163 (470)	347 (470)	7/8-9	4034 (456)	336 (456)
1-12	5152 (582)	429 (582)	1-8	5078 (574)	423 (574)
1 1/8 - 12	7351 (831)	613 (831)	1 1/8 - 7	7225 (816)	602 (816)
1 1/4 - 12	10 096 (1141)	841 (1141)	1 1/4 - 7	9667 (1092)	806 (1092)
1 3/8 - 12	13 448 (1519)	1121 (1519)	1 3/8 - 6	13 228 (1495)	1102 (1495)
1 1/2 - 12	17 470 (1974)	1456 (1974)	1 1/2 - 6	17 249 (1949)	1437 (1949)
1 3/4 - 12	27 417 (3098)	2285 (3098)	1 3/4 - 5	27 361 (3091)	2280 (3091)
2 - 12	41 447 (4683)	3454 (4683)	2 - 4 1/2	40 899 (4621)	3408 (4621)
2 1/4 - 12	59 013 (6667)	4918 (6667)	2 1/4-4 1/2	58 494 (6609)	4875 (6609)
2 1/2 - 12	80 940 (9145)	6745 (9145)	2 1/2 - 4	80 213 (9063)	6684 (9063)

GRADE B7M STEEL BOLTS/STUDS

Table 1.7.5 provides torque values for ASTM Specification A193, Grade B7M, steel bolts/studs.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.5 Torque Values for Grade B7M Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	108 (12)	-	1/4-20	99 (11)	-
5/16-24	208 (23)	-	5/16-18	195 (22)	-
3/8-24	363 (41)	30 (41)	3/8-16	336 (38)	28 (38)
7/16-20	567 (64)	47 (64)	7/16-14	530 (60)	44 (60)
1/2-20	629 (71)	52 (71)	1/2-13	599 (68)	50 (68)
9/16-18	888 (100)	74 (100)	9/16-12	850 (96)	71 (96)
5/8-18	1240 (140)	103 (140)	5/8-11	1180 (133)	98 (133)
3/4-16	2152 (243)	179 (243)	3/4-10	2064 (233)	172 (233)
7/8-14	3422 (387)	285 (387)	7/8-9	3297 (373)	275 (373)
1-12	5104 (577)	425 (577)	1-8	4932 (557)	411 (557)
1 1/8 - 12	7317 (827)	610 (827)	1 1/8 - 7	7012 (792)	584 (792)
1 1/4 - 12	10 089 (1140)	841 (1140)	1 1/4 - 7	9728 (1099)	811 (1099)
1 3/8 - 12	13 483 (1523)	1124 (1523)	1 3/8 - 6	12 870 (1454)	1073 (1454)
1 1/2 - 12	17 564 (1984)	1464 (1984)	1 1/2 - 6	16 860 (1905)	1405 (1905)
1 3/4 - 12	27 678 (3127)	2307 (3127)	1 3/4 - 5	26 705 (3017)	2225 (3017)
2 - 12	42 001 (4745)	3500 (4745)	2 - 4 1/2	39 977 (4517)	3331 (4517)
2 1/4 - 12	59 966 (6775)	4997 (6775)	2 1/4-4 1/2	57 510 (6498)	4793 (6498)
2 1/2 - 12	82 429 (9313)	6869 (9313)	2 1/2 - 4	78 817 (8905)	6568 (8905)

GRADE 8 STEEL BOLTS

Table 1.7.6 provides torque values for SAE Specification J429, Grade 8, steel bolts.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.6 Torque Values for Grade 8 Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	232 (26)	-	1/4-20	210 (24)	18 (24)
5/16-24	407 (46)	34 (46)	5/16-18	416 (47)	35 (47)
3/8-24	715 (81)	60 (81)	3/8-16	654 (74)	55 (74)
7/16-20	1114 (126)	93 (126)	7/16-14	1032 (117)	86 (117)
1/2-20	950 (107)	79 (107)	1/2-13	910 (103)	76 (103)
9/16-18	1374 (155)	115 (155)	9/16-12	1320 (149)	110 (149)
5/8-18	1918 (217)	160 (217)	5/8-11	1834 (207)	153 (207)
3/4-16	3327 (376)	277 (376)	3/4-10	3203 (362)	267 (362)
7/8-14	5290 (598)	441 (598)	7/8-9	5115 (578)	426 (578)
1-12	8193 (926)	683 (926)	1-8	7924 (895)	660 (895)
1 1/8 - 12	11 744 (1327)	979 (1327)	1 1/8 - 7	11 265 (1273)	939 (1273)
1 1/4 - 12	16 190 (1829)	1349 (1829)	1 1/4 - 7	15 625 (1765)	1302 (1765)
1 3/8 - 12	21 633 (2444)	1803 (2444)	1 3/8 - 6	20 675 (2336)	1723 (2336)
1 1/2 - 12	28 177 (3183)	2348 (3183)	1 1/2 - 6	27 079 (3059)	2257 (3059)

GRADE B6 STAINLESS STEEL BOLTS

Table [1.7.7](#) provides torque values for ASTM Specification A193, Grade B6, Type 410, stainless steel bolts.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.7 Torque Values for Grade B6 Stainless Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	194 (22)	-	1/4-20	174 (20)	-
5/16-24	342 (39)	29 (39)	5/16-18	316 (36)	26 (36)
3/8-24	604 (68)	50 (68)	3/8-16	546 (62)	46 (62)
7/16-20	940 (106)	78 (106)	7/16-14	862 (97)	72 (97)
1/2-20	803 (91)	67 (91)	1/2-13	753 (85)	63 (85)
9/16-18	1133 (128)	94 (128)	9/16-12	1070 (121)	89 (121)
5/8-18	1587 (179)	132 (179)	5/8-11	1488 (168)	124 (168)

Table 1.7.7 Torque Values for Grade B6 Stainless Steel Bolts, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
3/4-16	2759 (312)	230 (312)	3/4-10	2610 (295)	218 (295)
7/8-14	4390 (496)	366 (496)	7/8-9	4177 (472)	348 (472)
1-12	6544 (739)	545 (739)	1-8	6252 (706)	521 (706)
1 1/8 - 12	9407 (1063)	784 (1063)	1 1/8 - 7	8884 (1004)	740 (1004)
1 1/4 - 12	12 999 (1469)	1083 (1469)	1 1/4 - 7	12 366 (1397)	1031 (1397)
1 3/8 - 12	17 404 (1966)	1450 (1966)	1 3/8 - 6	16 331 (1845)	1361 (1845)
1 1/2 - 12	22 707 (2565)	1890 (2565)	1 1/2 - 6	21 450 (2423)	1788 (2423)
1 3/4 - 12	35 863 (4052)	2989 (4052)	1 3/4 - 5	33 948 (3835)	2828 (3835)
2 - 12	54 539 (6162)	4545 (6162)	2 - 4 1/2	50 863 (5747)	4239 (5747)
2 1/4 - 12	77 980 (8810)	6498 (8810)	2 1/4-4 1/2	73 416 (8295)	6118 (8295)
2 1/2 - 12	107 321 (12 125)	8943 (12 125)	2 1/2 - 4	100 583 (11 364)	8382 (11 364)

GRADE B8 STAINLESS STEEL BOLTS

Table [1.7.8](#) provides torque values for ASTM Specification A193, Grade B8, Type 304 stainless steel bolts.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.8 Torque Values for Grade B8 Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	57 (6)	5 (6)	1/4-20	51 (6)	4 (6)
5/16-24	107 (12)	9 (12)	5/16-18	99 (11)	8 (11)
3/8-24	188 (21)	16 (21)	3/8-16	171 (19)	14 (19)
7/16-20	293 (33)	24 (33)	7/16-14	270 (31)	23 (31)
1/2-20	216 (24)	18 (24)	1/2-13	208 (24)	17 (24)
9/16-18	412 (47)	34 (47)	9/16-12	388 (44)	32 (44)
5/8-18	577 (65)	48 (65)	5/8-11	540 (61)	45 (61)
3/4-16	1003 (113)	84 (113)	3/4-10	947 (107)	79 (107)

Table 1.7.8 Torque Values for Grade B8 Bolts, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
7/8-14	1596 (180)	133 (180)	7/8-9	1516 (171)	126 (171)
1-12	3008 (340)	251 (340)	1-8	2837 (321)	236 (321)
1 1/8 - 12	4338 (490)	362 (490)	1 1/8 - 7	4029 (455)	336 (455)
1 1/4 - 12	6008 (679)	501 (679)	1 1/4 - 7	5630 (636)	469 (636)
1 3/8 - 12	8261 (933)	688 (933)	1 3/8 - 6	7420 (838)	618 (838)
1 1/2 - 12	10 535 (1190)	878 (1190)	1 1/2 - 6	9776 (1105)	815 (1105)

GRADE B8M STAINLESS STEEL BOLTS/STUDS

Table 1.7.9 provides torque values for ASTM Specification A193, Grade B8M, Type 316 stainless steel bolts/studs.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.9 Torque Values for Grade B8M Stainless Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	57 (6)	-	1/4-20	51 (6)	-
5/16-24	107 (12)	-	5/16-18	99 (11)	-
3/8-24	188 (21)	-	3/8-16	171 (19)	-
7/16-20	293 (33)	24 (33)	7/16-14	270 (31)	23 (31)
1/2-20	216 (24)	-	1/2-13	208 (23)	17 (23)
9/16-18	412 (46)	34 (46)	9/16-12	388 (44)	32 (44)
5/8-18	577 (65)	48 (65)	5/8-11	540 (61)	45 (61)
3/4-16	1003 (113)	84 (113)	3/4-10	947 (107)	79 (107)
7/8-14	1596 (180)	133 (180)	7/8-9	1516 (171)	126 (171)
1-12	3008 (340)	251 (340)	1-8	2837 (320)	236 (320)
1 1/8 - 12	4338 (490)	362 (490)	1 1/8 - 7	4029 (455)	336 (455)
1 1/4 - 12	6008 (679)	501 (679)	1 1/4 - 7	5630 (636)	469 (636)
1 3/8 - 12	8261 (933)	688 (933)	1 3/8 - 6	7420 (838)	618 (838)
1 1/2 - 12	10 535 (1190)	878 (1190)	1 1/2 - 6	9776 (1105)	815 (1105)
1 3/4 - 12	16 680 (1885)	1390 (1885)	1 3/4 - 5	15 456 (1746)	1288 (1746)

Table 1.7.9 Torque Values for Grade B8M Stainless Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
2 - 12	25 424 (2872)	2119 (2872)	2 - 4 1/2	23 180 (2619)	1932 (2619)
2 1/4 - 12	36 411 (4114)	3034 (4114)	2 1/4 - 4 1/2	33 587 (3795)	2799 (3795)
2 1/2 - 12	50 176 (5669)	4181 (5669)	2 1/2 - 4	45 998 (5197)	3833 (5197)
2 3/4 - 12	67 107 (7582)	5592 (7582)	2 3/4 - 4	62 000 (7005)	5167 (7005)
3 - 12	87 389 (9873)	7282 (9873)	3 - 4	81 330 (9189)	6778 (9189)
3 1/4 - 12	111 391 (12 585)	9283 (12 585)	3 1/4 - 4	104 299 (11 784)	8692 (11 784)
3 1/2 - 12	139 353 (15 744)	11 613 (15 744)	3 1/2 - 4	131 224 (14 826)	10 935 (14 826)
3 3/4 - 12	171 181 (19 341)	14 265 (19 341)	3 3/4 - 4	162 412 (18 349)	13 534 (18 349)
4 - 12	208 859 (23 597)	17 405 (23 597)	4 - 4	198 185 (22 391)	16 515 (22 391)

GRADE 17-4PH STAINLESS STEEL BOLTS/STUDS

Table [1.7.10](#) provides torque values for AMS Specification 5643, Grade 17-4PH stainless steel bolts/studs.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.10 Torque Values for Grade 17-4PH Stainless Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	151 (17)	13 (17)	1/4-20	138 (16)	12 (16)
5/16-24	270 (31)	23 (31)	5/16-18	253 (29)	21 (29)
3/8-24	472 (53)	39 (53)	3/8-16	438 (50)	37 (50)
7/16-20	738 (83)	61 (83)	7/16-14	690 (78)	58 (78)
1/2-20	747 (84)	62 (84)	1/2-13	718 (81)	60 (81)
9/16-18	1095 (124)	91 (124)	9/16-12	1055 (119)	88 (119)
5/8-18	1529 (172)	127 (172)	5/8-11	1465 (165)	122 (165)
3/4-16	2653 (300)	221 (300)	3/4-10	2557 (289)	213 (289)

Table 1.7.10 Torque Values for Grade 17-4PH Stainless Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
7/8-14	4218 (477)	352 (477)	7/8-9	4082 (461)	340 (461)
1-12	5754 (650)	480 (650)	1-8	5569 (629)	464 (629)
1 1/8 - 12	8247 (932)	687 (932)	1 1/8 - 7	7919 (895)	660 (895)
1 1/4 - 12	11 367 (1284)	947 (1284)	1 1/4 - 7	10 981 (1241)	915 (1241)
1 3/8 - 12	15 186 (1716)	1265 (1716)	1 3/8 - 6	14 532 (1642)	1211 (1642)
1 1/2 - 12	19 778 (2234)	1648 (2234)	1 1/2 - 6	19 030 (2150)	1586 (2150)

STAINLESS STEEL WELD STUDS

Refer to Table [1.7.11](#) for torque values for stainless steel weld studs made from annealed stainless steel - Specification Stud Welding, Stainless Steel, Type 18-8 and 316.

NOTE

Torque values are based on bolts 1/2 in. (12.7 mm), and larger, diameter being lubricated per ES 9-54. Bolts smaller than 1/2 in. (12.7 mm) diameter are not to be lubricated.

Table 1.7.11 Torque Values for Stainless Steel Weld Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	76 (9)	6 (9)	1/4-20	68 (8)	6 (8)
5/16-24	143 (16)	12 (16)	5/16-18	132 (15)	11 (15)
3/8-24	251 (28)	21 (28)	3/8-16	228 (26)	19 (26)
7/16-20	391 (44)	33 (44)	7/16-14	360 (41)	30 (41)
1/2-20	288 (33)	24 (33)	1/2-13	277 (31)	23 (31)
9/16-18	549 (62)	46 (62)	9/16-12	517 (58)	43 (58)
5/8-18	769 (87)	64 (87)	5/8-11	720 (81)	60 (81)
3/4-16	1337 (151)	111 (151)	3/4-10	1263 (143)	105 (143)
7/8-14	2128 (240)	177 (240)	7/8-9	2021 (228)	168 (228)
1-14	4011 (453)	334 (453)	1-8	3783 (427)	315 (427)

1.7.12 Cotter Key Installation

Cotter keys are used to secure drilled bolts, clevis pins, and other fasteners that are subject to rotation. See Figure 1.7.17 for sample cotter key installation on a clevis pin. Key points for cotter key installation are:

- Cotter key ends are to be bent towards the center of the fastener being secured with excess length trimmed as shown in Figure 1.7.17.
- Do not deviate from listed torque values to bring cotter key holes into alignment. If fastener hole alignment cannot be obtained within specified torque limits, washers or fasteners should be changed until proper alignment is obtained within specified torque limits.

Refer to ES 9–54.

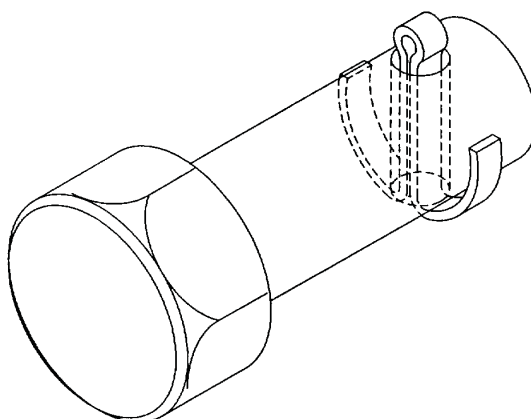


Figure 1.7.17 Cotter Key Installation, Clevis Pin

1.7.13 Safety Wire Installation

Use 0.032-in. (0.8-mm) diameter stainless steel safety wire for general applications in all locations accessible by routine servicing procedures. Use 0.020-in. (0.5-mm) diameter stainless steel safety wire for No. 8 or smaller screws, for electrical harness coupling nuts, and in other places where it is not practical to use 0.032-in. (0.8-mm) diameter wire.