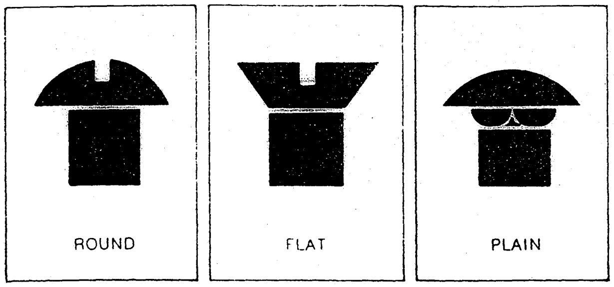
STAINLESS STEEL FASTENERS
A SYSTEMATIC APPROACH TO THEIR SELECTION

Contents



Preface

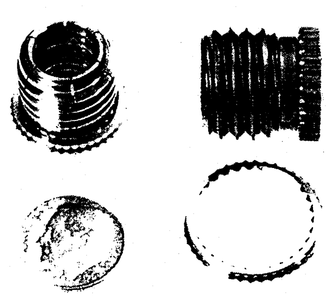
There was a time when the periodic repair of mechanical and electrical components was taken for granted. Today, with labor costs at record levels and going up, greater consideration at the design level is being given to the reduction—or even elimination—of maintenance. In cases where a joint must be taken apart and reassembled, the corrosion resistance of the fastener is particularly important so that corrosion will in no way hamper or prevent its removal. The cost of removing rusty bolts, and replacing them with new ones, is more expensive than using corrosion resistant fasteners to begin with.

Other costs resulting from fastener failure, such as downtime and lost production, make an even stronger case for stainless steel fasteners.

A systematic approach to stainless steel fastener selection

Selecting the optimum fastener can be an awesome task for any designer. There is a staggering diversity of fastener types available (over 500,000 standard items), and for any one type there can be a large number of sizes from which to choose. For example, one of the smallest standard fasteners has a head of 0.01 inch (.254mm); the largest has a head 4 feet (1.219m) in diameter. To further complicate the problem of fastener selection, there are special designs, which are not considered to be "off-the-shelf" items, and a wide variety of different materials.

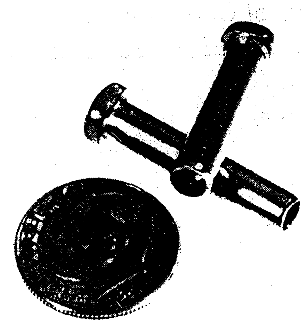
Stainless steel is one of these fastener materials, and it is used extensively throughout industry for both original equipment manufacture as well as for replacement. The purpose of this publication is to help designers trace an orderly path through the fastener complexity to arrive at a stainless steel fastener system that best fills the need.

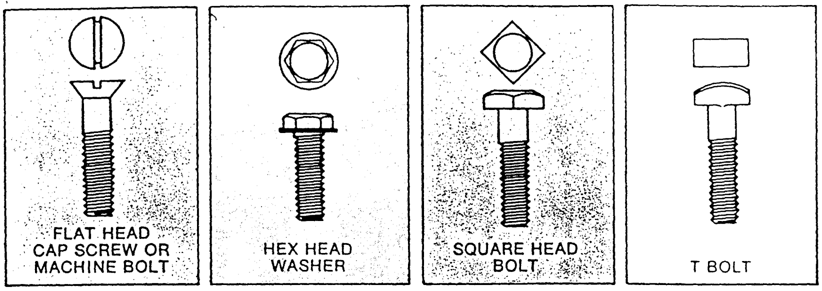


The designer should consider a fastener as a system, and regard the assembled joint as a critical and integral portion of the design—not as an afterthought—because the joint is normally an area under highest stress and often the place where failure is most likely to occur. A designer should start with the optimum fastener and design the joint around that, rather than starting with the joint and then looking for the fastener that seems most adequate.

Fastener materials

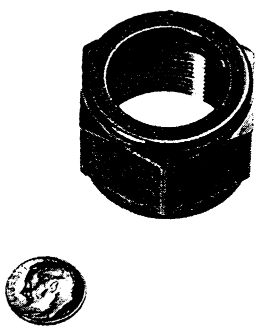
Fasteners have been made of a vast number of materials for one reason or another. The designer

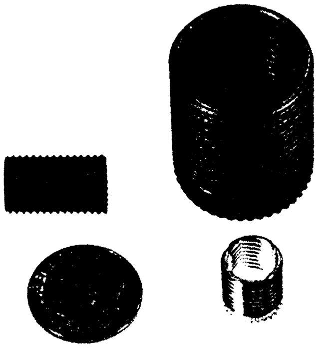




can specify anything from hard oak to Invar, a low coefficient-of-expansion material. There are indeed many cases wherein an exotic material must be used because of design requirements.

However, the common materials used to produce both standard and special fasteners should be considered first. The common materials are a first choice because of the ease in manufacturing fasteners from these materials, because they provide adequate physical characteristics at more economical cost, and because they are readily available from suppliers throughout the United States and Canada. The brief outline which follows identifies some different common fastener materials.





CARBON STEELS (AISI Type):

1008, 1010, 1015 are low-carbon steels used for the great majority of machine screws, wood screws, etc. Sometimes called mild steel, they have a tensile strength of about 55 ksi (379MPa), which cannot be increased by heat treatment.

1018, 1020, 1022 are medium low-carbon steels that can be heat treated for strength to a minor degree (except 1018), and they can be case hardened to form an outer layer of hard, tough, but brittle carburized steel. They are used for sheet metal screws, thread-cutting screws, and for grade 2 (bright) hexhead cap screws. About 59 ksi (407MPa) is the usual tensile strength for these materials.

1035, 1038 are high-carbon, medium alloy steels that can be heat treated to 120 ksi (827MPa) tensile strength. Cap screws are a typical use.

ALLOY STEELS (AISI Type):

4037, 4137 are molybdenum alloy steels that can be heat treated to 150 ksi tensile (1034MPa) and above. Typical uses include hex socket and cap screws and for spline fasteners.

FREE-CUTTING STEELS (AISI Type):

1110, 1112, 1113 are low-carbon, free-machining steels used for low-strength nuts that are used in all but critical applications.

STAINLESS STEELS (AISI Type):

303, 304, S30430 (UNS), 305 are in the "18-8" family of stainless steels that have tensile strengths in the 80 ksi (552MPa) and up range. They are not hardenable by heat treatment but are hardenable by cold working, such as by heading and thread rolling. They are nonmagnetic in the annealed condition and only slightly magnetic in the cold worked condition.

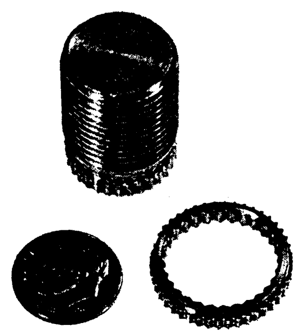
384 is a stainless steel that has lower work-hardening characteristics than Type 305. It is in the 18-8 family of stainless steels and is included in most AN and MS specifications.

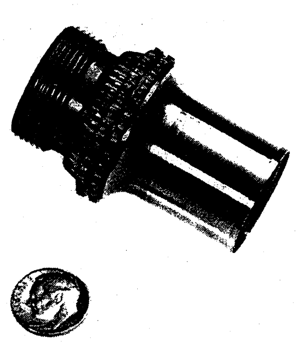
316 stainless steel has the highest degree of corrosion resistance of the commonly-used 18-8 stainless steels.

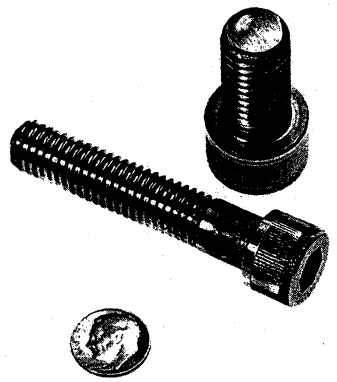
410, 416, 430 are magnetic stainless steels having less corrosion resistance than the 300 Series types. Types 410 and 416 are hardenable by heat treatment to 125-180 ksi tensile (862-1241MPa).

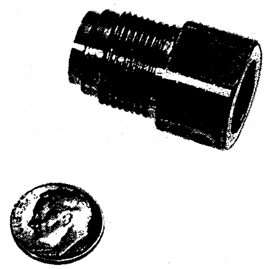
Designers also have choices to make from among a large group of nonferrous fasteners, and fasteners that have been plated either for purposes of corrosion protection or for appearance.

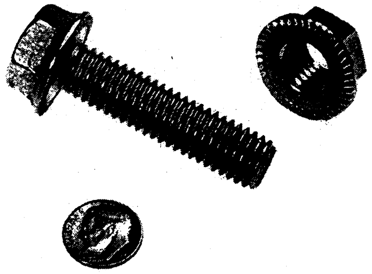
This publication is concerned only with stainless steels; however, some comments will be made concerning the other materials











because an evaluation requires a comparison of available materials.

Stainless steels

Stainless steel is a family of iron-base alloys containing about 10.5% chromium or more, plus other alloying elements such as nickel, manganese, molybdenum, sulfur, selenium, titanium, etc. The chromium is chiefly responsible for corrosion and heat resistance; the other alloying elements are present in stainless steel to enhance corrosion resistance and to impart certain characteristics with respect to strength and fabricability.

A total of 57 commercial stainless steel types are designated by the American Iron and Steel Institute as standard compositions. A complete listing of all AISI stainless steels and a description of each are contained in the AISI publication, "Steel Products Manual—Stainless and Heat-Resisting Steels, December 1974.[1]"

In addition to the standard AISI types, many special analysis and proprietary stainless steels are produced in the United States and Canada.

Identification

Most AISI stainless steels are identified by a system of numbers that are in either 200, 300, or 400 Series. In addition, all are identified by the new Unified Numbering System (UNS), which encompasses all commercial metals and rare earths. For example, Type 304 is Type S30400 in UNS. Special analysis and proprietary stainless steels are identified by trade names, some of which may resemble AISI numbers.

The terms *austenitic, martensitic, ferritic* and *precipitation hardening* serve to identify categories of stainless steels on the basis of their metallurgical structure. Designers should recognize these terms and understand what they mean, because stainless steels so classified tend to have similar characteristics with respect to corrosion resistance, hardenability, and fabricability.

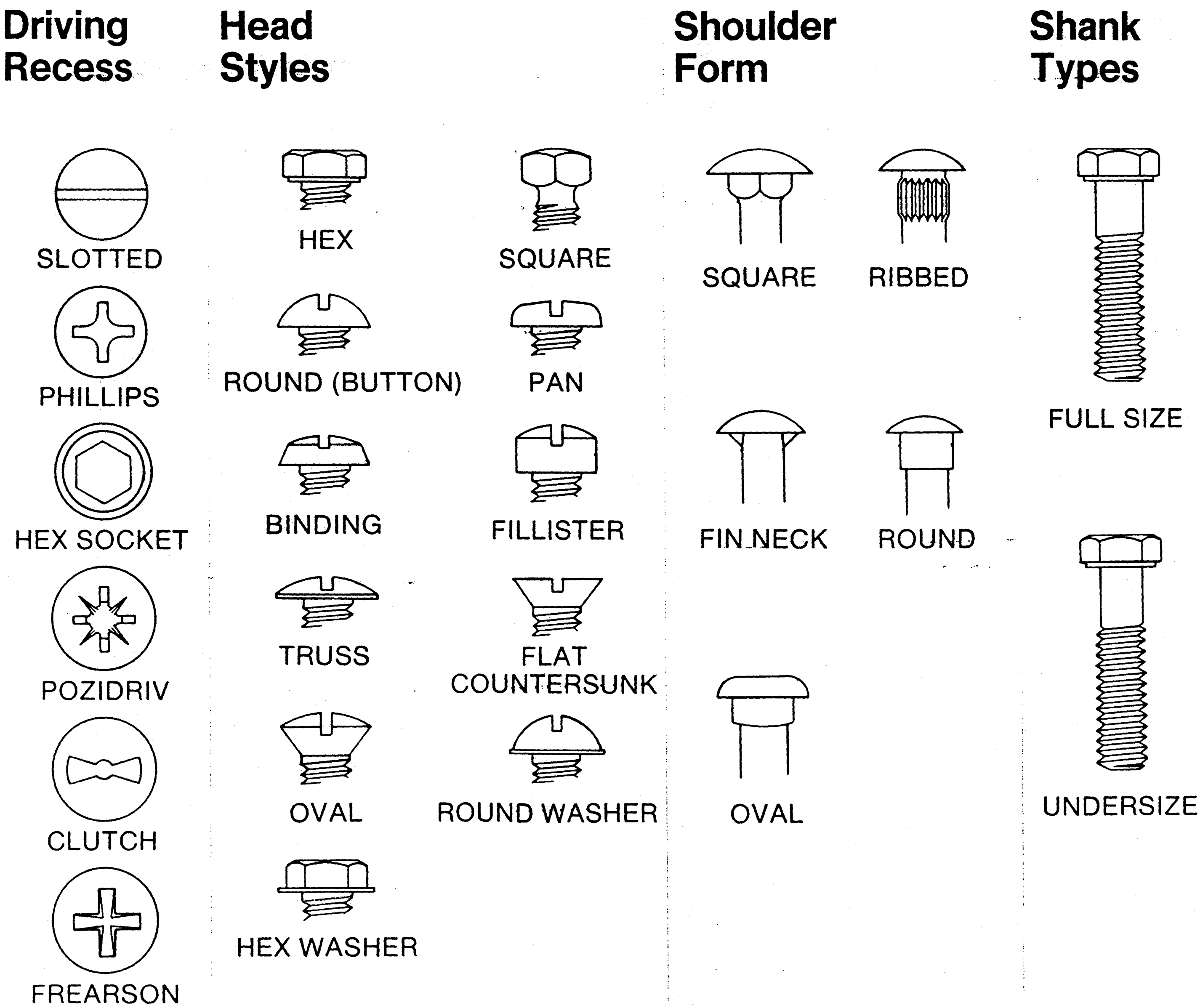
Austenitic stainless steels are chromium-nickel-manganese and chromium-nickel compositions identified by 200 and 300 Series numbers, respectively. They are hardenable only by cold working and are nonmagnetic in the annealed condition. Typical of the austenitic group is Type 304, which contains nominally 18% chromium and 8% nickel, hence the 18-8 name.

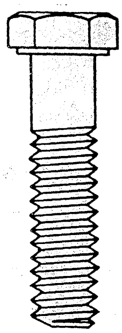
Ferritic stainless steels are straight-chromium steels in the 400 Series that are not hardenable by heat treatment and only slightly hardenable by cold working. All are magnetic. Type 430 is typical of this group.

Martensitic stainless steels are straight-chromium, 400 Series that can be hardened by heat treatment only. All are magnetic. Type 410 is typical of this group.

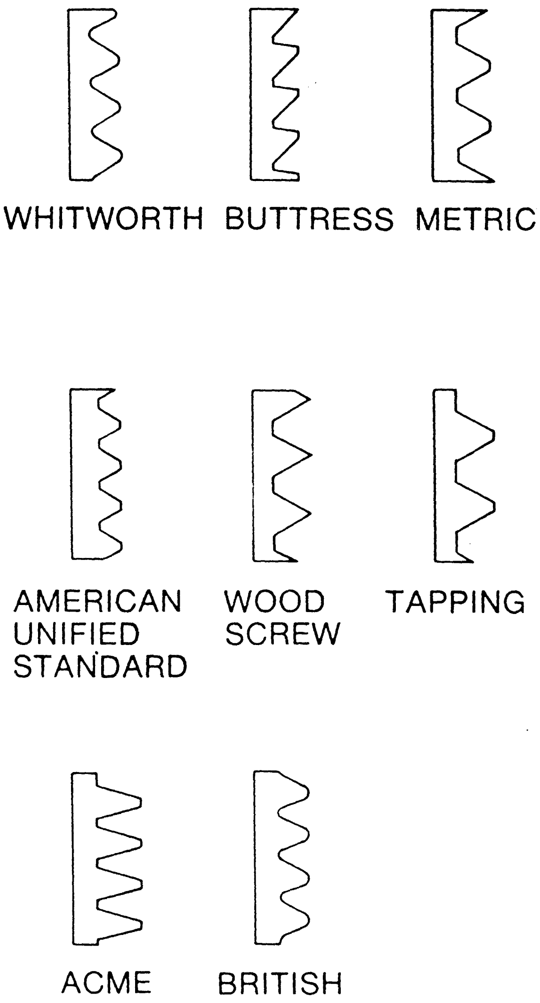
Precipitation hardening stainless steels are hardenable by a combination of a low-temperature

FASTENER BASICS

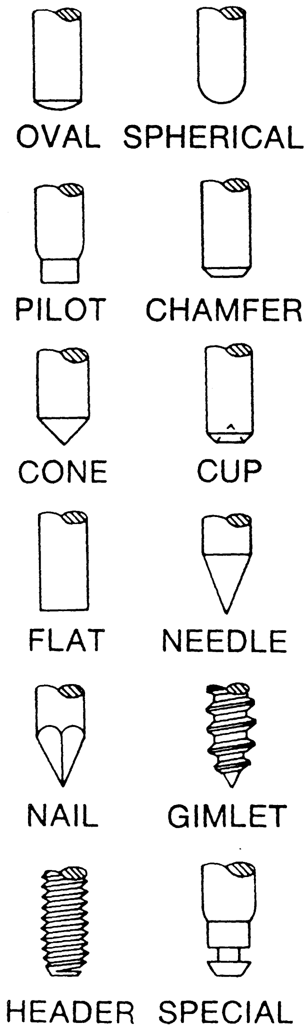




Thread Form



Point Styles

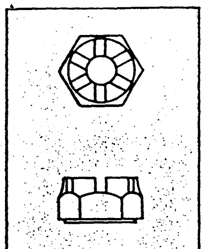


An analysis of standard fasteners, such as bolts and screws, reveals that all have certain characteristics in common. Further, their differences can be classified as shown here. Each bolt and screw is, in effect, made up of a series of component parts; thus, the fasteners may have some or all of these: (a) a head; (b) a driving recess; (c) a shoulder; (d) an unthreaded shank; (e) a threaded shank; and (f) a point.

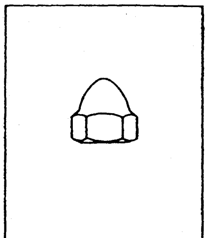
Certain combinations of these components, because of usage are considered standard. Others are non-standard, but nearly any combination can be readily produced.

This analysis of fastener parts is presented in the hope that it will assist the user in understanding and specifying bolts and screws.

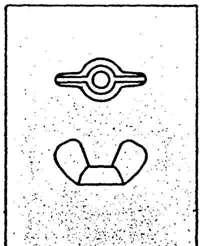
Source: ITT Harper



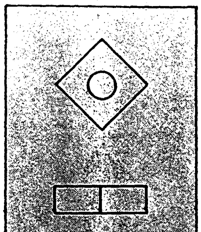
CASTLE NUT



CAP NUT (ACORN NUT)



WING NUT



SQUARE MACHINE SCREW NUT

aging treatment and cold working. The AISI types are identified by UNS numbers only (such as Type S17400), although many are referred to in literature by proprietary trade names such as 17-4PH. The precipitation hardening stainless steels are especially useful because fabrication can be completed in an annealed condition and uniform hardening achieved without a high-temperature treatment that can result in distortion and scaling.

Choosing the right stainless steel

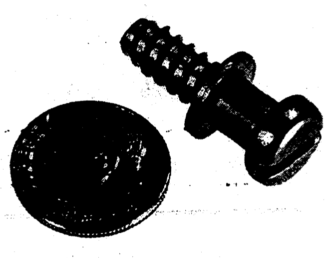
The stainless steels used most frequently as fasteners are Types 303, 304, UNS-S30430, 305, 384, 316, 410, 416, and 430. Selection of the right type for a fastener application is greatly simplified when they are classified according to metallurgical categories described on page 5.

- Austenitic —Types 303, 304, UNS-S30430, 305, 384, and 316
- Ferritic —Type 430
- Martensitic—Types 410 and 416

The selection process is further simplified when the designer understands the characteristics of each category and the relationship of alloys to one another in that group.

The austenitic stainless steels are characterized as having excellent corrosion resistance, with the higher alloyed materials accordingly having superior resistance. For example, Type 304 is the most widely used material that withstands ordinary rusting. It is virtually immune to foodstuffs, sterilizing solutions, most organic chemicals and dyestuffs, and a wide variety of inorganic chemicals. It resists nitric acid well, the sulfur acids moderately, and the halogen acids poorly. It is used for cryogenic applications, and is easily fabricated.

Types 303, UNS-S30430, 305, and 384 are variations of Type 304 that were developed to meet specific manufacturing requirements. For instance, Type 303 has a considerably higher sulfur content that enhances machining characteristics. If a fastener is made by machining, such as large bolts or specials that cannot be cold headed, more than likely it will be Type 303. On the other hand, Types UNS-S30430, 305, and 384 were developed specifically for cold-forming operations. Type UNS-S30430 contains copper and is used for cold headed fasteners.



Regardless of the diversity in numbering, the above-mentioned stainless steels are essentially 18-8 materials in that their composition is very close to the nominal composition of Type 304, which is 18% chromium and 8% nickel. Because they have similar corrosion resistance properties, these 18-8 materials are usually interchanged in fastener applications. If an application calls for Type 304, the designer can generally specify an 18-8 fastener material.

However, it should be recognized that while the 18-8 stainless steels are considered to have similar corrosion-resistance properties, they are not identical. The sulfur in Type 303, for example, causes it to have somewhat lower corrosion resistance than Type 304, especially when in direct and continuous contact with water or some chemical solution. Accordingly, a designer should specify Type 304 when it is known that Type 303 is not suitable for the application. When in doubt, the designer should consult with a corrosion engineer.

If an application calls for a material with corrosion resistant properties better than that of Type 304, Type 316 is the next logical candidate. Type 316 stainless steel is a higher alloyed material containing 2-3% molybdenum, which gives it corrosion-resistant properties superior to Type 304, especially in environments containing chlorides. It has wide application in pulp and paper mills, for example, because it is more resistant to sulfurous acid compounds. It is also widely used in phosphoric and acetic acids that tend to cause pitting corrosion in the 18-8 types.

Many fastener applications do not require the high degree of corrosion resistance offered by the 18-8 stainless steels or the higher alloyed types, in which case the designer can consider one of the straight-chromium types, some of which may be lower in cost. For example, Type 430 stainless steel contains about 18% chromium, but no nickel. Although it has lower corrosion-resistance properties than the 18-8 types, it has wide application for decorative trim because when it is buffed it closely resembles a material that has been chromium plated. Typical applications include trim on automobiles, cameras, vending machines, counters, appliances, showcases, and a host of other products that need dressing up or "eye appeal" to increase their salability.

On the other hand, there is Type 410, which contains 11.5-13.5% chromium, and accordingly has lower resistance to corrosion than Type 430 or the 18-8 materials. It will resist corrosion in mild atmospheres, fresh water, mine water, steam, carbonic acid, crude oil, gasoline, blood, alcohol, ammonia,

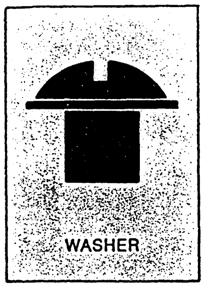
TABLE 1—CHEMICAL COMPOSITION LIMITS OF RAW MATERIAL (IFI-104)

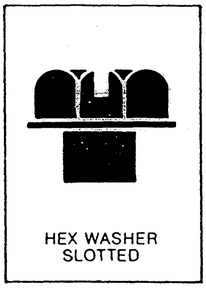
GRADE	GENERAL DESCRIPTION OF MATERIAL	SPECIFICATIONS[1] COVERING RAW MATERIALS REQUIREMENTS	CHEMICAL COMPOSITION, % MAX (UNLESS SHOWN AS MIN OR MAX/MIN LIMITS GIVEN) STAINLESS STEEL									
			C	Mn	P	S	Si	Cu	Mo	Ni	Cr	Other
303	Austenitic Stainless Steel	ASTM A276 Type 303 QQ-S-764 Class 303 AISI 303	0.15	2.00	0.20	0.15 min	1.00	—	0.60[3]	8.00 to 10.00	17.00 to 19.00	See Note (3)
304	Austenitic Stainless Steel	ASTM A276 Type 304 QQ-S-763 Class 304 AISI 304	0.08	2.00	0,045	0.030	1.00	—	—	8.00 to 12.00	18.00 to 20.00	—
305	Austenitic Stainless Steel	ASTM A276 Type 305 QQ-S-763 Class 305 AISI 305	0.12	2.00	0.045	0.030	1.00	—	—	10.00 to 13.00	17.00 to 19.00	—
316	Austenitic Stainless Steel	ASTM A276 Type 316 QQ-S-763 Class 316 AISI 316	0.08	2.00	0.045	0.030	1.00	—	2.00 to 3.00	10.00 to 14.00	16.00 to 18.00	—
XM7*	Austenitic Stainless Steel	ASTM A493 Type XM7	0.10	2.00	0.045	0.030	1.00	3.0 to 4.0	—	8.00 to 10.00	17.00 to 19.00	—
384	Austenitic Stainless Steel	AISI 384	0.08	2.00	0.045	0.030	1.00	—	—	17.00 to 19.00	15.00 to 17.00	—
410	Martensitic Stainless Steel	ASTM A276 Type 410 QQ-S-763 Class 410 AISI 410	0.15	1.00	0.040	0.030	1.00	—	—	—	11.50 to 13.50	—
416	Martensitic Stainless Steel	ASTM A276 Type 416 QQ-S-764 Class 416 AISI 416	0.15	1.25	0.06	0.15 min	1.00	—	0.60[2]	—	12.00 to 14.00	—
430	Ferritic Stainless Steel	ASTM A276 Type 430 QQ-S-763 Class 430 AISI 430	0.12	1.00	0.040	0.030	1.00	—	—	—	14.00 to 18.00	—

NOTES TO TABLE 1

1. Legend of specification designations —
   ASTM—American Society for Testing and Materials
   AISI—American Iron and Steel Institute
   QQ-X-XXX—Federal Government
2. May be added at manufacturer's option.
3. ASTM A276 permits addition of molybdenum, and also 0.12/0.30% lead at manufacturer's option. AISI requires the addition of molybdenum but permits no lead.

* Type S30430


WASHER


HEX WASHER SLOTTED

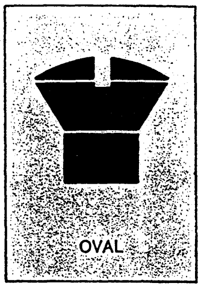

OVAL

TABLE 2—MECHANICAL REQUIREMENTS FOR STAINLESS STEEL BOLTS, SCREWS, STUDS AND NUTS (IFI-104)

GRADE[1]	GENERAL DESCRIPTION	MECHANICAL REQUIREMENTS							
		BOLTS, SCREWS AND STUDS						NUTS	
		FULL SIZE BOLTS, SCREWS, STUDS		MACHINED TEST SPECIMENS OF BOLTS, SCREWS, STUDS			HARDNESS ROCKWELL	PROOF LOAD STRESS	HARDNESS ROCKWELL
		YIELD[2] STRENGTH min ksi	TENSILE STRENGTH min ksi	YIELD[2] STRENGTH min ksi	TENSILE STRENGTH min ksi	ELONGATION[3] % Min	Min	ksi	Min
303-A	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B75	75	B75
304-A	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B75	75	B75
304	Austenitic Stainless Steel-Cold Worked	50	90	45	85	20	B85	90	B85
304-SH	Austenitic Stainless Steel-Strain Hardened	See Note 6	See Note 6	See Note 6	See Note 6	15	C25	See Note 6	C20
305-A	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B70	75	B70
305	Austenitic Stainless Steel-Cold Worked	50	90	45	85	20	B85	90	B85
305-SH	Austenitic Stainless Steel-Strain Hardened	See Note 6	See Note 6	See Note 6	See Note 6	15	C25	See Note 6	C20
316-A	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B70	75	B70
316	Austenitic Stainless Steel-Cold Worked	50	90	45	85	20	B85	90	B85
316-SH	Austenitic Stainless Steel-Strain Hardened	See Note 6	See Note 6	See Note 6	See Note 6	15	C25	See Note 6	C20
XM7-A*	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B70	75	B70
XM7*	Austenitic Stainless Steel-Cold Worked	50	90	45	85	20	B85	90	B85
384-A	Austenitic Stainless Steel-Sol. Annealed	30	75	30	75	20	B70	75	B70
384	Austenitic Stainless Steel-Cold Worked	50	90	45	85	20	B85	90	B85
410-H	Martensitic Stainless Steel-Hardened and Tempered	95	125	95	125	20	C22	125	C22
410-HT	Martensitic Stainless Steel Hardened and Tempered	135	180	135	180	12	C36	180	C36
416-H	Martensitic Stainless Steel-Hardened and Tempered	95	125	95	125	20	C22	125	C22
416-HT	Martensitic Stainless Steel-Hardened and Tempered	135	180	135	180	12	C36	180	C36
430	Ferritic Stainless Steel-	40	70	40	70	20	B75	70	B75

NOTES TO TABLE 2

1. Legend of grade designations: —
   A—solution annealed
   SH—strain hardened
   H—hardened and tempered at 1100 F min.
   HT—hardened and tempered at 525 F ± 50 F
2. Yield strength is the stress at which an offset of 0.2% of gauge length occurs for all stainless steels.
3. Elongation is determined using a gauge length of 2 in. or 4 diameters of test specimen in accordance with Federal Standard 151, Method 211.
4. Loads at minimum yield strength and minimum ultimate tensile strength for full size products may be computed by multiplying the yield strength and tensile strength stresses as given in Table 2 by the stress area for the product size and thread series as given in Table 2a. below.
5. Proof loads of nuts in pounds may be computed by multiplying the proof load stress as given in Table 2 by the stress area for the nut size and thread series given in Table 2a.
6. Austenitic stainless steel, strain hardened bolts, screws, studs and nuts shall have the following strength properties.

PRODUCT SIZE	BOLTS, SCREWS, STUDS				NUTS
	TESTED FULL SIZE		MACHINED TEST SPECIMENS		PROOF LOAD STRESS
in.	YIELD STRENGTH min ksi	TENSILE STRENGTH min ksi	YIELD STRENGTH min ksi	TENSILE STRENGTH min ksi	ksi
to 5/8 in.	100	125	90	115	125
over 5/8 to 1 in.	70	105	65	100	105
over 1 to 1½ in.	50	90	45	85	90

TABLE 2a—TENSILE STRESS AREAS AND THREADS PER INCH

PRODUCT SIZE DIA. in.	COARSE THREAD		FINE THREAD	
	STRESS AREA, sq in.	THREADS per in.	STRESS AREA, sq in.	THREADS per in.
6	0.00909	32	0.01015	40
8	0.0140	32	0.01474	36
10	0.0175	24	0.0200	32
12	0.0242	24	0.0258	28
1/4	0.0318	20	0.0364	28
5/16	0.0524	18	0.0580	24
3/8	0.0775	16	0.0878	24
7/16	0.1063	14	0.1187	20
1/2	0.1419	13	0.1599	20
9/16	0.1820	12	0.2030	18
5/8	0.2260	11	0.2560	18
3/4	0.3340	10	0.3730	16
7/8	0.4620	9	0.5090	14
1	0.6060	8	0.6630	12
1 1/8	0.7630	7	0.8560	12
1 1/4	0.9690	7	1.0730	12
1 3/8	1.1550	6	1.3150	12
1 1/2	1.4050	6	1.5810	12

Tensile stress areas are computed using the following formula:

$$A_s = 0.7854 \left[D - \frac{0.9743}{n} \right]^2$$

Where A_s = tensile stress area in square inches
D = nominal size (basic major diameter) in inches
n = number of threads per inch

* Type 30430

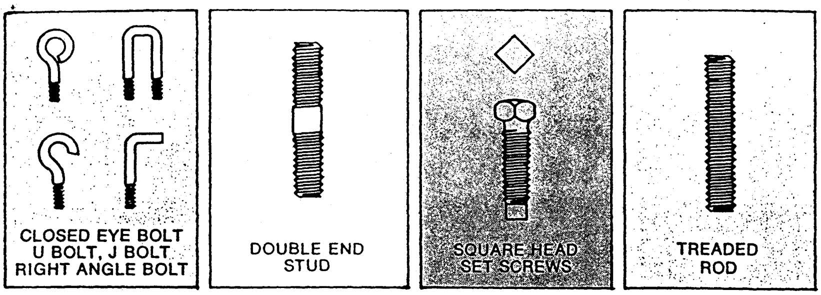
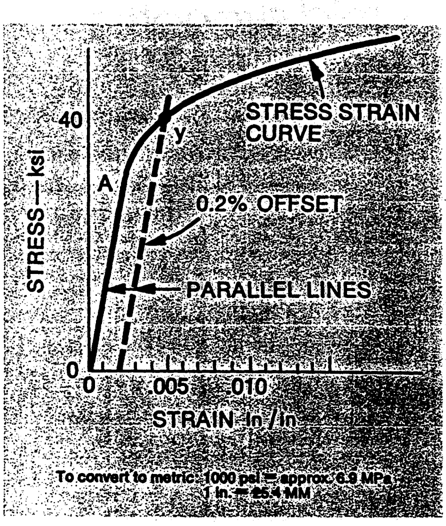


FIGURE 1. YIELD STRENGTH—DETERMINED BY OFFSET



mercury, soap, sugar solutions and other reagents. It also has good scaling and oxidation resistance up to 1200F (649C), which is discussed in greater detail beginning on page 16. Type 416 is a free-machining variation of Type 410 and has similar characteristics.

To review briefly, the relative resistance to corrosion among the common stainless steel fastener materials is as follows:

Category	Type	Corrosion Resistance
Austenitic	316	Superior
	(18-8)	Excellent
Ferritic	430	Good
Martensitic	410	Fair

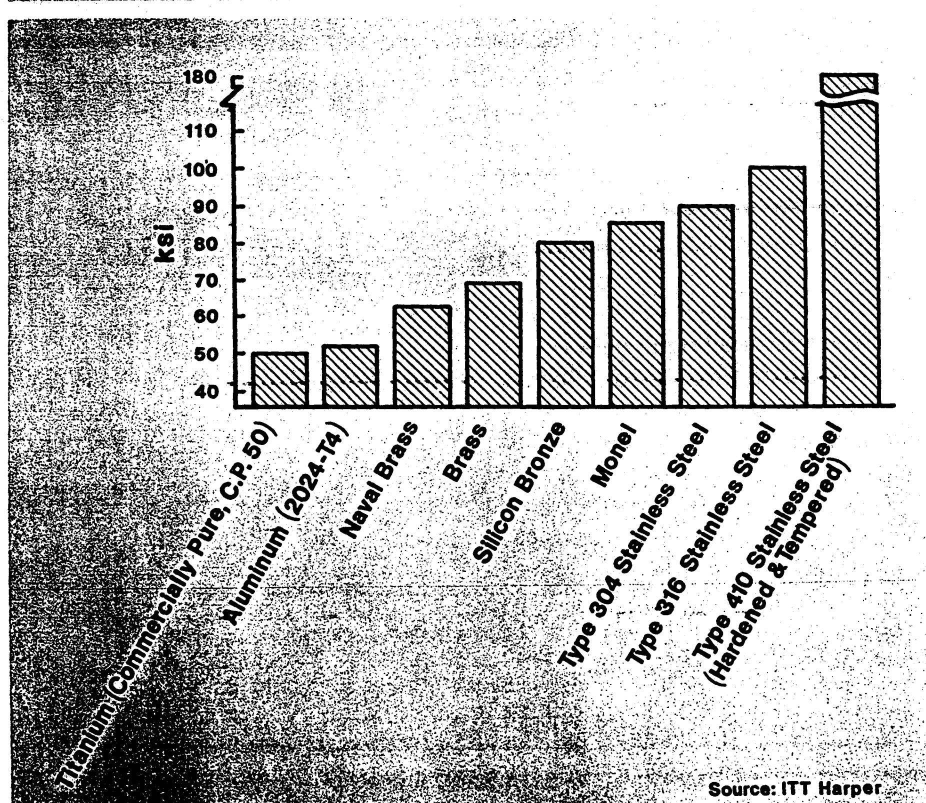
The corrosion Data Survey published in 1968 by the National Association of Corrosion Engineers (NACE) contains data on the use of these materials in various chemical environments, with specific information on temperatures and concentrations. These data can be very helpful in narrowing down the choice of materials for any given corrosive environment. The final determination, however, should be based on tests conducted under actual working conditions. If this is not practical for a designer, he should consult with a corrosion engineer having experience with stainless steels. Assistance can be obtained through the companies listed on the back cover of this publication.

The stainless steels described so far represent only the common ones covered by fastener industry specifications.[3] Other stainless steel types are available to meet specific requirements of fabrication or end use, many of which are used in fastener form. For example, there are variations of the 18-8 group having lower-carbon contents, such as Types 304L and 316L. These are used for welded fabrications that will be exposed to acid environments. Other stainless steels are especially suited for high-temperature environments, such as Types 309, 310, 314, 321, 347, 348, 436, 442, and 446.

Another group of stainless steels has improved mechanical properties, such as high strength and hardness. Included in this group are Types 304N, 316N, 422, 431, 440A, 440B, and 440C, plus the precipitation hardening grades—Types UNS-S13800, UNS-S15500, UNS-S17400, and UNS-S17700.

Nearly all of the stainless steels can be made into fasteners, although special arrangements with a fastener manufacturer may be necessary in some cases.

FIGURE 2. TENSILE STRENGTH OF NINE FASTENER ALLOYS

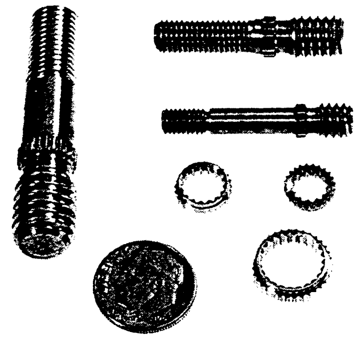


Stainless steel fastener properties

Once the design engineer has determined candidate fastener materials on the basis of their corrosion-resistant properties, his next concern probably will be the mechanical and physical properties of these materials. Once again, the family of stainless steels covers a wide choice. The choice, however, should not be a difficult one to make if the designer uses the guidelines available to him, such as the specifications published by the Industrial Fasteners Institute.

Many an engineer who has attempted to design a product using stainless steel fasteners has learned that meaningful data on fastener properties are sometimes difficult to find. In many situations, the designer has had to rely on technical data based on the mechanical properties of the *materials* from which the fasteners are made. All too often these properties vary considerably from the actual properties of the manufactured fasteners.

The Industrial Fasteners Institute (IFI), however, has a specification—IFI-104—that covers the mechanical, metallurgical, and quality requirements of the common



stainless steels used for bolts, screws, studs, and nuts up to and including 1½ inch (38.1mm) in diameter. The specification is especially useful because it is based entirely on the properties of full-size *finished fasteners,* which in many cases are different from the properties of the bar or wire from which they are made. Tables 1 and 2 present some of the data contained in the IFI-104 specification.

Tensile and yield strengths

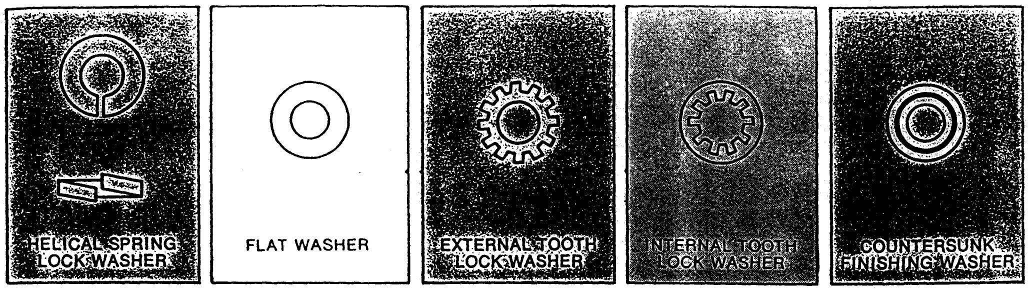
Tensile or ultimate strength is that property of a material which determines how much load it can withstand until failure. Yield strength is a measure of the resistance of a material to plastic deformation; that is, to taking of a permanent set under load. For stainless steels, the yield strength is calculated on a stress-strain diagram. (Figure 1) and it is a point at which a line drawn parallel to and offset 0.2% from the straight line portion of the curve intersects the curve.

It can be seen from the data in Table 2 that there is a considerable spread between the tensile and yield strength values, which is characteristic of stainless steels. Yield strength is used in design

TABLE 3—STRENGTH-TO-WEIGHT RATIO

Material	Typical Tensile Strength ksi	Density Lbs./Cu. In.	Strength-to-Weight Ratio Inches x 10^2
Martensitic Stainless Steel (410, 416)	180	.280	6.4
Aluminum (2024-T4)	60	.098	6.1
Austenitic Stainless Steel (18-8) Strain hardened	125	.290	4.3
Titanium Commercially pure	50	.163	3.1
Nylon	12	.041	2.9
Austenitic Stainless Steel (18-8), annealed	80	.290	2.8
Monel 400	80	.319	2.5
Silicon Bronze	75	.308	2.4
Brass	60	.308	2.0
Mild Steel	50	.282	1.8

Source: ITT Harper



calculations, however, because it stands to reason that if the yield strength is exceeded, deformation will occur in the fastener.

In looking at the data in Table 2, it is noted that three different sets of properties are given for Types 304, 305, and 316, and two sets of properties for Types S30430 and 384. The reason is that 300 Series stainless steels increase in strength as a result of cold working.

For example, full size bolts of 18-8 stainless steel in the annealed condition will have a minimum yield strength of 30 ksi (207 MPa). If the bolt is cold worked 15-20%, its yield strength level will increase to 50 ksi (345MPa) minimum. Cold worked from 35 to 40%—indicated in Table 2 as "strain hardened"—the minimum yield strength level is as high as 100 ksi (690MPa), depending upon size of the fastener.

In the 400 Series, only the martensitic stainless steels are hardenable, and that is by thermal treatment. Two sets of values are

TABLE 5—
CREEP STRENGTHS OF TYPICAL STAINLESS STEEL FASTENER MATERIALS

AISI TYPE	LOAD FOR 1% ELONGATION IN 10,000 Hr, ksi				
	1000 F	1100F	1200 F	1300 F	1500 F
303	16.5	11.5	6.5	3.5	0.7
304	20	12	7.5	4	1.5
305	19	12.5	8	4.5	2
309	16.5	12.5	10	6	3
310	33	23	15	10	3
316	25	17.4	11.6	7.5	2.4
321	18	17	9	5	1.5
347	32	23	16	10	2
430	8.5	4.7	2.6	1.4	—
446	6.4	2.9	1.4	0.6	0.4
410	11.5	4.3	2	1.5	—
416	11	4.6	2	1.2	—

Source: Industry Data

TABLE 4—ALLOWABLE SHEAR STRESS FOR STAINLESS STEEL BOLTS[4]

Type	Finish	Condition and Specification	Diameter d (In.)	Minimum Tensile Requirements		Allowable Shear Stress (ksi)	
				0.2% Yield Strength (ksi)	Tensile Strength (ksi)	No Threads in Shear Plane	Threads in Shear Plane
302** 304 316	Hot Finished	Condition A (Annealed) in ASTM A276-71 Class 1 (solution treated) in ASTM A193-71	all	30.0	75.0	15.0	10.5
302 304 316	Cold Finished	Condition A (Annealed) in ASTM A276-71	≤ ½	45.0	90.0	18.0	12.6
302** 304 316	Cold Finished	Condition B (cold-worked) in ASTM A276-71 Class 2 (solution treated and strain hardened) in ASTM A193-71*	≤ ¾	100.0	125.0	25.0	17.5

* For Class 2: B8M in ASTM A193, the allowable shear stress is 22.0 ksi when threading is excluded from the shear plane, or 15.0 ksi when threads are in the shear plane.
** ASTM A276-71 only.

given in Table 2 for Types 410 and 416, representing two levels of hardening and tempering. Type 430 is not hardenable.

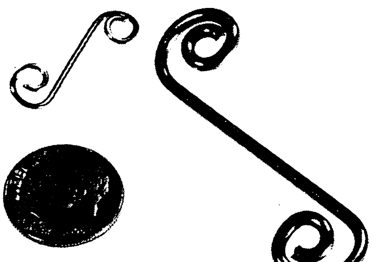
Figure 2 is a relative comparison of strength values between stainless steels and other corrosion resistant fastener materials.

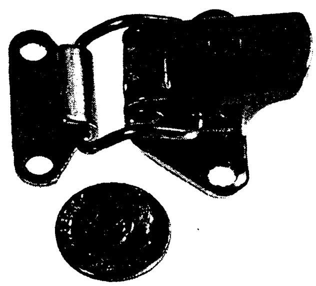
In selecting a stainless steel on the basis of mechanical and physical properties, designers should keep in mind the following considerations:

TABLE 6—
THERMAL EXPANSION OF CORROSION-RESISTANT FASTENER ALLOYS

Alloy	Temperature Range°F	Mean Coefficient of Thermal Expansion In./In./°F (10^{-6})
Type 304 Stainless Steel	32 to 212	9.6
	32 to 572	9.9
	32 to 1112	10.4
Type 316 Stainless Steel	32 to 212	8.9
	32 to 572	9.0
	32 to 1112	10.3
Type 410 Stainless Steel	32 to 212	6.1
	32 to 1000	7.2
Brass	68 to 572	11.3
Naval Bronze	68 to 572	10.0
Silicon Bronze	68 to 572	11.8
Monel	68 to 212	7.8
Titanium	32 to 68	4.7
	32 to 1600	5.6
Aluminum (2024)	−76 to 68	21.4
	68 to 212	22.8
	68 to 392	23.9

Source: ITT Harper





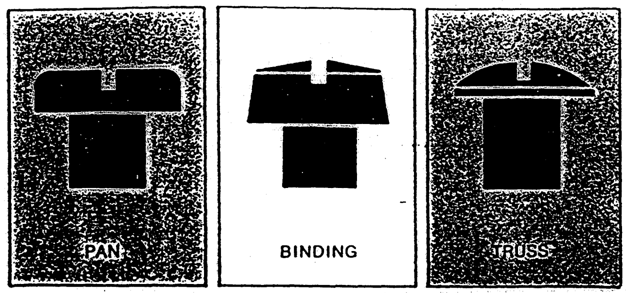
Thread Strength Thread forms on fasteners are manufactured by cutting, rolling, or grinding. The best quality highest-strength thread, however, is achieved by thread rolling. This is because the plastic deformation—or cold working—involved in rolling threads results in (1) more accurate, more uniform thread dimensions, giving a better fit between threaded parts and fewer concentrated loads at points of misfit; (2) smoother thread surfaces and, thus, fewer scratches and other markings to initiate cracks, or galling; and (3) higher yield, tensile, and shear properties to better withstand service loads.

Strength-To-Weight Ratio In applications where weight is an important consideration, designers look to strength-to-weight ratios for an indication of the most efficient material to use. The strength-to-weight ratio is defined as the ratio of tensile strength to density. Some typical properties of corrosion-resistant fastener materials, including strength-to-weight ratios, are given in Table 3. Of particular interest is the similarity between Type 410 stainless steel and aluminum, and the fact that Type 410 has a higher strength-to-weight ratio than aluminum 2024-T4.

Shear Strength

Shear is transverse rupture. It is caused by a pushing or pulling force at 90° from the axis of a part. Thus, a rivet used as a pulley axle will shear if the load on the pulley exceeds the shear value of the rivet. Shear strength is defined as the load in pounds to cause rupture, divided by the cross-sectional area in square inches of the part along the rupture plane.

The allowable shear stresses for stainless steel bolts are given in Table 4, which is based on the AISI



publication, "Stainless Steel Cold-Formed Structural Design Manual, 1974 Edition.[4]" The allowable shear stress for bolts with no threads in the shear plane was taken as 60% of the minimum tensile strength divided by a safety factor of 3.0. This allowable shear stress provides a minimum safety factor of about 1.2 against shear yielding of the bolt material. When threads are included in the shear plane, 70% of the nominal allowable shear stress is used due to the fact that the actual shear stress in bolts is to be calculated on the basis of the gross cross-sectional area or nominal area, and that the ratios of stress area to nominal area range from 0.65 to 0.76 for diameters of bolts varying from ¼ to ¾ inch (6.3-19.1mm).

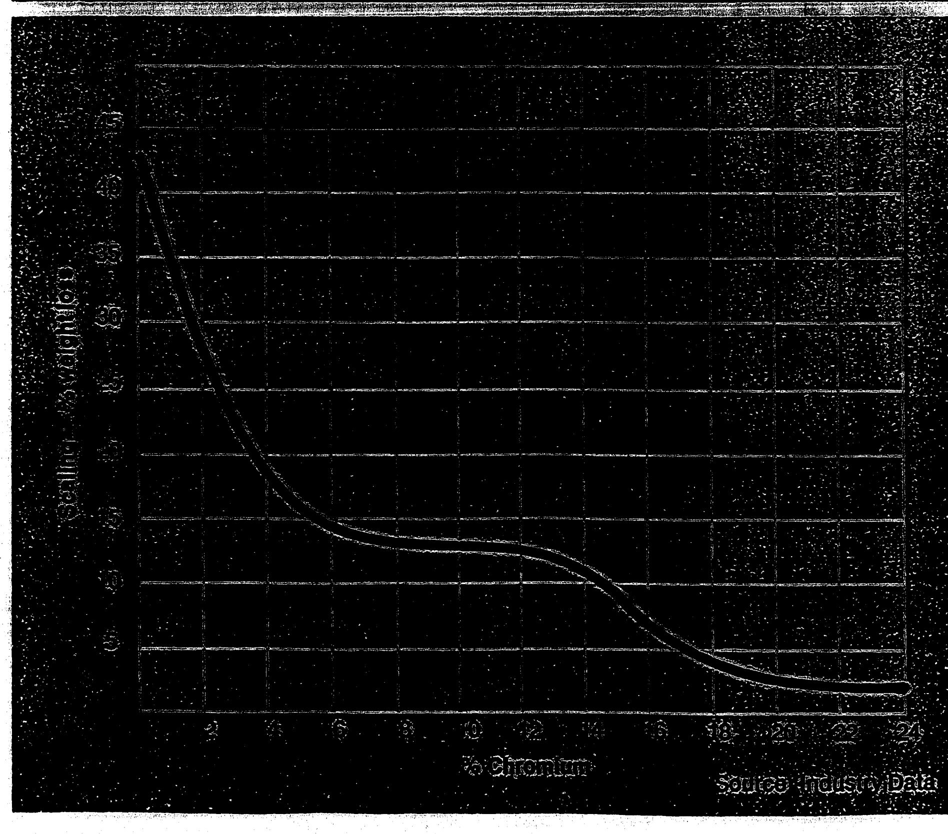
This practice is comparable to that for high-strength carbon steel structural bolts. However, it is slightly more liberal because of the generally shorter joint lengths in cold-formed stainless steel construction. For bolts not listed in Table 4, the allowable shear stress can be determind in the same manner.

TABLE 7—SCALING (OXIDATION) RESISTANCE OF TYPICAL STAINLESS STEEL FASTENER MATERIALS

AISI TYPE	MAX. CONTINUOUS SERVICE, AIR, °F	MAX. INTERMITTENT SERVICE, AIR, °F
303	1650	1400
304	1650	1550
305	1650	—
309	1950	1850
310	2050	1900
316	1650	1550
321	1650	1550
347	1650	1550
430	1550	1650
446	1950	2050
410	1300	1450
416	1250	1400

Source: Stainless Steel Industry Da

FIGURE 3. EFFECT OF CHROMIUM CONTENT ON SCALING RESISTANCE OF CHROMIUM-IRON ALLOYS (At 1800°F or 982°C)



High-and low-temperature service

The selection of stainless steel fasteners for high-temperature service is complex because of the many factors involved. Mechanical and physical properties have to be considered together with corrosion resistance.

In all bolted joints, the fasteners are tightened to some initial elastic

TABLE 8—CRYOGENIC PROPERTIES OF STAINLESS STEELS

AISI TYPE	Test Temperature		Yield Strength 0.2% Offset		Tensile Strength		Elongation % in 2" (5.08 cm)	% Reduction of Area	Izod-Impact	
	°F	°C	ksi	kg/mm²	ksi	kg/mm²			ft-lb	kg-m
304	−40	−40	34.0	24.0	155.0	109.0	47.0	64.0	110	15.2
	−80	−62	34.0	24.0	170.0	120.0	39.0	63.0	110	15.2
	−320	−196	39.0	27.0	221.0	155.0	40.0	55.0	110	15.2
	−423	−252	50.0	35.0	243.0	171.0	40.0	50.0	110	15.2
316	−40	−40	41.0	29.0	104.0	73.0	59.0	75.0	110	15.2
	−80	−62	44.0	31.0	118.0	83.0	57.0	73.0	110	15.2
	−320	−196	75.0	53.0	185.0	130.0	59.0	76.0	Not Available	
	−423	−252	84.0	59.0	210.0	148.0	52.0	60.0	Not Available	
430	−40	−40	41.0	29.0	76.0	53.0	36.0	72.0	10	1.4
	−80	−62	44.0	31.0	81.0	57.0	36.0	70.0	8	1.1
	−320	−196	88.0	62.0	92.0	65.0	2.0	4.0	2	0.3
410	−40	−40	90.0	63.0	122.0	86.0	23.0	64.0	25	3.5
	−80	−62	94.0	66.0	128.0	90.0	22.0	60.0	25	3.5
	−320	−196	148.0	104.0	158.0	111.0	10.0	11.0	5	0.7

Source: Stainless Steel Industry Data

FIGURE 4: WHEN COLD WORKING IS EMPLOYED SOME NORMALLY NON-MAGNETIC AUSTENITIC STEELS BECOME SUBSTANTIALLY MAGNETIC

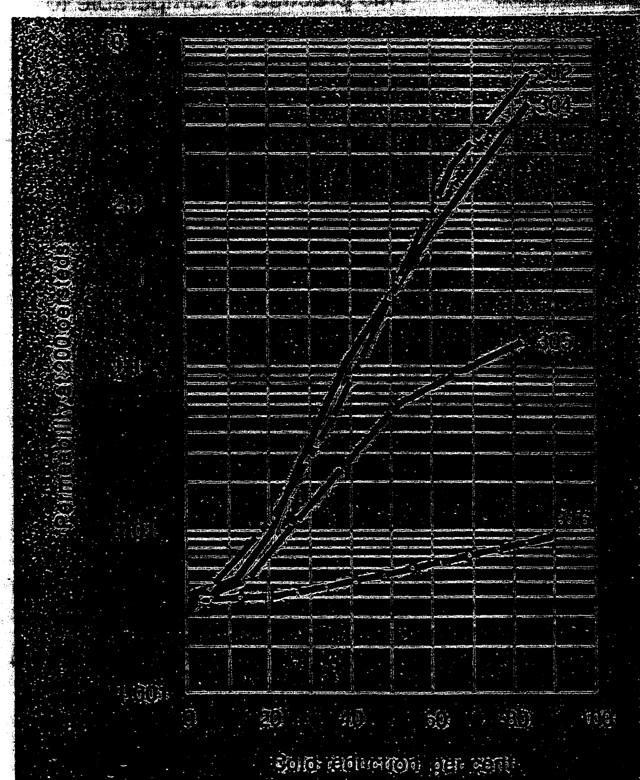
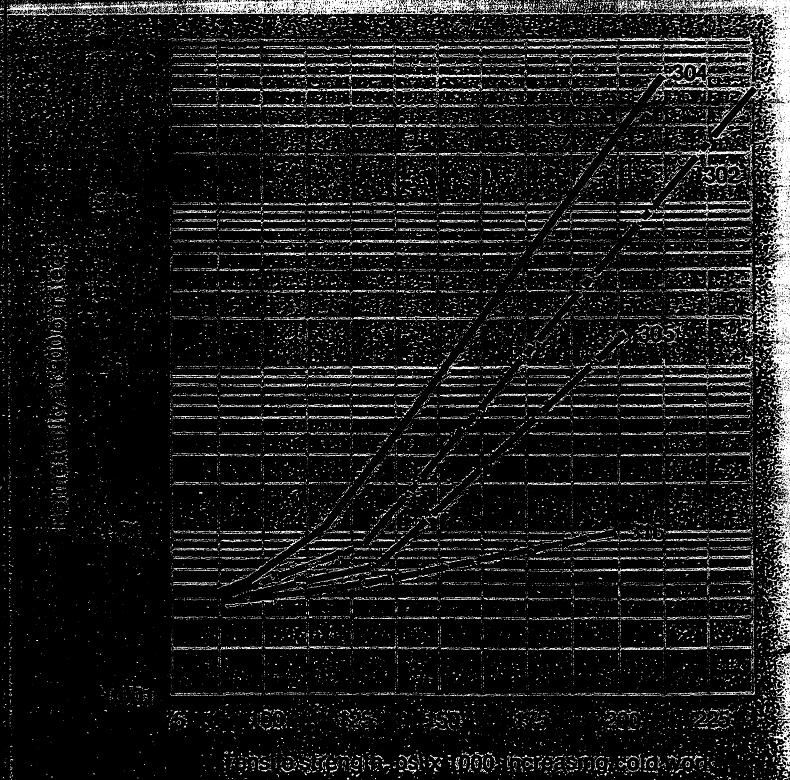


FIGURE 5: MAGNETIC PERMEABILITY OF AUSTENITIC ALLOYS SUBJECTED TO COLD WORKING CAN ALSO BE EXPRESSED AS A FUNCTION OF TENSILE STRENGTH



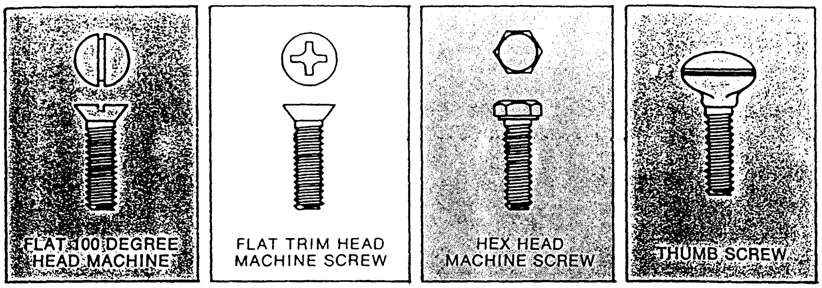
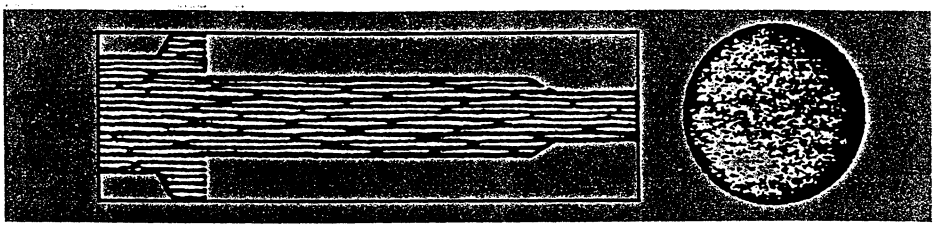
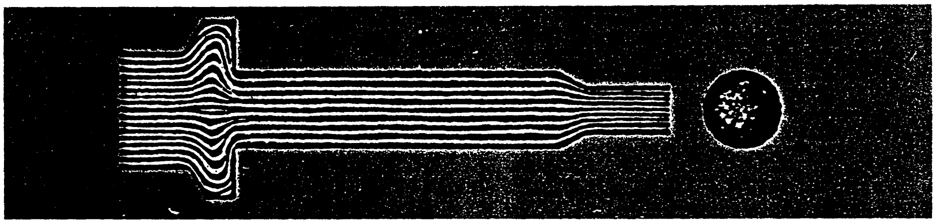


FIGURE 6. MACHINING



Illustrated above is the same part produced by machining from a large diameter bar or wire, shown to the right. Grain or metal flow lines are broken through the head and washer section, which creates planes of weakness.

FIGURE 7. COLD-HEADING



Illustrated above is a cold headed part formed from the diameter of wire shown to the right. Unbroken metal flow lines (grain) greatly increase fatigue life and enhance load-carrying ability.

stress and corresponding strain. At elevated temperatures, creep occurs in which some of the elastic strain is transformed to plastic strain with a corresponding reduction in stress. This behavior is termed relaxation. When bolts relax they no longer maintain a tight joint.

Resistance to creep, or relaxation, is an important consideration for fastener systems at elevated temperature. Table 5 shows creep values for several widely used stainless steels, some of which are readily available as "off-the-shelf" fasteners.

Other considerations for elevated-temperature service include thermal expansion characteristics and oxidation resistance.

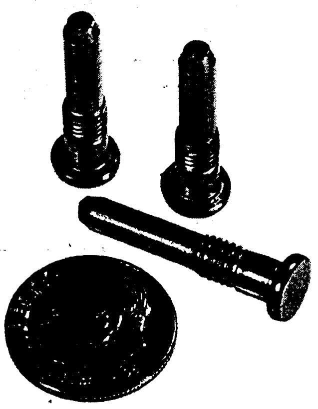
The thermal expansion of a fastener should match the expansion characteristics of the materials being fastened, with a logical conclusion that stainless steel fasteners are best for stainless steel base metal joints; otherwise, there can be overstressing and possible failure, or a rapid loss in clamping stress. Table 6 shows the thermal expansion characteristics of several corrosion resistant fastener materials.

The oxidation or scaling resistance of stainless steels under constant temperature condition is, for the most part, related to chromium content, as illustrated in Figure 3. In Table 7, scale resistance is expressed as temperature at maximum continuous service in air or maximum intermittent service (in which temperature cycling occurs).

As the high-temperature environment becomes contaminated by compounds of sulfur, carbon, hydrogen, and the halogens, the problem of materials selection becomes even more complex. Nevertheless, stainless steels are widely used in these environments. A fairly comprehensive discussion of their application is found in a publication by The International Nickel Company, "Corrosion Resistance of the Austenitic Chromium-Nickel Stainless Steels in High-Temperature Environments.[5]"

Of primary importance to the development of the world's natural gas supplies is the handling and storage of liquid natural gas (LNG). Fasteners have a role in LNG processing for piping and heat exchanger flanges, pumps, and various related equipment.

Austenitic stainless steels are the most widely used materials in cryogenic applications, especially Type 304, because it does not become brittle as it is chilled. Not only does Type 304 remain tough and ductile at LNG temperature—minus 260F (−162C)—but it retains excellent properties with liquid hydrogen (−423F or −253C) and liquid helium at −452F (−268C). Table 8 shows low-temperature mechanical properties of several stainless steels used in cryogenic service.



Magnetic and electrical properties

Magnetism, for purposes of this discussion, is the ability of a part to be attracted by a magnet and *not* the part's ability to function as a magnet. It is more accurately expressed as magnetic permeability, and it can be an important design consideration. One reason is the need to have a magnetic material for automatic assembly operations. On the other hand, some highly sophisticated electronic equipment may require materials with very low or nil magnetic permeability. Stainless steels can

satisfy either requirement.

The austenitic group of stainless steels have essentially low magnetic permeability in the annealed condition; i.e., they will not be attracted by a magnet. Some of the austenitic materials, however, are weakly attracted by a magnet after severe cold working. The effect of cold working on magnetic properties for a few common 18-8 stainless steels is shown in Figure 4. The magnetic permeability of the same group, but expressed as a function of tensile strength, is shown in Figure 5.

The straight-chromium, 400 Series stainless steels are always strongly magnetic. The degree of magnetic permeability, however, is affected by chemical composition and heat treatment. For highest initial permeability, the carbon content should be kept low; Types 416 and 430 should be fully annealed for the best magnetic behavior.

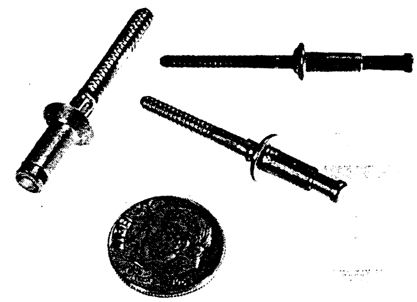
During annealing, a dry hydrogen atmosphere should be used to keep surfaces bright and free of contamination, such as carbon or nitrogen contamination which can decrease permeability.

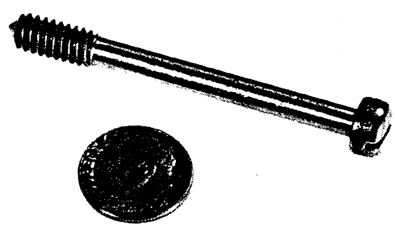
Chemical cleaning (passivation), which removes iron particles from the surface, may also improve permeability.

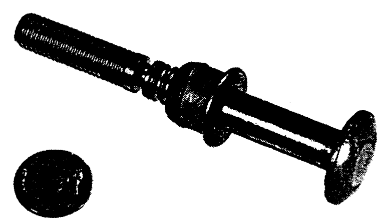
Electrical conductivity

The conductivity of a fastener material may be important, although good design seldom calls for a fastener to be a current-carrying member. Following are some conductivity values expressed as a percent of the International Annealed Copper Standard at 68F (20C).

Low silicon bronze (cold-formed fasteners)	12%
High silicon bronze (hot-formed and machined)	7%
Naval bronze	26%
Brass (cold formed)	27%
Brass (machined)	26%
Electrolytic copper	101%
Stainless Steel (18-8)	5%
Aluminum (2024-T4)	30%

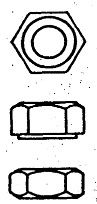




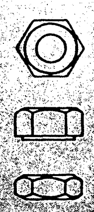


Manufacture of stainless steel fasteners

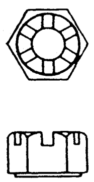
While designers seldom get involved in the manufacture of fasteners, it can be useful to know something about the processes involved. This can be especially true if the product requires a fastener of special design, such as the many



REGULAR HEX NUT
FULL AND JAM



FINISHED HEX NUT
FULL AND JAM



HEX SLOTTED
NUT

"specials" illustrated in the photographs throughout this booklet.

There are two basic methods for producing fasteners—machining and cold heading—both of which are applicable to stainless steels.

Machining is the oldest method for fastener production, and it is still specified for very large diameters and for small production runs. Machining, however, has a significant disadvantage, as illustrated in Figure 6. It disrupts metal grain flow and creates planes of weakness in the critical head-to-shank fillet area. The result is some loss in load-carrying ability and a drastic reduction in fatigue resistance.[6]

Cold heading is a method of forming wire into various shapes by causing it to plastically flow into die and punch cavities without preheating the material (Figure 7). Bolts, screws, nails and rivets have long been made by cold heading, but recent developments in this field have expanded the market for special fasteners.

Cold heading has many important advantages in both quality and economy. Production rates, for example, can exceed 12,000 parts per hour. Cold heading also cold works stainless steels, which results in significant increases in strength for the 300 Series types.

Following heading, the blank is ready for threading, which is frequently done by roll threading, another cold forming technique that preserves grain flow patterns.

There are other operations involved in fastener production, such as head slotting, shank slotting (for thread-cutting screws), head drilling, etc. But the making of and threading the blank are the two major processes.

TABLE 9—TORQUE GUIDE

BOLT SIZE	TYPE 304 ST. ST.	TYPE 316 ST. ST.
2-56	2.5	2.6
2-64	3.0	3.2
3-48	3.9	4.0
3-56	4.4	4.6
4-40	5.2	5.5
4-48	6.6	6.9
5-40	7.7	8.1
5-44	9.4	9.8
6-32	9.6	10.1
6-40	12.1	12.7
8-32	19.8	20.7
8-36	22.0	23.0
10-24	22.8	23.8
10-32	31.7	33.1
1/4"-20	75.2	78.8
1/4"-28	94.0	99.0
5/16"-18	132	138
5/16"-24	142	147
3/8"-16	236	247
3/8"-24	259	271
7/16"-14	376	393
7/16"-20	400	418
1/2"-13	517	542
1/2"-20	541	565
9/16"-12	682	713
9/16"-18	752	787
5/8"-11	1110	1160
5/8"-18	1244	1301
3/4"-10	1530	1582
3/4"-16	1490	1558
7/8"-9	2328	2430
7/8"-14	2318	2420
1"-8	3440	3595
1"-14	3110	3250
1 1/8"-7	413	432
1 1/8"-12	390	408
1 1/4"-7	523	546
1 1/4"-12	480	504
1 1/2"-6	888	930
1 1/2"-12	703	732

Source: ITT Harper

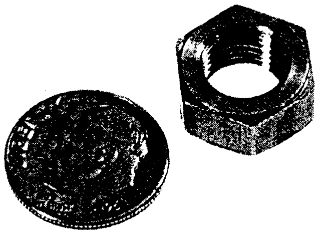
Suggested Max Torquing Values—a guide based upon industry tests on dry products wiped clean. Values thru 1" diameter are stated in inch pounds; over 1" diameter, in foot pounds. The 3/8" diameter and under metal products were roll-threaded and, where size range permitted, were made on Bolt Maker equipment.

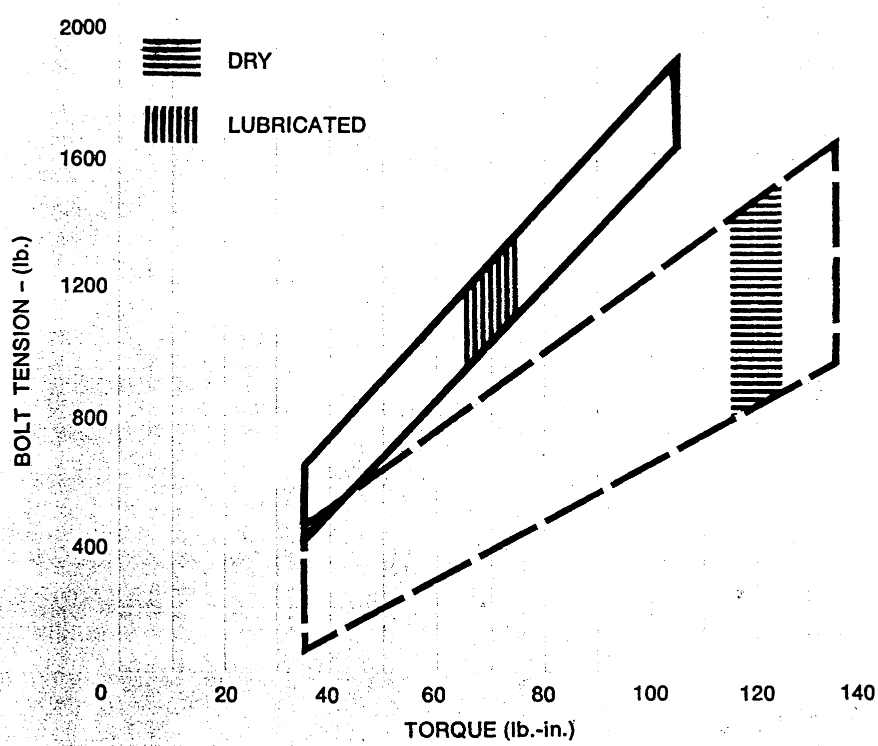
Plated coatings

Some designers may be inclined to think of plated fasteners as a low-cost solution to corrosion. While plated fasteners do serve a useful purpose in some applications, such as when a plated coating is added for purposes of creating a special finish or color match, it is far more desirable to use a fastener in which corrosion protection is inherent within the material itself and not just added to the surface.

Stainless steels do not need any form of protective coating for resistance to corrosion, in contrast with plain steel and some nonferrous fastener materials. While plated or

FIGURE 8. FASTENER LUBRICATION

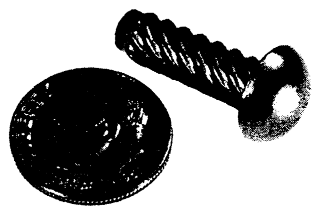


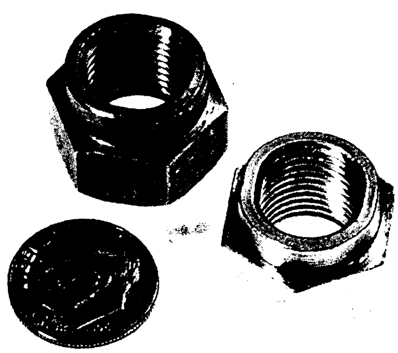


Effect of lubrication on torque-tension relationships is shown by the chart which is based on results obtained with 9/16-18 steel bolt driven into aluminum. For a non-lubricated bolt, torques of 115 to 125 lb.-in. were required to develop tensions of 800 to 1400 lb. For a lubricated bolt, torque values ranged from 65 to 75 lb.-in. for 1000 to 1250 lb. tension range.

Torque values are affected in various ways by different types of lubricants. Wax on either the bolt or nut, or both, also acts to reduce the torque requirements.

Source: Skidmore-Wilhelm Mfg. Co.

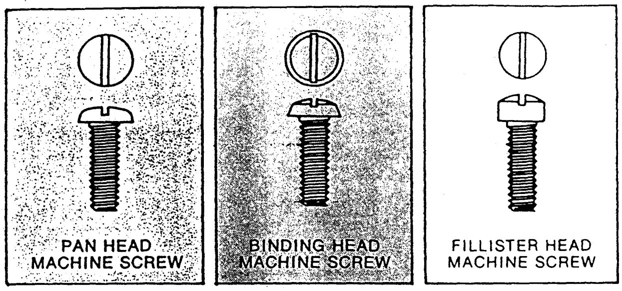


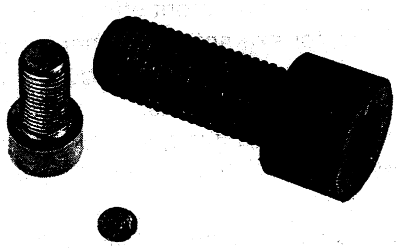


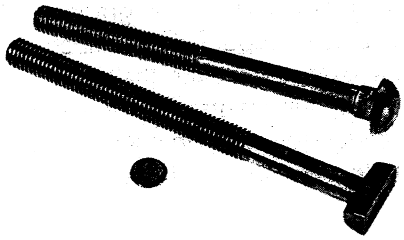
galvanized steel fasteners are adequate where corrosive conditions are not severe, many designers consider the extra cost of stainless steel fasteners as inexpensive insurance against possible failure or loss of eye appeal. When the cost of failure is considered, in conjunction with the ease in which damage can occur to a protective coating, it makes good sense to specify a fastener made of a material which is inherently corrosion resisting. Often, a minute discontinuity in a plated surface is all that is needed to lead to corrosive failure. Such discontinuities result from wrench or driver damage, poor plating practices, or simply from the turning action of thread against thread.

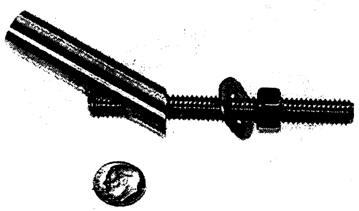
Furthermore, while the cost of stainless steel fasteners may be more than plated fasteners, the overall cost of the finished product (from a small appliance to a large plant) will generally be affected only by an insignificant amount.

Interestingly, plated coatings are applied to stainless steels for purposes of changing appearance. For instance, the designer may









want a black fastener, or a highly reflective chrome plated fastener to match the surfaces being joined. Such requirements can be accommodated in stainless steel.

Effective utilization of stainless steel fasteners

In order to have an effective fastener system, the designer should also be concerned with proper utilization, especially as to how the fasteners will be installed.

With any product, effective utilization requires knowledge of the product's characteristics as well as its proper use. Failure to follow accepted practices can lead to difficulties, such as seizing and galling, which can be encountered with fasteners made of any material including stainless steels. There are several courses of action open to designers that will minimize or eliminate such difficulties.

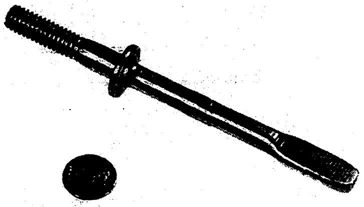
Fasteners made in accordance with nationally recognized standards, such as published by the American National Standards Institute, Inc., (ANSI), will assure that nuts and bolts are uniformly threaded. One of the common causes for galling is mismatched threads, or threads that are not uniform from shank or shoulder to point. Standards provide for product uniformity supported by quality control practices.

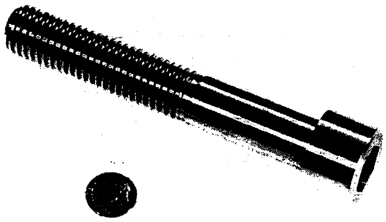
Reasonable care should be exercised in the handling of fasteners to keep threads clean and free of dirt, especially coarse grime or sand. If threads are tightened down on sand, the chance of galling or seizing—in any fastener material—increases significantly.

Torque, another consideration in a properly fastened joint, is the twisting force applied to a fastener. Table 9 offers some *suggested* maximum torque values for stainless steel fasteners. This table is a guide based on industry tests that provide maximum clamping values with minimum risk of seizing. The values are based on fasteners that are dry—free of any lubricant—and wiped clean of chips and foreign matter.

Most production lines are equipped with assembly tools that can be adjusted to specific torque values. The most trouble occurs when replacement is being made under conditions where torque tools are not available. There are some guidelines for these circumstances:

1) Tighten the nut finger tight—about one foot-pound of torque or less.
2) Tighten the nut one additional turn, 360 degrees, for proper torque. This is an arbitrary figure that applies primarily to 300 Series fasteners. For





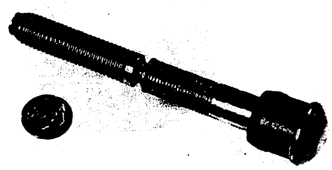


FIGURE 9. GALVANIC SERIES OF METALS AND ALLOYS

Magnesium Magnesium Alloys Zinc Aluminum 1100 Cadmium Aluminum 2024-T4 Steel Iron Cast Iron	Anodic More Likely to Be Attacked
Lead-Tin Solders Lead Tin Brasses Copper Bronzes Copper-Nickel Alloys	
Stainless Type 430 (Passive) Stainless Type 304 (Passive) Stainless Type 316 (Passive) Silver Graphite Gold Platinum	More Noble Cathodic

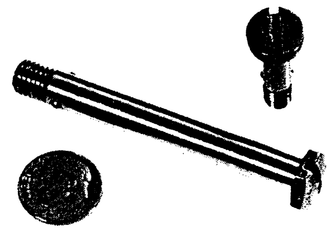
Source: ITT Harper

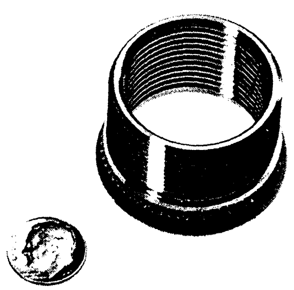
hardened and tempered 400 Series fasteners, this may be too high. In any event, a trial test should be conducted with a torque wrench for best results.

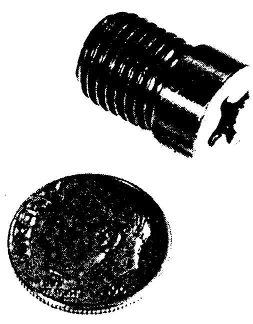
In service at elevated temperature, the buildup of oxides or scale on fastener surfaces may "fuse" threaded surfaces together. Regular loosening and retightening can prevent this from happening

Some engineers are of the opinion that the only way to avoid seizing and galling is to lubricate the threaded joint before it's assembled. Adding a lubricant can affect the torque-tension relationships, as shown in Figure 8. A lubricated fastener requires less torque to achieve the same degree of tension or clamping force. Different lubricants have different effects also. Wax, for example, on either the bolt or nut, or both, acts to reduce the torque requirements.

If a lubricant is going to be used, tests should be conducted to determine torque requirements and to evaluate the compatibility of the lubricant to the environment—such as high temperature. Among the popular lubricants are those which contain substantial amounts of molybdenum disulfide, graphite, mica, talc, copper or zinc fines, or zinc oxide. However, the zinc-bearing lubricants are not recommended for use with stainless steel at elevated temperatures.



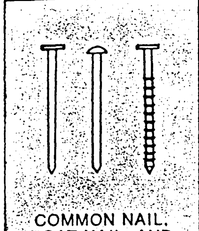




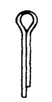
Designing for optimum corrosion resistance

The best approach in effectively combatting the destructiveness of corrosion in a fastener system is *prevention*.

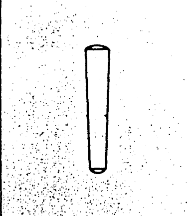
Since corrosion resistance is an important aspect of product reliability, inherent in any attempt to prevent corrosion is the careful selection of fastener materials. A common practice in industry is to use fasteners made of metals or alloys that are more corrosion



COMMON NAIL, BOAT NAIL, AND ESCUTCHEON PIN



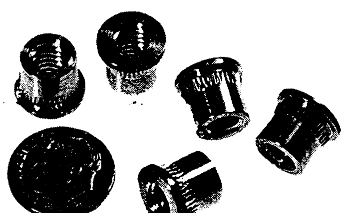
COTTER PIN

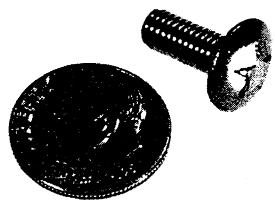


TAPER PIN

resistant than the materials they join. This practice is justified because the fasteners may have to withstand higher loads with greater unit stress than the parts they hold together. Also, corrosion-weakened fasteners may lead to a more immediate failure with more serious consequences than the same amount of corrosive attack elsewhere in the assembly.

Types of corrosion





Corrosion protection for a fastened joint encompasses much more than a consideration of the corrosion resistance of the fastener itself. Actually required is an analysis of the entire assembled joint as a system. This system includes structural design, materials, stresses, product life expectancy and environmental conditions.

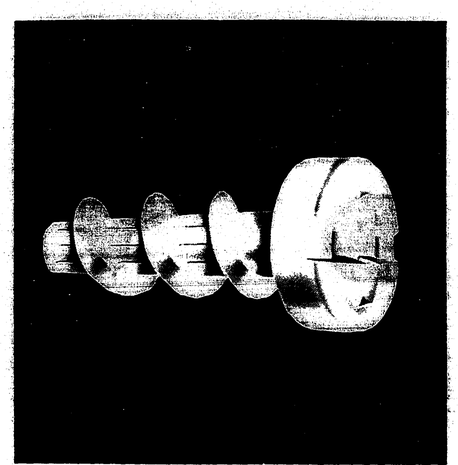
Because of the variety of special environmental conditions possible, the subject of corrosion is very complex. To simplify the subject, however, this discussion will attempt to put some of the more important factors in perspective.

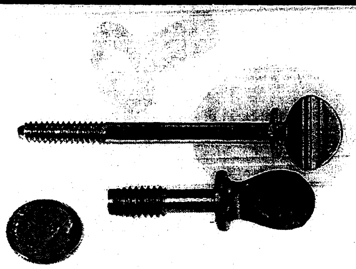
Corrosion is the wearing away or alteration of a metal either by direct chemical attack or by electrochemical reaction. There are several basic types of corrosion that may occur singly or in combination. The most prevalent form of attack in fasteners, however, is electrochemical in nature and can best be understood by a discussion of *galvanic* corrosion.

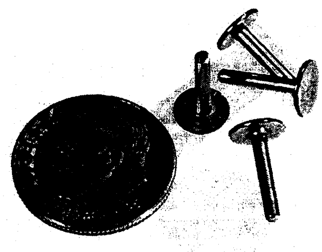
Galvanic Corrosion can occur when dissimilar metals are in contact in the presence of an electrolyte, which may be nothing more than a wet industrial atmosphere. When two different metals are in contact, in polluted water for example, in effect a battery is created, current flows, and one of the metals corrodes. In considering a bimetallic couple, it is important to know which of the two metals is more anodic (least noble). A guide to this is the arrangement of metals in the galvanic series chart shown in Figure 9. Any metal in this series will tend to have corrosion accelerated when it is coupled, in the presence of an electrolyte, with a metal in a lower position. The corrosion of this lower metal will tend to be reduced.

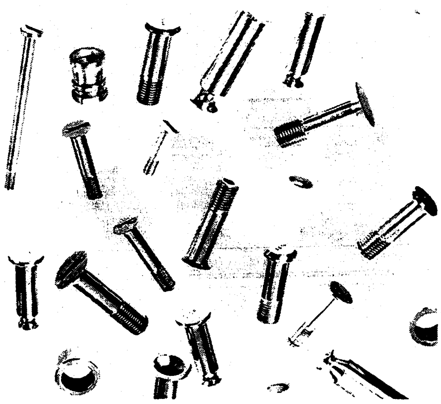
Some of the metals in the galvanic series, it will be noted, are in groups. Under ordinary circumstances no serious galvanic action will result from the coupling of metals within the same group. As is the case with the series as a whole, the safest galvanic combinations are those produced by metals located nearest each other. Conversely, the chance of serious corrosion effect is greater the further apart the metals are located in the series. For example, one of the worst galvanic joints would consist of magnesium and Type 316 stainless steel.

A very important factor to consider in evaluating the potential for galvanic corrosion problems is the relative surface area of the two different metals that are in direct (electrical) contact in an assembly. For example, steel is located above stainless steel in the galvanic series and is accordingly subject to accelerated corrosion when a galvanic couple is established. But the extent of this galvanic action depends on the relative area of each material. For instance, if small steel fasteners, such as rivets, are used to join stainless steel plates, and the assembly is immersed in water, the steel rivets will corrode









quickly. If, on the other hand, stainless steel rivets are used to join steel plates in water, both rivets and plates will suffer negligible galvanic attack, even in the immediate vicinity of the rivets. Aircraft designers, for instance, who specify stainless steel fasteners in aluminum structures depend upon this *area-relationship* principle. The greater the relative area of the anodic metal (the metal that corrodes), the less severe the corrosion.

The area relationship depends not only on the relative area of the materials in the structure, but also on the number of fasteners. Sometimes an acceptable balance of incompatible metals may be achieved by adjusting the number of fasteners used, or by relocating the fasteners to distribute them more uniformly to avoid a local condition of low relative area.

A general rule to remember is to use the more-noble metal for the part with the smaller surface area. This makes a good case for using stainless steel fasteners for joining metals that are less corrosion resistant. Table 10 provides guidelines for the selection of fasteners for various base metals. If the potential is high for galvanic corrosion in a fastened joint, it is possible to insulate the fastener.

Other types of corrosion of concern to the designer are direct attack, concentration cell corrosion or crevice attack, fretting, oxidation, stress-corrosion cracking, and corrosion fatigue.

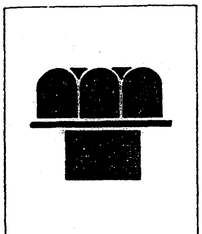
Direct Attack is the most common form of corrosion affecting all metals and structures. It is a direct and general chemical reaction of the metal with a corrosive environment—liquid, gas, or even a solid. Usually a material can be found that will provide the needed corrosion resistance. Stainless steels have resistance to a broad range of aggressive environments.

Concentration Cell Corrosion takes place where metals are in close proximity and, unlike galvanic corrosion, does not require dissimilar metals. When two or more areas on the surface of a metal are exposed to different concentrations of the same solution, such as under dirt or in crevices, a difference in electrical potential results, and corrosion takes place. To avoid such corrosion, keep surfaces smooth and minimize or eliminate lap joints, crevices, and seams. Surfaces should be clean of organic material and dirt. Bolts and nuts should have smooth surfaces, especially in the seating areas. Flush-head bolts should be used when possible.

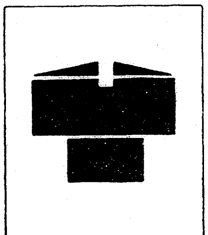
Fretting corrosive attack may occur between contacting, high-loaded metal surfaces subjected to very slight vibratory motion. It is most likely to occur in high tensile, high-frequency dynamically loaded applications, and it can be prevented by specifying fasteners with high hardness and requiring maximum preloading of the fastened joint. A higher clamping force results in a more rigid joint with less movement.

Oxidation is the reaction with oxygen, or other gases, at high temperatures. Some stainless steels have good oxidation resistance at high temperature. (See discussion of stainless steels for high-temperature service on page 16.)

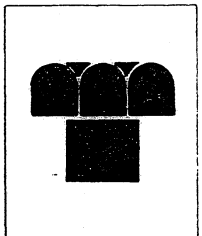
Stress-Corrosion Cracking is believed to be caused by the combined and mutually accelerating effects of a tensile stress and a corrosive environment—such as



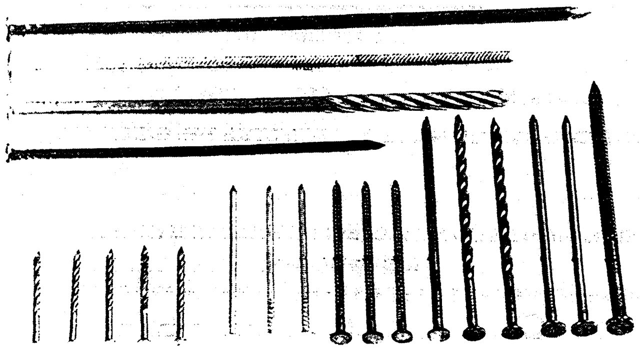
HEX WASHER

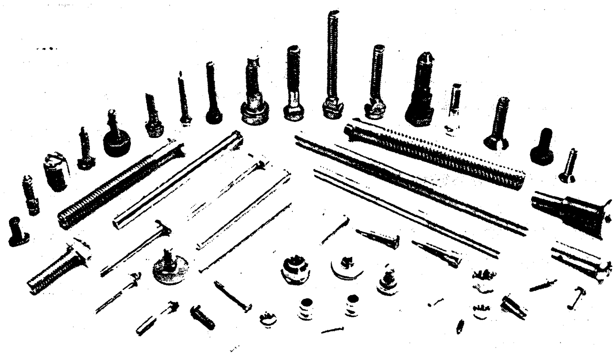


FILLISTER



HEXAGON





with copper-base alloys in a sulfur environment or with some stainless steels in chloride environments at elevated temperature. Methods of combatting stress-corrosion cracking include relieving the stress, removing the critical environment, or selecting a more corrosion-resistant stainless steel or a stainless steel (straight-chromium 400 series or proprietary grade) that is not subject to this phenomenon.

Corrosion Fatigue is accelerated fatigue failure occuring in a corrosive medium. It differs from stress-corrosion cracking in that dynamic alternating stress is the contributing factor. Factors extending fatigue performance are application and maintenance of a high preload, and proper alignment to avoid bending stresses.

Availability of stainless steel fasteners

A booklet, "Stainless Steel Fasteners Suggested Source List" published by the Committee of Stainless Steel Producers in 1975 identifies over 300 companies where stainless steel fasteners can be purchased. With the name and address of each company is a list of the fastener types available from that company. There are 62 fastener types listed, including bolts, nuts, screws, staples, washers, rivets, lock nuts, nails, studs, threaded rod, pins, cap screws, hooks, hose clamps, and specials.

References

1 "Steel Products Manual—Stainless and Heat-Resisting Steels," American Iron and Steel Institute, December 1974.

2 "Compilation of Trade Names, Specifications, and Producers of Stainless Alloys and Superalloys," ASTM Data Series DS 45, American Society for Testing and Materials.

3 "Mechanical and Quality Requirements for Stainless Steel and Nonferrous Bolts, Screws, Studs, and Nuts," IFI-104, a standard published by the Industrial Fasteners Institute of Cleveland, Ohio.

4 "Stainless Steel Cold-Formed Structural Design Manual," 1974 Edition, American Iron and Steel Institute.

5 "Corrosion Resistance of Austenitic Chromium-Nickel Stainless Steels in High-Temperature Environments," The International Nickel Company, 1963.

6 Varrese, F. R., "A User's Guide to Fastener Reliability," METAL PROGRESS, December 1974.

Acknowledgement

The Committee of Stainless Steel Producers acknowledges the data and materials that were received from the following:

Accurate Threaded Fasteners, Inc.
Adjustable Bushing Corp.
Ajax Hardware Corporation
Avibank Mfg. Inc.
Clendenin Bros. Inc.
Dzus Fastener Co., Inc.
Harvey Hubbell, Inc.
Hi-Shear Corporation
Huck Manufacturing Company
Lamson & Sessions
MacLean-Fogg Lock Nut Co.
Mid-West Fabricating Co.
West Bent Bolt Division
Rosan, Inc.
Standard Pressed Steel Co.
Stillwater Assoc.
Townsend Division of Textron Inc.

TABLE 10—GUIDELINES FOR SELECTION OF FASTENERS BASED ON GALVANIC ACTION

Fastener Metal → / ↓Base Metal↓	Zinc & Galvanized Steel	Aluminum & Aluminum Alloys	Steel & Cast Iron	Brasses, Copper, Bronzes, Monel	Martensitic Stainless Type 410	Austenitic Stainless Types 302/304, 303, 305
Zinc and Galvanized Steel	A	B	B	C	C	C
Aluminum and Aluminum Alloys	A	A	B	C	Not Recommended	B
Steel and Cast Iron	AD	A	A	C	C	B
Terne (Lead-Tin) Plated Steel Sheets	ADE	AE	AE	C	C	B
Brasses, Copper, Bronzes, Monel	ADE	AE	AE	A	A	B
Ferritic Stainless Steel (Type 430)	ADE	AE	AE	A	A	A
Austenitic Stainless Steel (Type 302/304)	ADE	AE	AE	AE	A	A

Key:
A. The corrosion of the base metal is not increased by the fastener.
B. The corrosion of the base metal is marginally increased by the fastener.
C. The corrosion of the base metal may be markedly increased by the fastener material.
D. The plating on the fastener is rapidly consumed, leaving the bare fastener metal.
E. The corrosion of the fastener is increased by the base metal.

NOTE: Surface treatment and environment can change activity.

Committee of Stainless Steel Producers
American Iron and Steel Institute
1000 16th Street, N.W.
Washington, D.C. 20036

The following companies are represented on the Committee of Stainless Steel Producers:

Airco Vacuum Metals, Division Airco, Inc.
Allegheny Ludlum Steel Corporation
Armco Steel Corporation
Atlas Steels, A Division of Rio Algom Ltd.
Carpenter Technology Corporation
ITT Harper
Jones & Laughlin Steel Corporation
Joslyn Stainless Steels
Republic Steel Corporation
United States Steel Corporation
Universal-Cyclops Specialty Steel Division,
  Cyclops Corporation
Washington Steel Corporation

The following alloy suppliers are also represented on the Committee:

Climax Molybdenum Company
Falconbridge International Ltd.
Foote Mineral Company
The International Nickel Company, Inc.
Union Carbide Corporation, Metals Division

Stainless Steel

Quality from American Labor

April 1976

AISI SS 502-476-18M-CP
Printed in U.S.A.