DESIGNER

HANDBOOK

with Directory of
Fastener Manufacturers

STAINLESS STEEL FASTENERS

A SYSTEMATIC APPROACH
TO THEIR SELECTION

Stainless Steel
The Value Option®

TABLE OF 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 consideration of high integrity fastener systems.

The 300 series stainless steels offer excellent corrosion resistance to most freshwater environments, but their yield strengths are low for some applications.

The 400 series stainless steels offer high mechanical strength, but have a tendency to pit and corrode in many freshwater systems.

The precipitation hardened stainless steels (e.g. 17-4 PH) provide alternative material considerations to meet both sets of criteria—strength and corrosion resistance—while the duplex stainless steels and super austenitic stainless steels offer excellent solutions for handling more aggressive environments.

Consequently, the designer needs to consider a fastener as a system, and regard the assembled joint as a critical and integral portion of the design, since the joint is normally an area under the 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.

ACKNOWLEDGEMENT

The SSINA wishes to acknowledge that some of the data contained in this handbook were originally prepared by the committee of Stainless Steel Producers, American Iron and Steel Institute.

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) in diameter; the largest has a head of 4 feet (1.219m).

Stainless steel 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.

STAINLESS STEEL FASTENERS

The stainless steel fastener materials are identified as the B8 class of alloys and are identified in the ASTM Specification A193/193M (Standard Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service). The corresponding nut specification is ASTM Specification A194/194M.

ASTM Specification F593 (Standard Specification for Stainless Steel Bolts, Hex Cap Screws and Studs) covers the broad range of commercial ferritic, martensitic and precipitation hardened grades of stainless steel, 0.25 to 1.5 inch nominal diameter.

These specifications cover the 300 series stainless steels and high manganese and high silicon austenitic grades, all of which are essentially 18-8 (18% chromium and 8% nickel) materials, with compositions very close to the nominal composition for Type 304. Because they have similar corrosion resistance properties, these 18-8 materials are often interchanged in fastener applications. If an application calls for Type 304, the designer can generally specify an 18-8 (Grade 8) fastener material.

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 “specials” illustrated in the photographs throughout this booklet.

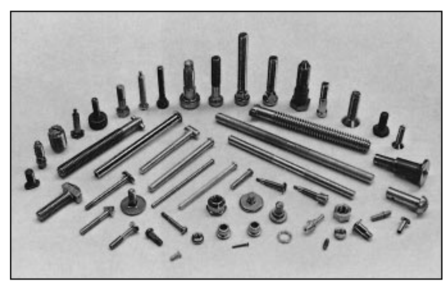
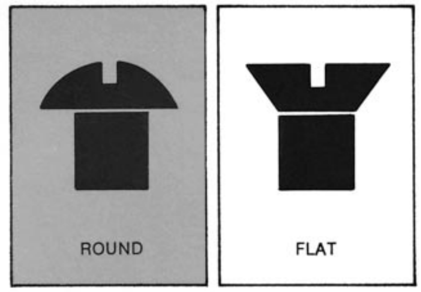


Table 1 **GRADE 8 FASTENER MATERIALS**

SYMBOL	ALLOY
B8/B8A	Type 304
B8C/B8CA	Type 347
B8M/B8MA/B8M2/B8M3	Type 316
B8P/B8PA	Type 305
B8N/B8NA	Type 304N
B8MN/B8MNA	Type 316N
B8MLCuN/B8MLCuNA	6% molybdenum alloy
B8T/B8TA	Type 321
B8R/B8RA	Nitronic 50
B8S/B8SA	Nitronic 60

Source: Stainless Steel Industry Data



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 of 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 1a. 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.

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 1b). 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.

The markings for stainless steel fasteners are defined in ASTM Specification A193/193M. The grades of stainless steel are also organized within classes, 1 through 2C. The grade, listed in Table 1 on page 1, and manufacturer's identification symbols can be found on the end of the stud or bolt that indicates conformance to the specification.

WHAT IS STAINLESS STEEL

Stainless steel is a family of iron-based alloys containing about 10.5% chromium or more, plus other alloying elements such as nickel, manganese, molybdenum, sulfur, selenium, titanium, etc. (See Table 2 on page 3.) 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 60 commercial stainless steel types were originally recognized by the American Iron and Steel Institute (AISI) as standard compositions. A complete listing of all stainless steels and a description of each are contained in the SSINA publication, *Design Guidelines for the Selection and Use of Stainless Steel.*

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 in either 200, 300, or 400 Series. In addition, all are identified by the Unified Numbering System (UNS). 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.

There are five primary classifications of stainless steel:

- Austenitic
- Martensitic
- Ferritic
- Precipitation hardening
- Duplex

Each characterizes its metallurgical structure, which, in turn, reflects different 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 can only be hardened by cold work and are non-magnetic 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

Figure 1a **METALLURGICAL METAL FLOW FOR MACHINED MATERIALS**

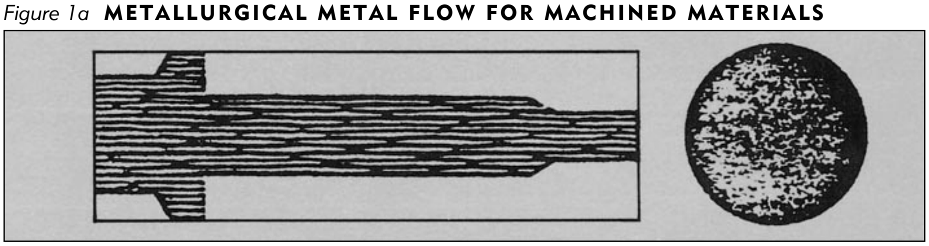
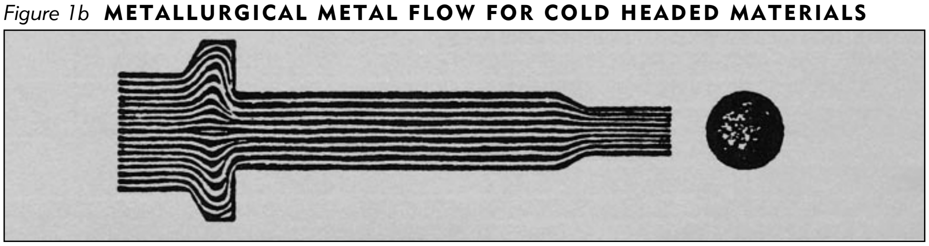


Figure 1b **METALLURGICAL METAL FLOW FOR COLD HEADED MATERIALS**



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 aging treatment and cold working. The AISI types are identified by UNS numbers only, e.g. 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 may result in distortion and scaling.

DUPLEX stainless steels are characterized by their 50% austenitic 50% ferritic structures which allow these materials to offer the corrosion resistance for the austenitic grades of material while providing higher design properties.

SUPER-AUSTENITIC stainless materials should be given consideration in those cases where aggressive chloride environments are encountered. They have higher nickel and molybdenum contents for improved pitting and crevice corrosion resistance.

STAINLESS STEEL CHARACTERISTICS

The austenitic stainless steels are characterized as having excellent corrosion resistance. For example, Type 304 is the most widely used material that withstands ordinary rusting. It is virtually immune to

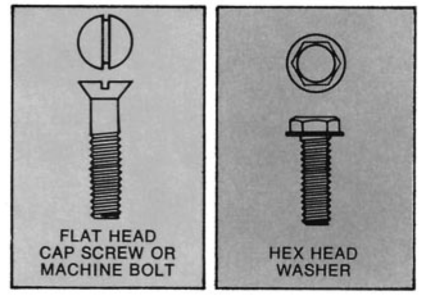
Table 2 **CHEMICAL COMPOSITION LIMITS OF RAW MATERIAL (ASTM F593-91)**

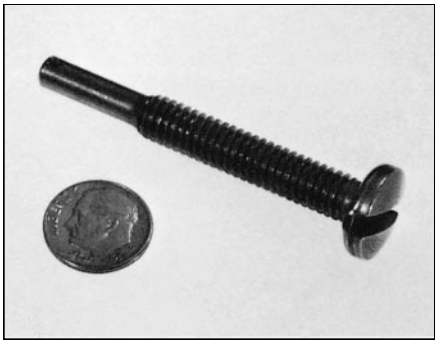
GRADE	GENERAL DESCRIPTION OF MATERIAL	SPECIFICATIONS[1] COVERING RAW MATERIALS REQUIREMENTS	CHEMICAL COMPOSITION, % MAX (UNLESS SHOWN AS MIN OR MAX/MIN LIMITS GIVEN)									
			STAINLESS STEEL									
			C	Mn	P	S	Si	Cu	Mo	Ni	Cr	Other
303	Austenitic Stainless Steel	ASTM A276 Type 303 QQ-S-764 Class 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	—
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	0.060	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	—
17-4 PH	Precipitation Hardened Austenitic Stainless	ASTM A564 AISI 630	0.07	1.00	0.040	0.030	1.00	3.0 to 5.0	—	3.0 to 5.0	15.00 to 17.50	See Note (4)
2205	Duplex Stainless Steel	ASTM A479 ASTM A276	0.03	2.00	0.030	0.015	1.00	—	3.20	5.50	22.00	N 0.18

NOTES TO TABLE 2

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.
4. Cb & Ta 0.15 to 0.45

*Type S30430





foodstuffs, sterilizing solutions, most organic chemicals and dyestuffs, and a wide variety of inorganic chemicals. In fact, the 18-8 austenitic stainless steels are used in the food and beverage, pharmaceutical and electronic chip industries, because they maintain product purity, with the minimum of contamination.

A general characterization for stainless steels in handling these environments is summarized as follows:

Category	Type	Corrosion Resistance
Austenitic	316	Superior
	304	Excellent
Duplex	2205	Superior
Precipitation Hardened	17-4	Excellent
Ferritic	430	Good
Martensitic	410	Fair

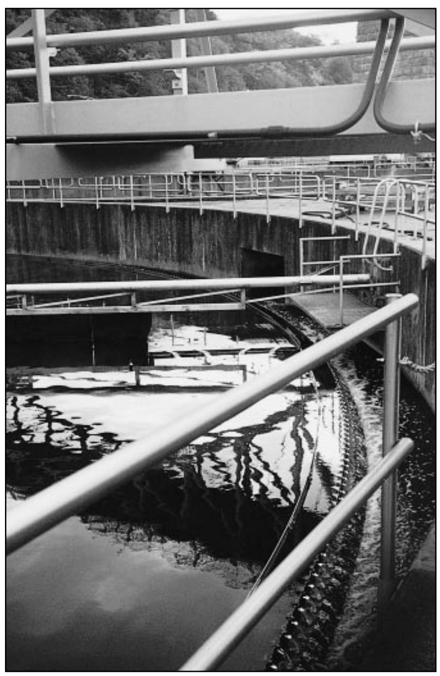
This guideline can be helpful in narrowing down the choice of materials for any given corrosive environment. The final determination, however, should be based on tests conducted under actual working conditions. If this is not practical for a designer, he should consult with a corrosion engineer having experience with stainless steels.

CORROSION RESISTANCE

Chromium is the element that provides the stainless steel with its "stainless" name. Generally those alloys with greater than 12% chromium in their composition will not rust. The martensitic grades of material (such as Type 400) offer marginal or lower corrosion resistance than the 300 series stainless steel for this reason.

However, type 410, performed well in mild atmospheres, fresh water, mine

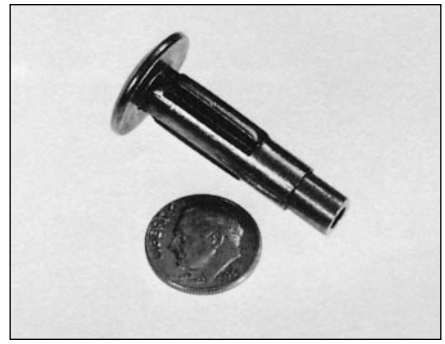
This photograph shows a secondary clarifier retrofit at a municipal wastewater treatment plant.



This is a close up of the weirs of the clarifier and shows the use of 316 stainless steel bolting.

water, steam, carbonic acid, crude oil, gasoline, blood, alcohol, ammonia, mercury, soap, sugar solutions and other reagents. It also has good scaling and oxidation resistance up to 1000F (649C). Type 416 is a free-machining variation of Type 410 and has similar characteristics.

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 provides



improved pitting and crevice corrosion-resistant properties, especially in environments containing chlorides. It has wide application in pulp and paper mills and water treatment plants (see photograph of clarifier construction, bolted weirs and handrail). It is also widely used in phosphoric and acetic acids that tend to cause pitting corrosion in the 18-8 types.

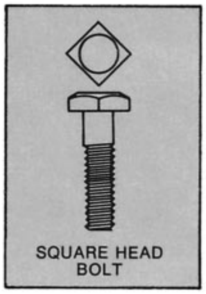
In more aggressive pitting environments, those materials with higher levels of molybdenum should be considered. For further guidance on material selection, consult with a corrosion engineer.

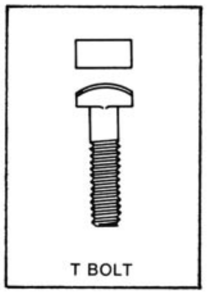
STRENGTH

Nickel is added to the iron-base alloys to provide fabricability and improved ductility. It is a primary austenite former that directly benefits the workability characteristics for these alloys. Carbon and nitrogen directly impact the strength of these alloys. The nitrogen variant of these alloys will offset the loss of mechanical properties of low carbon grades of austenitic stainless steels.

Alternatively, the addition of aluminum, titanium and/or columbium to the austenitic stainless steel chemistry can significantly increase the mechanical properties for these materials through heat treatment (ageing). Types UNS S13800, UNS S15500, UNS S17400 and UNS S17700 are used to advantage by designers in the aerospace industry or in the manufacture of large diameter bolting for major civil engineering requirements.

Mixed structures (ferrite/austenite), typical of the duplex stainless steels, will also provide higher strength characteristics than those of the fully austenitic grades, while retaining excellent corrosion properties.





MACHINABILITY

The addition of sulfur and selenium to the austenitic grades of material improves the machinability of these alloys. These elements, in combination with the chromium and manganese in these alloys, form stringer like inclusions in the structure, which allow better chip removal.

For instance, Type 303 has a considerably higher sulfur content that enhances machining characteristics. This property might be very beneficial in the production of large bolts or where small production runs or specials are needed.

However, it should be recognized that while the 18-8 stainless steels are considered to have similar corrosion resistance to one another, the sulfide stringers in Type 303 can result in end grain attack at cut ends, especially when exposed to water or some chemical solutions. Accordingly, a designer should specify Type 304 when it is known that Type 303 is not suitable for the application. When in

Table 3 **MECHANICAL REQUIREMENTS FOR STAINLESS STEEL BOLTS, SCREWS, STUDS AND NUTS (ASTM F593-91)**

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

* Type 30430

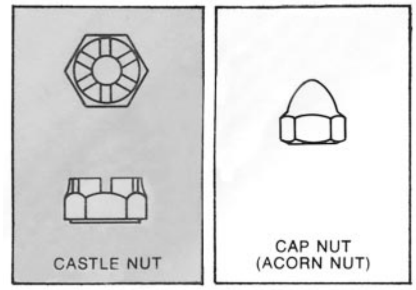
KEYS TO TABLE 3

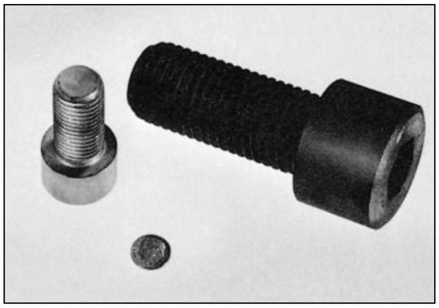
1. Legend of grade designations: —
   A—solution annealed
   SH—strain hardened
   H—hardened and tempered at 1100 F min.
   HT—hardened and tempered at 525 F± 50 F
2. Yield strength is the stress at which an offset of 0.2% of gauge length occurs for all stainless steels.
3. Elongation is determined using a gauge length of 2 in. or 4 diameters of test specimen in accordance with Federal Standard 151, Method 211.

NOTES

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 3 by the stress area for the product size and thread series as given in Table 5.
5. Proof loads of nuts (in pounds) may be computed by multiplying the proof load stress as given in Table 3 by the stress area for the nut size and thread series given in Table 5.
6. Ausenitic stainless steel, strain hardened bolts, screws, studs and nuts shall have the following strength properties:

	BOLTS, SCREWS, STUDS				NUTS
	TESTED FULL SIZE		MACHINED TEST SPECIMENS		
PRODUCT SIZE in.	YIELD STRENGTH min ksi	TENSILE STRENGTH min ksi	YIELD STRENGTH min ksi	TENSILE STRENGTH min ksi	PROOF LOAD STRESS ksi
to ⅝ in.	100	125	90	115	125
over ⅝ to 1 in.	70	105	65	100	105
over 1 to 1½ in.	50	90	45	85	90





doubt, the designer should consult with a corrosion engineer.

Type 416-ferritic stainless steel also has sulfur in its composition in order to provide improved machinability for the martensitic grades of stainless steel.

COLD HEADING QUALITY

The addition of copper in Type 302 stainless steel (UNS S30430) and higher levels of nickel in Types 305 (UNS S30500) and 384 (UNS S38400) results in lower work-hardening rates, which allows improved cold heading and workability for these grades of material. This is very desirable for lower costs and for large production runs.

These materials have been used for fasteners, cold headed bolts, screws, upset nuts, instrument parts and jobs involving severe coining, extrusion and swaging.

APPEARANCE/ AESTHETICS

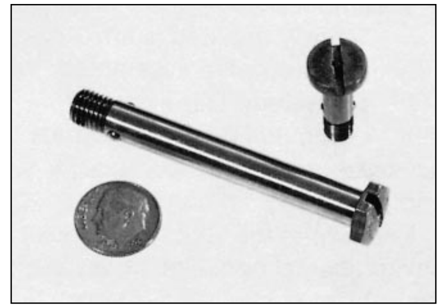
Type 304 and 316 fasteners have been used extensively in architectural applications for both their eye appeal and their structural and corrosion properties (see photograph of handrails and sign supports at Ronald Reagan Washington National Airport).

Some applications do not require the high degree of corrosion resistance offered by the 18-8 stainless steels or the higher alloyed types. In these cases, the designer can consider types that 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.

STAINLESS STEEL— NO PROTECTIVE COATING NECESSARY

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.

Bolting applications at the Ronald Reagan National Airport, Washington, DC.



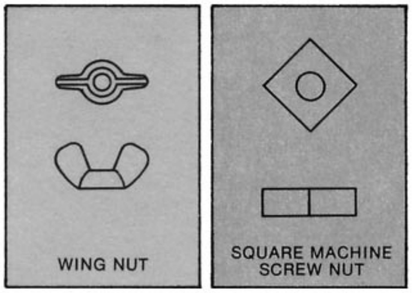
Stainless steels do not need any form of protective coating for resistance to corrosion, in contrast with plain steel and some nonferrous fastener materials. While plated or galvanized steel fasteners are adequate where corrosive conditions are not severe, many designers consider the extra cost of stainless 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 resistant. 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.

CHOOSING THE RIGHT STAINLESS STEEL

Once the design engineer has determined the correct candidate fastener materials on the basis of their corrosion-resistant properties, the next concern probably will be the mechanical and physical properties



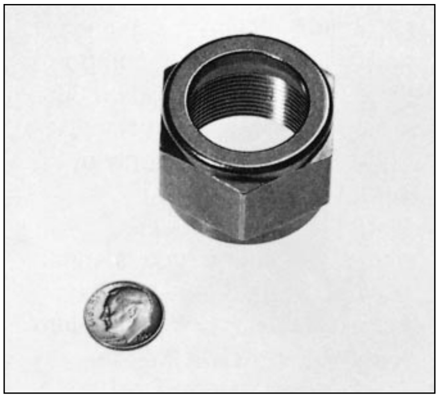


Table 4 **STRENGTH-TO-WEIGHT RATIO**

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

of these materials. Once again, the family of stainless steels offers a wide choice.

Many engineers who have attempted to design a product using stainless steel fasteners have 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.

ASTM Specifications A193/193M, A194/194M, F593 and F594 provide the reference base for material selection and specification purposes.

The original Industrial Fasteners Institute (IFI) specification—IFI-104—that covered the mechanical, metallurgical and quality requirements of the common stainless steels used for bolts, screws, studs, and nuts, has been replaced by the respective ASTM specifications relating to these materials and their product forms, e.g., ASTM specifications F467/467M, F468/468M, F738M, F836M, F837/837M, F879/879M and F880/880M.

TENSILE AND YIELD STRENGTH

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, before assuming a permanent set under load. For stainless steels, the yield strength is calculated on a stress-strain diagram (Figure 2), 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. For stainless steel, the yield point is not a clear-cut, identifiable point.

It can be seen from the data in Table 3 on page 5 that there is a considerable spread between the tensile and yield strength values, which is characteristic of stainless steels. The yield strength is used for design calculations and is the stress at which the mechanical properties (tensile and yield strengths) can be increased by cold work or strain hardening.

The ASTM specification clearly distinguishes these finished conditions as:

CLASS 1 - Carbide solution annealed
CLASS 2 - Carbide solution annealed and strain hardened.

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 (345 MPa) minimum. Cold worked from 35 to 40%, the material is considered to be "strain-hardened" and the minimum yield strength level is as high as 100 ksi (690 MPa), depending upon size of the fastener. This condition allows the design engineer to specify and take advantage of a corrosion resistant material with higher strength criteria.

Likewise, the characteristics of the stress-strain curve can be changed by heat treatment and ageing of the precipitation hardened stainless steel and hardening and tempering of the martensitic grades of stainless steel. The different conditions are designated by a letter;

A - Solution annealed
SH - Strain hardened
H- Hardened
HT - Hardened and tempered
AH - Age hardened

Figure 2 **YIELD STRENGTH— DETERMINED BY OFFSET**

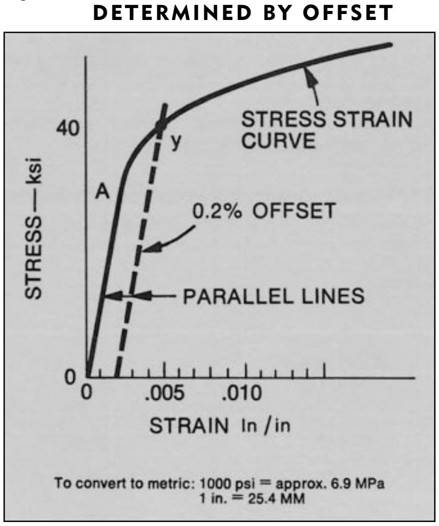


Figure 3 is a relative comparison of strength values between stainless steels and other corrosion resistant fastener materials. In applications where weight is an important consideration, as in aircraft design, designers look to strength-to-weight ratios for an indication of the most efficient material 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 4 on page 7. 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.

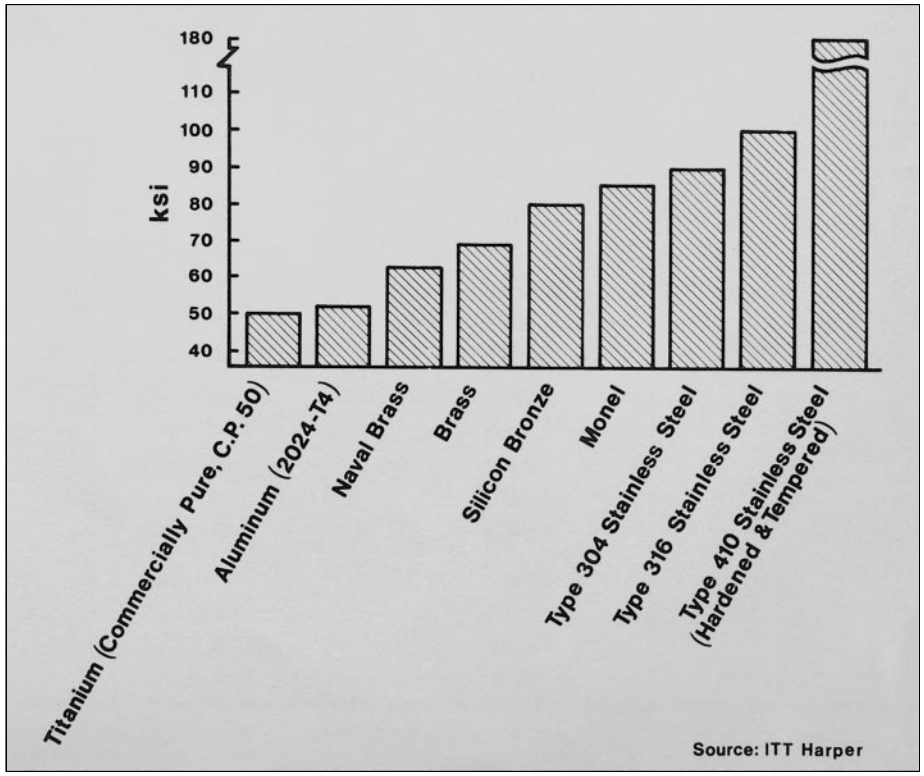
ANCHORS

There are a number of types of mechanical anchor systems—inserts; wedge-type; drop-in; shell-type; sleeve-type. All types can be considered for anchorage into concrete. Sleeve-type anchors can be considered for use in masonry, grout filled block and hollow block.

Unlike mechanical anchors, which exert pressure on concrete when expanded, chemical anchors using adhesives provide secure fastening in which the load is distributed along the length of the anchor. These systems are suitable for anchoring concrete and hollow masonry applications.

The austenitic stainless steels provide excellent corrosion resistance in a wide variety of masonry and concrete environments, where high alkalinity (pH) is prevalent. They also provide axial strength in wall tie systems to withstand wind loadings and tension and compression stresses in accommodating normal building movement.

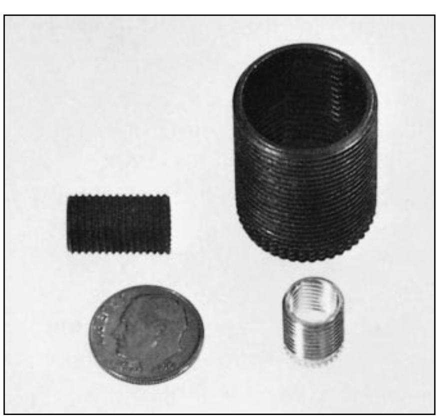
Figure 3 **TENSILE STRENGTH OF NINE FASTENER ALLOYS**

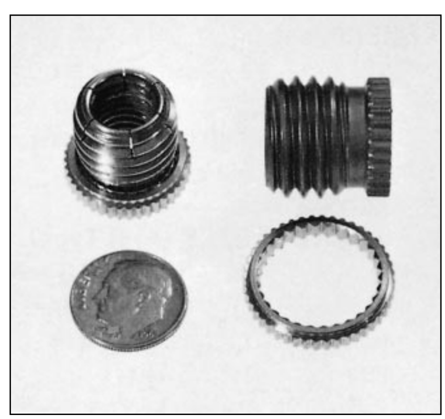


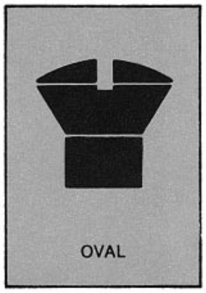
DESIGNING & ENGINEERING CONSIDERATIONS

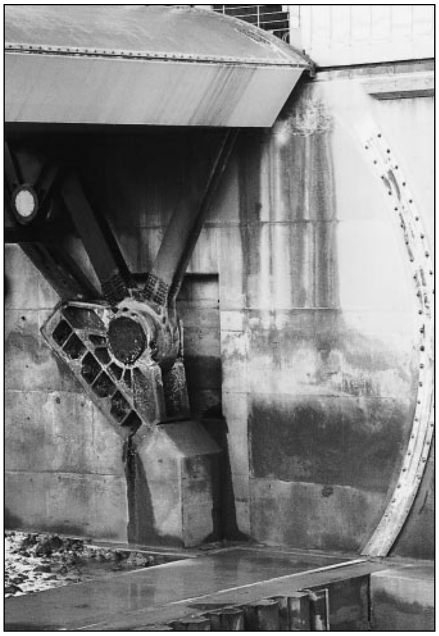
In selecting a stainless steel on the basis of mechanical and physical properties, designers should keep in mind the following considerations.

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 and 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 ser-









This is a photograph of a sluice gate (open position) on the Thames River Barrier in London. Monel alloy K-500 bolting was used for all the structurals.

Table 5 **TENSILE STRESS AREAS AND THREADS PER INCH**

PRODUCT SIZE DIA. in.	COARSE THREAD (UNC) STRESS AREA sq in.	COARSE THREAD (UNC) THREADS per in.	FINE THREAD (UNF) STRESS AREA sq in.	FINE THREAD (UNF) 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

vice loads. Design characteristics are based on the number of threads per inch of stock and the bolt diameter, as shown in Table 5. This can be important in civil engineering applications as shown in the sluice gate photograph.

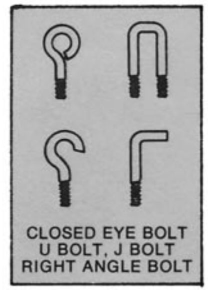
SHEAR STRENGTH - Shear is transverse rupture. It is caused by a pushing or pulling force at 90° from the axis of a part. Thus, a rivet used as a pulley axle will shear if the load on the pulley exceeds the shear value of the rivet. Shear strength is defined as the load in pounds to cause rupture, divided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

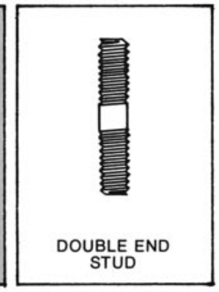
The allowable shear stresses for stainless steel bolts are given in Table 6, which is based on the AISI publication, "Stainless Steel Cold-Formed Structural Design Manual, 1974 Edition." The allowable shear stress for bolts with no threads in the shear plane was taken as 60% of the minimum tensile strength 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

Table 6 **ALLOWABLE SHEAR STRESS FOR STAINLESS STEEL BOLTS**

Type	Finish	Condition and Specification	Diameter d (in.)	Minimum Tensile Requirements: 0.2% Yield Strength (ksi)	Minimum Tensile Requirements: Tensile Strength (ksi)	Allowable Shear Stress (ksi): No Threads in Shear Plane	Allowable Shear Stress (ksi): 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	≤ 1/2	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*	≤ 3/4	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.





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 1/4 to 3/4 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 6, the allowable shear stress can be determined in the same manner.

TORQUE - Another consideration in a properly fastened joint is the twisting force applied to a fastener. Table 7 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.

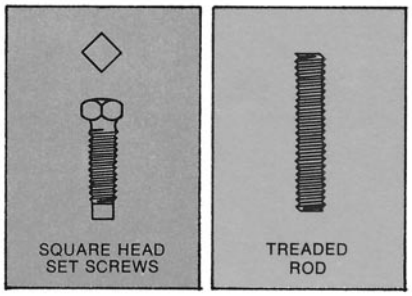
Most production lines are equipped with assembly tools that can be adjusted

Table 7 **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
¼"-20	75.2	78.8
¼"-28	94.0	99.0
5/16"-18	132	138
5/16"-24	142	147
⅜"-16	236	247
⅜"-24	259	271
7/16"-14	376	393
7/16"-20	400	418
½"-13	517	542
½"-20	541	565
9/16"-12	682	713
9/16"-18	752	787
⅝"-11	1110	1160
⅝"-18	1244	1301
¾"-10	1530	1582
¾"-16	1490	1558
⅞"-9	2328	2430
⅞"-14	2318	2420
1"-8	3440	3595
1"-14	3110	3250
1⅛"-7	413	432
1⅛"-12	390	408
1¼"-7	523	546
1¼"-12	480	504
1½"-6	888	930
1½"-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 ⅜" diameter and under metal products were roll-threaded and, where size range permitted, were made on Bolt Maker equipment.



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.

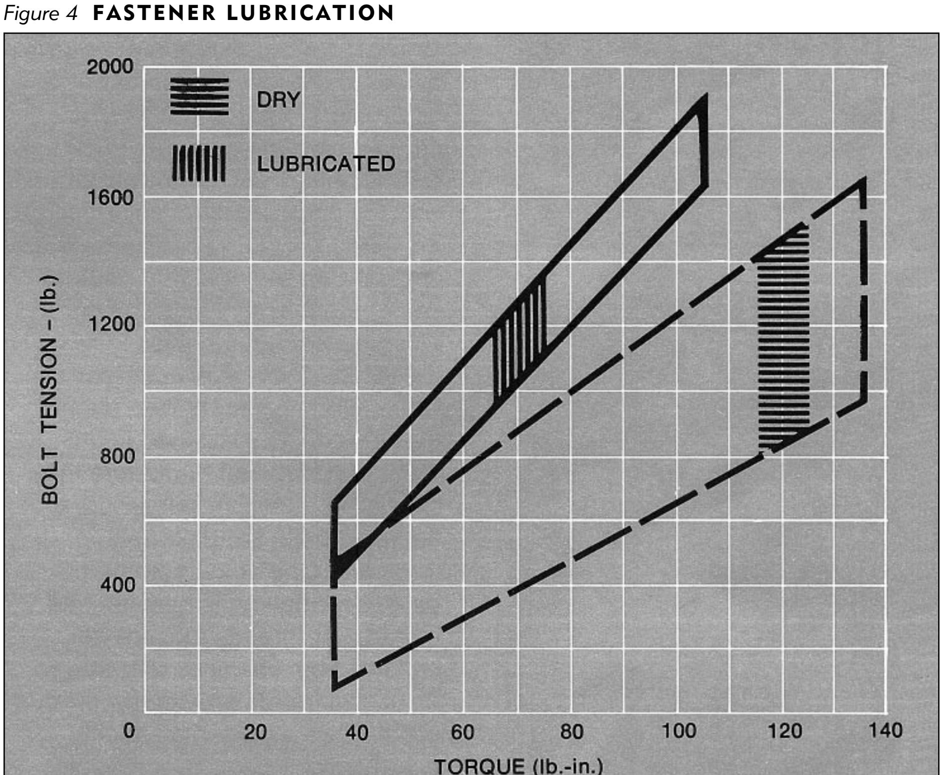
2. Tighten the nut one additional turn, 360 degrees, for proper torque. This is an arbitrary figure that applies primarily to 300 Series fasteners. For hardened and tempered 400 Series fasteners, they may be too high. In any event, a trial test should be conducted with a torque wrench for best results.

In service at elevated temperature, the buildup of oxides or scale on fastener surfaces may "fuse" threaded surfaces together. Regular loosening and re-tightening 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 4. 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- and copper-bearing anti-seize lubricants are not recommended for use with stainless steel.

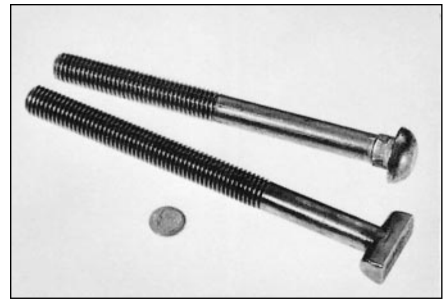
Figure 4 **FASTENER LUBRICATION**

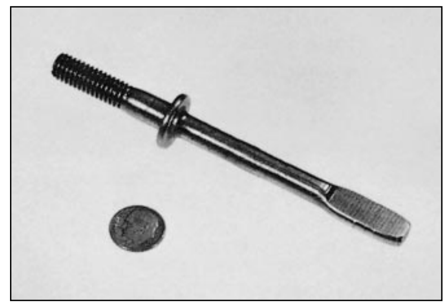


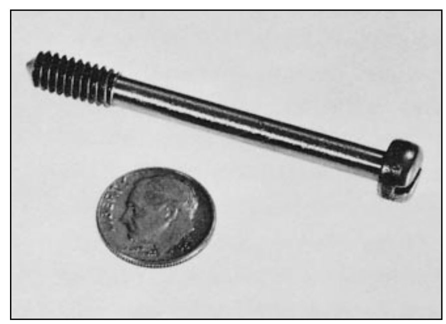
Effect of lubrication on torque-tension relationships is shown by the chart which is based on results obtained with 9/16-18 steel bolt driven into aluminum. For a non-lubricated bolt, torques of 115 to 125 lb.-in. were required to develop tensions of 800 to 1400 lb. For a lubricated bolt, torque values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





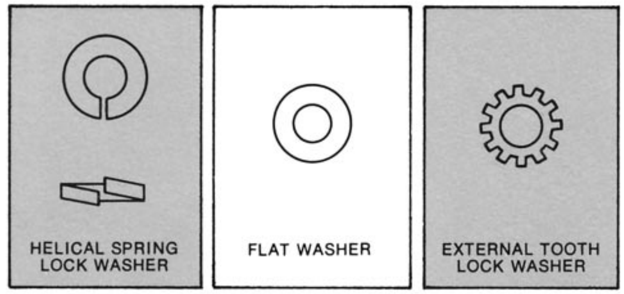


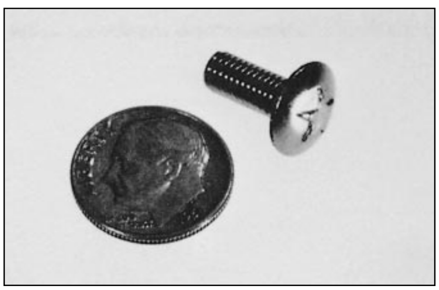
GALLING & SEIZING

To have an effective fastener system, the designer should also be concerned with proper utilization, especially 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.

One of the common causes for galling is mismatched threads, or threads that





are not uniform from shank or shoulder to point. Fasteners made in accordance with nationally recognized standards, such as those published by the American National Standards Institute, Inc., (ANSI), will assure that nuts and bolts are uniformly threaded.

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

DESIGNING FOR OPTIMUM CORROSION RESISTANCE

Corrosion protection for a fastened joint encompasses much more than a consideration of the corrosion resistance of the fastener itself. By their very nature, fastener systems represent inherent crevices (under aqueous conditions) and notches (fatigue; corrosion fatigue impact), if not designed or specified correctly for the conditions of operation. An analysis of the entire assembled joint as a system is required, which would include evaluation of the structural design, materials, stresses, product life expectancy and environmental conditions.

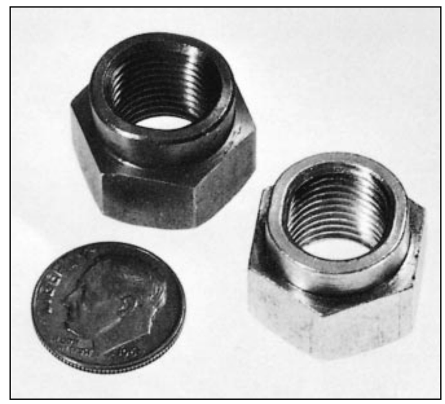
Since corrosion resistance is an important aspect of product reliability, inherent in any attempt to prevent corrosion is the careful selection of fastener materials. A common practice in industry is to use fasteners made of metals or alloys that are more corrosion resistant than the materials they join.

The austenitic stainless steels, with more than 12% chromium in their chemistry, provide corrosion resistance to a wide variety of environments and especially in low chloride waters (less than 2000ppm chlorides). Additionally, stainless steel is invariably more noble (cathodic) than the structural members they join, and are therefore protected by them.

The “stainless” characteristics of these materials make them ideal fasteners for many architectural applications and suitable for atmospheric (indoor and outdoor) services.

This photograph shows a secondary clarifier retrofit at a municipal wastewater treatment plant.

Bolting applications at the Ronald Reagan National Airport, Washington, DC.



AQUEOUS CORROSION

Corrosion is the wearing away or alteration of a metal either by direct chemical attack or by electrochemical reaction. This can lead to a weakened or impaired structural system, which could result in downtime, replacement and repairs.

Overall corrosion loss, reflected by weight loss, is the most common form of attack. More serious attack can often be seen in the form of localized pitting and pitting attack. This is especially prevalent in chloride and acid chloride types of environments. If the environment cannot be controlled, modified or changed, then materials with higher corrosion resistance may have to be considered.

There are several basic types of corrosion that may occur, singly or in combination, necessitating an understanding of material selection for basic design guidelines.

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 with one another, in the presence of a liquid, a battery cell is created, allowing

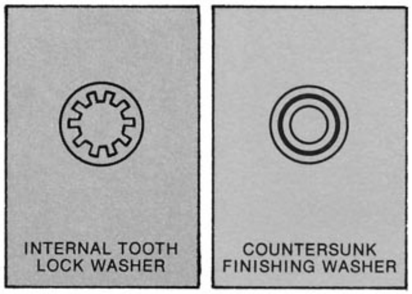
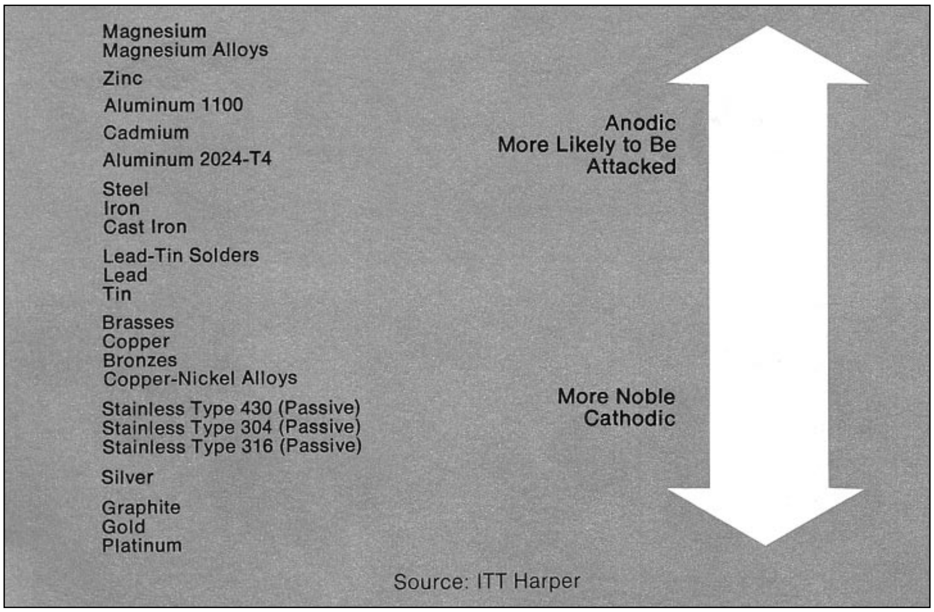
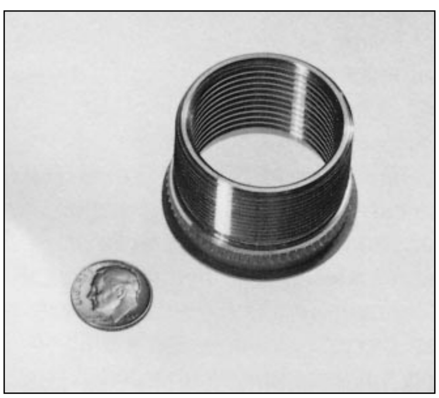
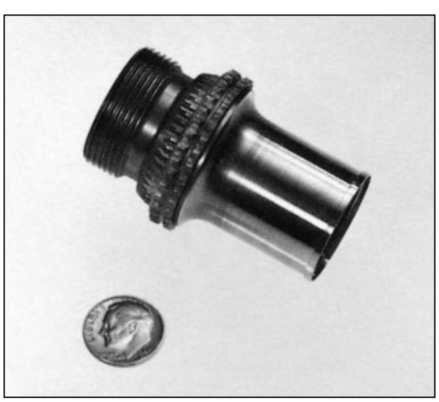


Figure 5 **GALVANIC SERIES OF METALS & ALLOYS IN SEAWATER**







current to flow with corrosion occurring at the anodic component of the cell. Figure 5 provides a guide to the relative anodic and cathodic relationships of metals to one another when exposed in sea water, which is known as the galvanic series of metals and alloys. The further apart the combination of alloys, the greater is the corrosion attack at the anodic component. It is well recognized that magnesium, zinc and aluminum anodes, when attached to a steel hull of a ship, will corrode preferentially, thereby protecting the structural integrity of the cathodic components. By comparison, no serious galvanic action will result from the coupling of metals with the same group (stainless to stainless) or to near alloys in the galvanic series (stainless to copper-nickel).

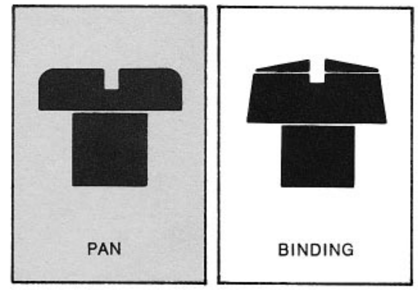
It is also important to have an understanding of the relative areas of the two different materials that are in direct contact with one another (the fastener system will normally represent the smallest surface area for materials being joined). Consequently, the fastener system should be cathodic to the materials being joined. This can be seen in the photographs showing the bolting materials used in the construction of the Thames River Barrier on page 14.

In the aircraft industry, designers depend on this area-relationship principle when they specify stainless steel fasteners in aluminum structures. The greater the relative area of the anodic (aluminum material), the less severe is the corrosion. By comparison, steel or copper alloy studs for joining stainless steel would accelerate corrosion of the fastener system, although the extent of the galvanic attack would depend upon the relative area of each material.

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 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 12 on page 20 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.

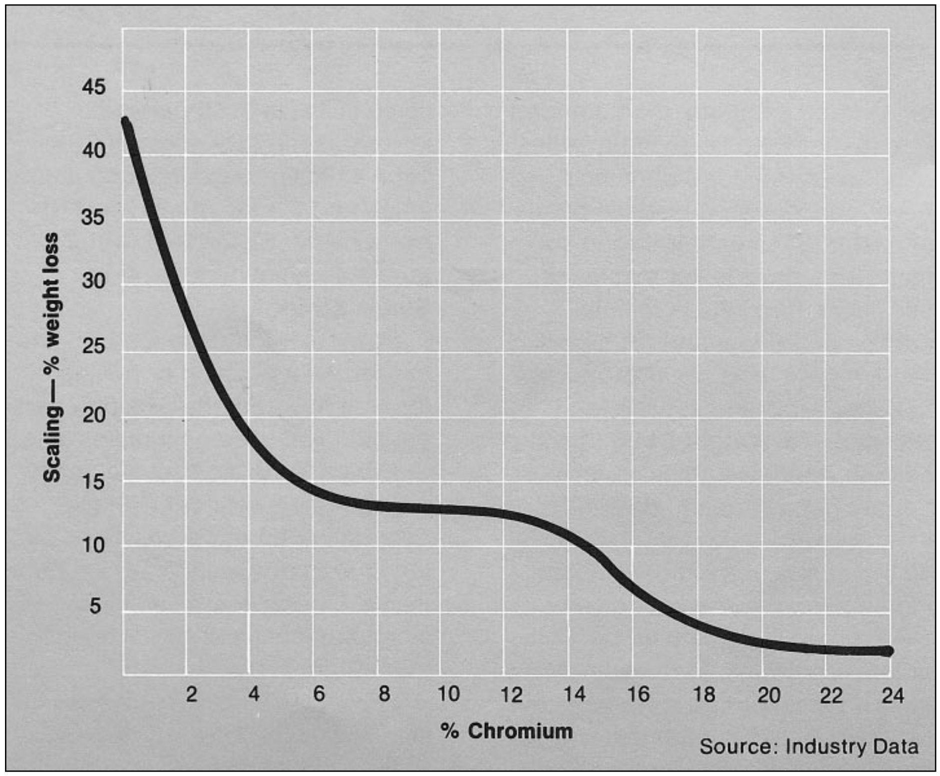
CONCENTRATION CELL CORROSION occurs when two or more areas on the surface of a metal are exposed to different concentrations of the same solution, such as under deposits or in crevices. A difference in electrical potential results and corrosion takes place. Unlike galvanic corrosion, it does not require dissimilar metals.



Thames River Barrier

Typical stainless steel structural bolting.
(Thames River Barrier)

Figure 6 **EFFECT OF CHROMIUM CONTENT ON SCALING RESISTANCE OF CHROMIUM-IRON ALLOYS (AT 1800°F OR 982°C)**



In the case of very tight stationary crevices, oxygen depletion at the interface of the metals, relative to the aqueous environment, can create localized anodic and cathodic differences at the mating interfaces. Such might be the case at flanged joints where gaskets or o-ring seals are used, or at bolted connections. Underdeposit or crevice attack may occur, especially when chlorides are present in the aqueous system.

In the case of ambient temperature, it has been determined that this form of attack is unlikely to occur with Type 304 stainless steel systems when the chloride levels are less than 200ppm, and, in the case of Type 316 stainless steel systems, when the chloride levels are less than 1000ppm. Higher molybdenum containing alloys offer greater corrosion resistance to this form of attack than the 300 series stainless steel materials.

To avoid this form of 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 where possible.

CHLORIDE ION STRESS CORROSION CRACKING is a recognized phenomenon with the 300 series stainless steel materials. Three conditions must exist before it can occur; chlorides (environment) must be present; stress (inherent with tensioning of fasteners); and temperature (usually does not occur below 60°C). Under this combination of conditions, alternative stainless steel materials can be considered, namely the duplex stainless steels or the more highly alloyed nickel containing materials, typical of 6% molybdenum grades. The straight chromium 400 series stainless steels are not subject to this form of attack, but usually they do not provide suitable corrosion resistance.

CORROSION FATIGUE is accelerated fatigue failure occurring in a corrosive medium. The general fatigue characteristics of the ferritic, martensitic and alloy steels are usually significantly reduced, as a result of general aqueous corrosion or pitting attack. The austenitic, duplex and super austenitic stainless steels exhibit some lowering of their air-fatigue properties.

Factors extending fatigue performance are application and maintenance of a high preload, and proper alignment to avoid bending stress.

HIGH 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.

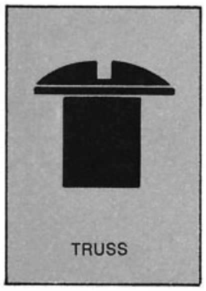
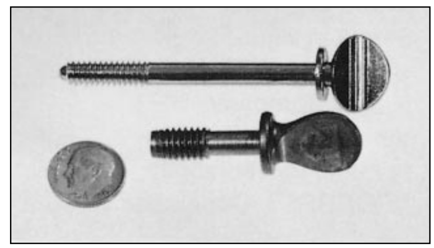


Table 8 **CREEP STRENGTHS OF TYPICAL STAINLESS STEEL FASTENER MATERIALS**

	LOAD FOR 1% ELONGATION IN 10,000 Hr, ksi				
AISI TYPE	**1000 F**	**1100 F**	**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



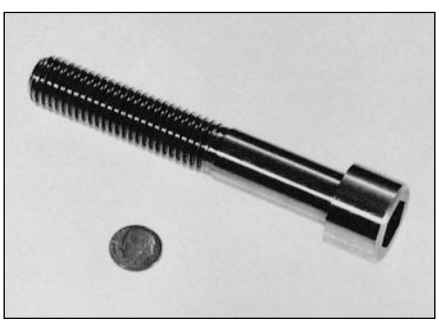
Chromium also plays an important part in the high temperature resistance characteristics for stainless steels. Figure 6 on page 14 shows this effect on the scaling resistance of chromium-iron alloys. Consequently, stainless steel Types 309, 310, 314, 442 and 446 would provide suitable performance in many of these environments, while grades with titanium, columbium and tantalum such as type 321, 347 and 348 can also be considered for elevated temperature service.

In all bolted joints, the fasteners are tightened to some initial elastic 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 8 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 (Table 9), with a logical conclusion that stainless steel fasteners are best for stainless steel



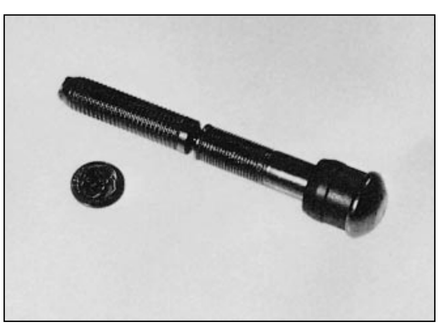


Table 9 **THERMAL EXPANSION OF CORROSION-RESISTANT FASTENER ALLOYS**

Alloy	**Temperature Range °F**	**Mean Coefficient of Thermal Expansion In./In./°F(10^6)**
Type 304 Stainless Steel	32 to 212 32 to 572 32 to 1112	9.6 9.9 10.4
Type 316 Stainless Steel	32 to 212 32 to 572 32 to 1112	8.9 9.0 10.3
Type 410 Stainless Steel	32 to 212 32 to 1000	6.1 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 32 to 1600	4.7 5.6
Aluminum (2024)	-76 to 68 68 to 212 68 to 392	21.4 22.8 23.9

Source: ITT Harper

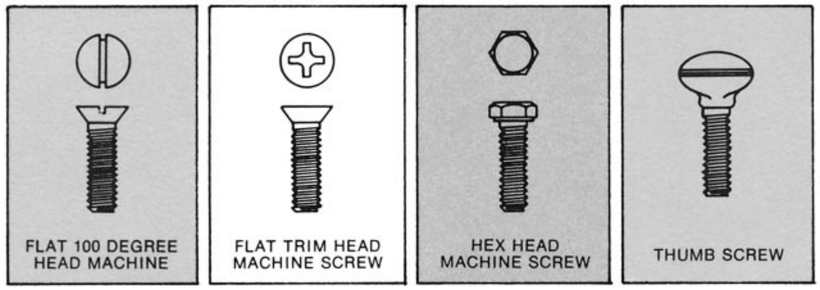


Table 10 **SCALING (OXIDATION) RESISTANCE OF TYPICAL STAINLESS STEEL FASTENER MATERIALS**

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 Data

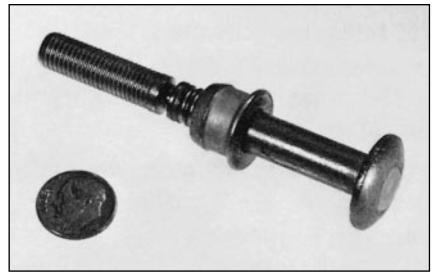
base metal joints; otherwise, there can be over-stressing and possible failure, or a rapid loss in clamping stress.

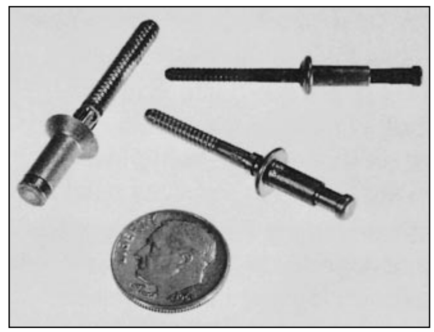
The oxidation or scaling resistance of stainless steels under constant temperature condition is, for the most part, related to chromium content, as illustrated in Figure 6 on page 14. In Table 10, scale resistance is expressed as temperature at maximum continuous service and maximum intermittent service (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."

LOW TEMPERATURE SERVICE

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.



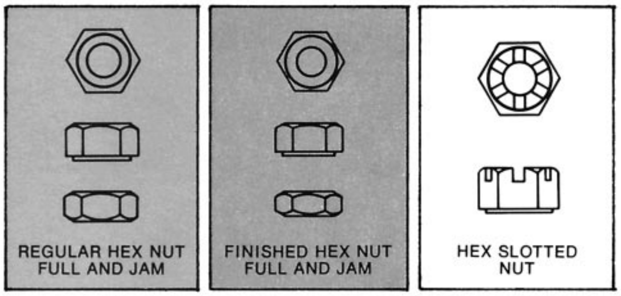


Austenitic stainless steels are the most widely used materials in cryogenic applications, especially Type 304, because it does not become brittle as it is chilled. Not only does Type 304 remain tough and ductile at LNG temperature—minus 260F (-162C)—but it retains excellent properties with liquid hydrogen at minus 423F (-253C) and liquid helium at minus 452F (-268C). Table 11 shows low-temperature mechanical properties of several stainless steels used in cryogenic service.

Table 11 **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



STAINLESS STEEL PHYSICAL PROPERTIES

MAGNETIC PROPERTIES

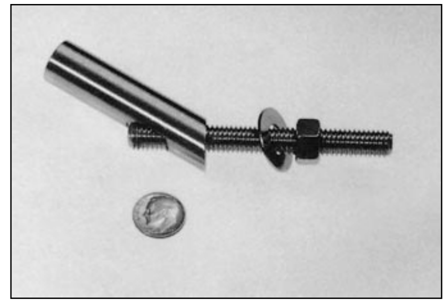
Magnetism, for purposes of this discussion, is the ability of a part to be attracted by a magnet and not the part's ability to function as a magnet. It is more accurately expressed as magnetic permeability, and it can be an important design consideration. One reason is the need to have a magnetic material 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 7. The magnetic permeability of the same group, but expressed as a function of tensile strength, is shown in Figure 8.

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, which can decrease permeability.

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



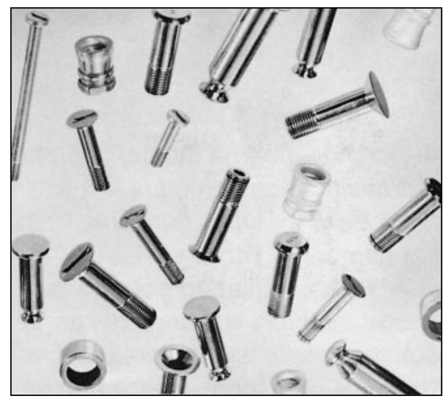


Figure 7 **WHEN COLD WORKING IS EMPLOYED, SOME NORMALLY NON-MAGNETIC AUSTENITIC STEELS BECOME SUBSTANTIALLY MAGNETIC**

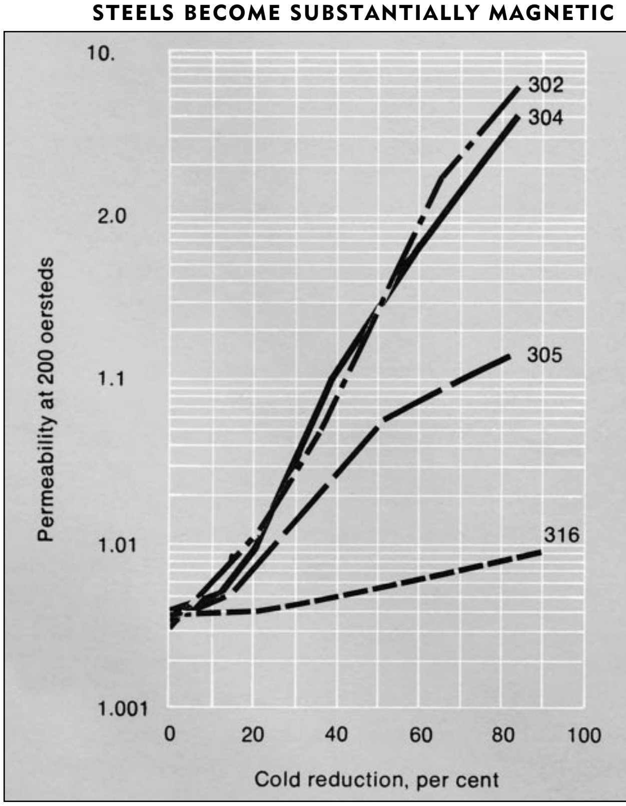
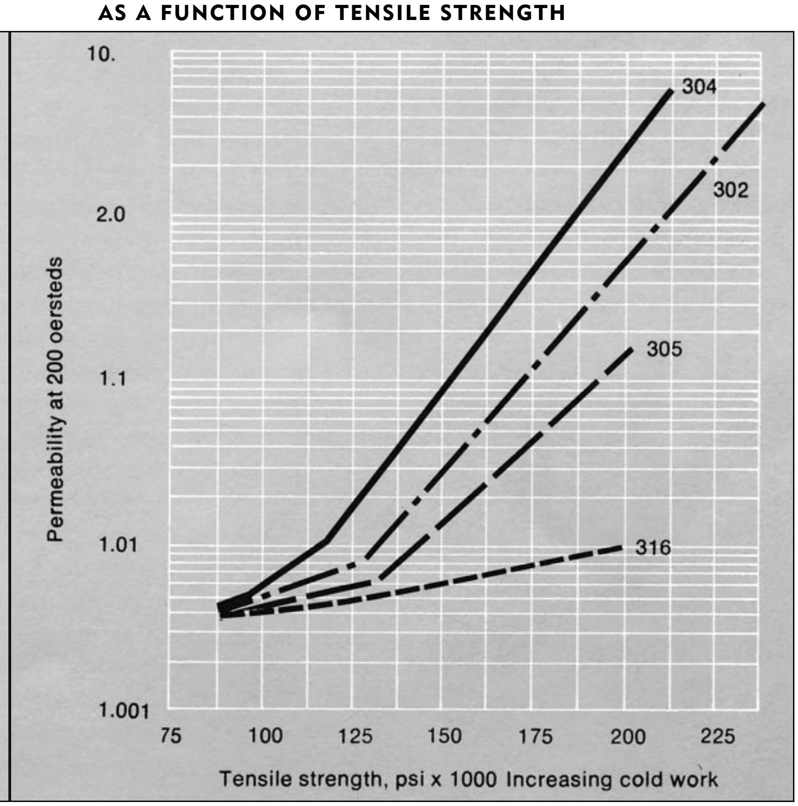
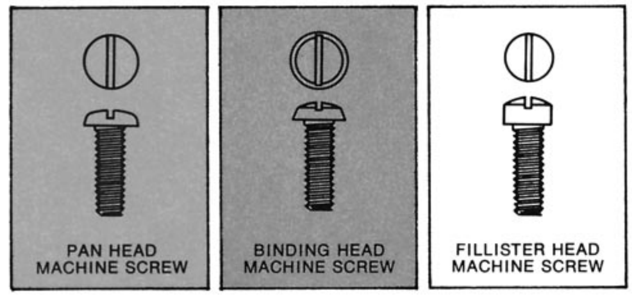


Figure 8 **MAGNETIC PERMEABILITY OF AUSTENITIC ALLOYS SUBJECTED TO COLD WORKING CAN ALSO BE EXPRESSED AS A FUNCTION OF TENSILE STRENGTH**





FASTENER MARKINGS

ASTM SPECIFICATION **Bolts, Screws and Studs (High Temperature Service)**	ALLOY DESCRIPTION	GRADE MARKING Class1 I	IA	IB	IC	II
ASTM A193	AISI 510	B5				
	AISI 410	B6				
	AISI 304N		B8N	B8NA		
	AISI 316N		B8MNA	B8MN		
	UNS 20901 (XM19)				B8R[2]	
					B8RA[3]	
Bolts, Screws and Studs (High and Low Temperature Service)						
ASTM A193 & ASTM A320	AISI 304	B8	B8A			B8
	AISI 347	B8C	B8CA			B8C
	AISI 316	B8M	B8MA			B8M
	AISI 305	B8P	B8PA			B8P
	AISI 321	B8T	B8TA			B8T
	AISI 304N	B8LN	B8LNA			B8N
	AISI 316N	B8MLN	BMNLNA			B8MN

Key

1. Classes I & IB: Carbide solution treated (annealed)
   Classes IA & IC: Carbide solution treated in the finished condition.
   Class II: Strain hardened condition
2. Carbide solution treated.
3. Carbide solution treated in the finished condition.

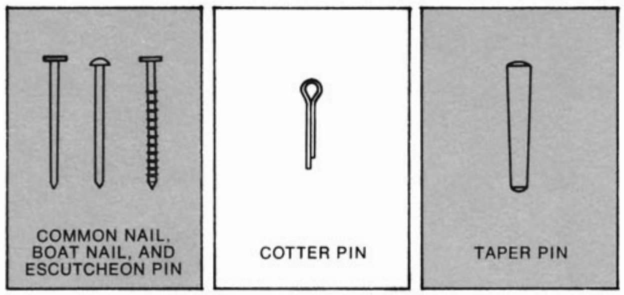
ASTM SPECIFICATION **Nuts (High Pressure and Temperature Service)**	ALLOY DESCRIPTION	GRADE MARKING Machined From Bar	Forged	Soln. Treat	Strain Harden
ASTM A194	AISI 510 (Heat treated)	3	3A		
	AISI 410 (Heat treated)	6	6B		
	AISI 304	8	8B	8A	8
	AISI 347	8C	8CB	8CA	8C
	AISI 316	8M	8MB	8MA	8M
	AISI 321	8T	8TB	8TA	8T
	AISI 303 or 303Se	8F	8FB	8FA	8F
	AISI 305	8P	8PB	8PA	8P
	AISI 304N	8N	8NB	8NA	8N
	AISI 316N	8MN	8MNB	8MNA	8MN
	XM19	8R	8RB	8RA	
	AISI 304 low C	8LN	8LNB	8LNA	
	AISI 316 low C	8MLN	8MLNB	8MLNA	

ASTM SPECIFICATION **Bolts, Hex Cap Screws and Studs (General Corrosion Resistant Service)**	ALLOY DESCRIPTION	GRADE MARKING	TEMPER CONDITION
ASTM 593	AISI 304, 305, 384, XM7	1	CW
	AISI 316	2	CW
	AISI 321, 347	3	CW
	AISI 430	4	A
	AISI 431	5	H
	Alloy 630	6	AH

Key

CW coldworked
A annealed or solution annealed
H hardened and tempered at 1050F minimum
AH age hardened

NOTE: Unless otherwise specified on the inquiry or order, fasteners will be supplied in the above condition.



ASTM SPECIFICATION Nuts (General Corrosion Resistant Service)	ALLOY DESCRIPTION	GRADE MARKING
ASTM A594	AISI 303 or 303Se, 304, 305	
	AISI 384, XM1, XM7	1
	AISI 316	2
	AISI 321	3
	AISI 430, 430F	4
	AISI 410, 416, 416Se	5
	AISI 431	6
	Alloy 630	7

Note: The same markings are used for ASTM Specification F593 (Bolts, Hex Cap Screws and Studs)

ASTM SPECIFICATION Metric Nuts	ALLOY DESCRIPTION	GRADE MARKING	TEMPER CONDITION
ASTM A836	AISI 303, 304, 305,		
	AISI 384, XM1, XM7	A1-50	A
		A1-70	CW
		A1-80	M
	AISI 321, 347	A2-50	A
		A2-70	CW
		A2-80	M
	AISI 316	A4-50	A
		A4-70	CW
		A4-80	M
	AISI 430, 430F	F1-45	M
		C1-70	H565
		C1-110	H275
	AISI 431	C3-80	H565
		C3-120	H275
	AISI 416, 416Se	C4-70	H565
		C4-110	H275
	Alloy 630	P1-90	AH

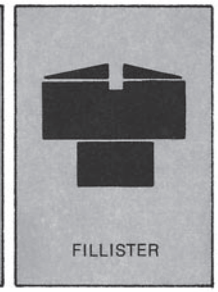
Key

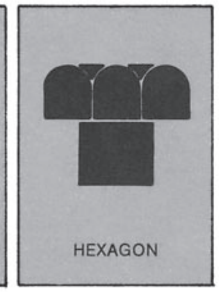
A Machined from ann. or soln. ann stock and re-annealed
M Machined from strain hardened stock.
CW Cold worked
H565 Hardened and tempered at 565C
H275 Hardened and tempered at 275C
AH Solution annealed and age hardened after forming

ASTM SPECIFICATION (Metric Bolts, Hex Cap Screws and Studs)	ALLOY DESCRIPTION	GRADE MARKING	TEMPER CONDITION
ASTM F738	AISI 303, 303Se, 304, 305,		
	AISI 384, XM1, XM7	A1-70	CW
		A1-80	M
	AISI 321, 347	A2-50	A
		A2-70	CW
		A2-80	M
	AISI 316	A4-50	A
		A4-70	CW
		A4-80	M
	AISI 410	C1-50	M
		C1-70	H565
		C1-110	H275
	AISI 431	C3-80	H565
		C3-120	H275
	AIAI 416, 416Se	C4-50	M
		C4-70	H565
		C4-110	H275
	AISI 430, 430F	F1-45	A
		F1-60	CW

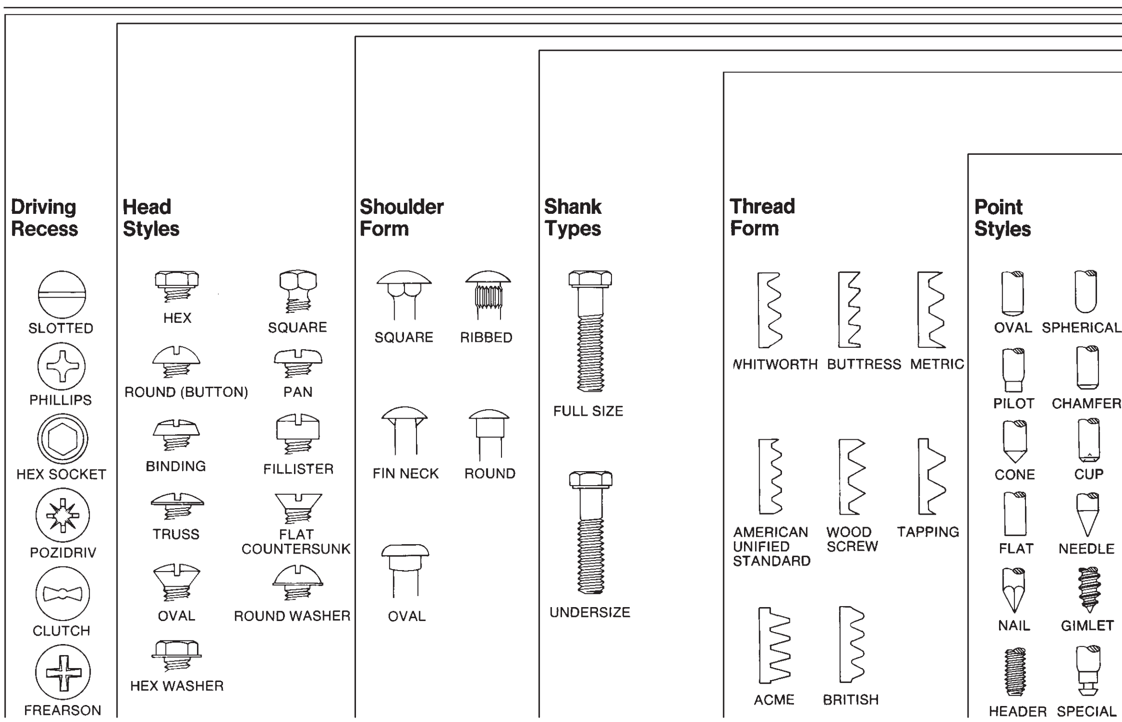
Key

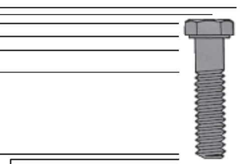
A Headed and rolled from annealed stock and re-annealed
M Machined from strain hardened stock
CW Cold Worked
H580 Hardened and tempered at 565C min.
H275 Hardened and tempered at 275C min.





FASTENER BASICS





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

DIRECTORY OF FASTENER MANUFACTURERS