Mechanical Properties and Identification Markings for Threaded Fasteners

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The information contained in this booklet represents a significant collection of technical information about mechanical properties and identification markings for threaded fasteners. This information will help to achieve increased reliability at a decreased cost. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of information given in this booklet is mainly derived from literature on the subject from the sources as per the references given at the end of this booklet. For more information, please refer them. All information contained in this booklet has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please view the disclaimer uploaded on http://www.practicalmaintenance.net.

(Edition: September 2020)

Content

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Introduction

A standard or a norm is a document containing agreements, specifications or criteria about a material, product, process or service. They are used to ensure that materials, products, processes and services are fit for their purpose. Standards are established within a company, an organization, a consortium of organizations or recognized standardization bodies.

When a standard exists, a product / material requires little or no further description. Most of the features of a product / material are described in the standard. Most industrial threaded fasteners are covered by two basic standards: one for materials and properties; the other, for dimensions and tolerances.

In ordinary usage of steel bolts, the chemical composition of the material and the manufacturing process are of little interest to the user, provided that the service requirements are met.

Fastener material specification systems have been developed according to this reasoning. Most specifications are basically performance specifications. They emphasize performance criteria such as strength, hardness, ductility, and impact resistance. The material composition is usually flexible. This allows the manufacturer to choose the best material for the fastener.

There always seems to be some confusion regarding mechanical versus metallurgical properties. Mechanical properties are those associated with elastic or inelastic reaction when force is applied, or that involve the relationship between stress and strain. Metallurgical testing includes chemical composition, microstructure, grain size, carburization and decarburization, and heat treat response. The chemical composition is established when the material is melted. Nothing subsequent to that process will influence the basic composition. The microstructure and grain size can be influenced by heat treatment. Carburization is the addition of carbon to the surface which increases hardness. It can occur if heat treat furnace atmospheres are not adequately controlled. Decarburization is the loss of carbon from the surface, making it softer. Partial decarburization is preferable to carburization, and most industrial standards allow it within limits.

There are two main systems for measuring weights and distances: the metric system and the imperial system. For material standards, the primary standardization organizations for the metric system fasteners are the International Organization for Standardization (ISO) and the German Institute for Standardization (DIN) whereas for the imperial fasteners they are the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE). In view of this, information about mechanical properties and identification markings as per them is given in this booklet.

Note:

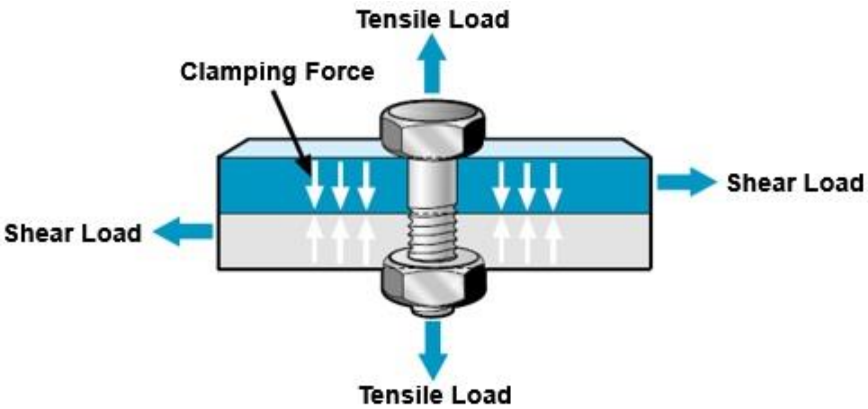
In ISO standards, comma (,) is used as a decimal marker. However, to maintain uniformity with general practice, I have used full point (.) as the decimal marker for the information given about ISO standard in this booklet.

Mechanical Properties

Most fastener applications are designed to support or transmit some form of externally applied load. For joint designing, fasteners are covered by standards/specifications that define required mechanical properties such as tensile strength, yield strength, proof load and hardness. Other mechanical properties are shear strength, fatigue strength and torsional strength. In view of this, information about bolted joints and mechanical properties is given in this chapter.

Bolted Joints

Loads can be applied to bolted joints in a number of different ways, each of which produces unique effects on the joint. These effects result from the way the joint is loaded, as well as how the joint responds to the load. Some of the various load types include tensile, shear and bending. The type of bolted joint derives its name from the external load applied to the joint.



Tensile Load and Shear Load

The stress in the bolt when the bolt has been tightened to the design extent is known as the pre-stress. The tensile load corresponds to the force that clamps the joint members together.

Torsion in the bolt results from friction between the threads in the bolt and the nut.

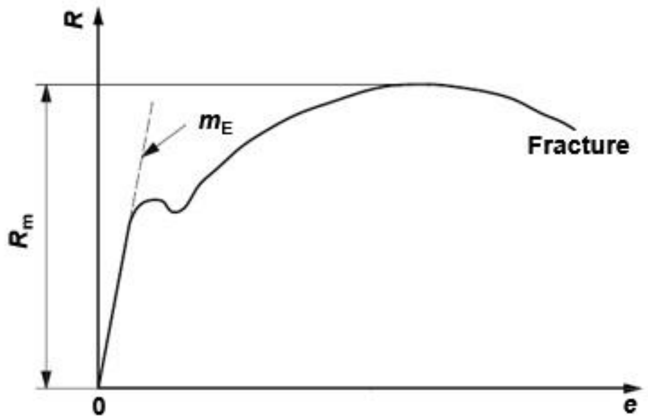
Some bolts are also exposed to shear loads which occur when the external force slides the members of the joint in relation to each other perpendicular to the clamping force. In a properly designed joint the external shear force should be resisted by the friction between the components. A joint of this kind is called a friction joint. If the clamping force is not sufficient to create the friction needed, the bolt will also be exposed to the shear load. Joints are frequently designed for a combination of tensile and shear loads.

Tensile Properties

The tensile properties; tensile strength and yield strength are determined by a tensile test. To find out tensile properties of a fastener material, a machined test piece is fitted in the jaws of the tensile testing machine (Universal Testing Machine) and subjected to a tensile force. The applied force and the resulting elongation of the test piece are measured. The process is repeated with increased force until the test piece breaks. The gauge length of the test piece is the length of the parallel portion of the test piece between gauge length marks on which elongation is measured at any moment during the test. The percentage elongation of the test piece is the elongation expressed as a percentage of the original gauge length. The elongation of the test piece is measured as extension by an arrangement consisting of dial gauge and clamps called the extensometer.

The stress (intensity of force) at any moment during the test is the force divided by the original cross-sectional area of the test piece. The strain is the elongation of the test piece, increase in the extensometer gauge length at any moment during the test. It is expressed as a percentage extension, extension (increase in extensometer gauge length) expressed as a percentage of the extensometer gauge length. Using the readings of the test, a stress - strain (percentage extension) diagram is plotted to find out tensile properties.

Tensile Strength



Where,
***R* is stress**
***e* is percentage extension (strain)**
R_m is tensile strength
m_E is slope of the elastic part of the stress - percentage extension curve

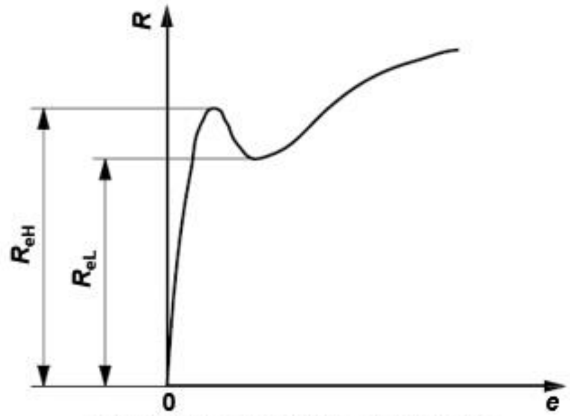
Tensile Test, Stress - Strain Diagram

As shown in above stress - strain (percentage extension) diagram, tensile strength (R_m) is the stress corresponding to the maximum force, F_m.

Fracture is phenomenon which is deemed to occur when total separation of the test piece occurs.

Yield Strength

Yield strength is the strength when the metallic material exhibits a yield phenomenon, stress corresponding to the point (called yield point) reached during the test at which plastic deformation occurs without any increase in the force.



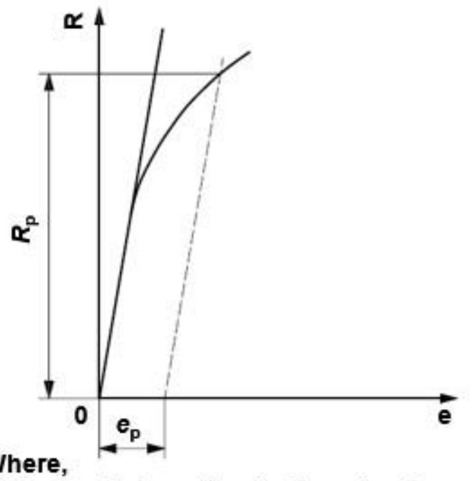
Upper and Lower Yield Strengths

As shown in above figure, upper yield strength (R_{eH}) is the maximum value of the stress prior to the first decrease in force and the lower yield strength (R_{eL}) is the lowest value of the stress during plastic yielding, ignoring any initial transient effects.

It may be noted that after reaching yield point, extension/elongation begins to increase disproportionately with increasing tensile force. A plastic elongation remains after relief.

Proof Strength or Non-Proportional Extension/Elongation

As it is difficult to determine yield strength of harder materials, proof strength (R_p) is defined for them. Proof strength (R_p) is determined from the stress - strain curve by drawing a line parallel to the linear portion of the curve and at a distance from it equivalent to the prescribed plastic percentage extension, e.g. 0.2 %. The point at which this line intersects the curve gives the stress corresponding to the desired proof strength plastic extension.



Where,
R_p is proof strength, plastic extension
e_p is specified percentage plastic extension

Proof Strength, Non-Proportional Extension/Elongation

As shown in above figure, proof strength or non-proportional extension/elongation (R_p) also called plastic extension is the stress at which the plastic extension is equal to a specified percentage of the extensometer gauge length. A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{p0.2}$.

The most widely associated mechanical property associated with standard threaded fasteners is tensile strength. Tensile strength is the maximum tension, applied load the fastener can support prior to or coinciding with its fracture. Ultimate tensile load a fastener can withstand is determined by the formula:

$F_m = R_m \times A_s$

Where,
F_m = Ultimate tensile load (N, lb.)
R_m = Tensile strength (MPa, psi)
A_s = Tensile stress area in thread (mm^2, in.^{2})

When a standard threaded fastener fails in pure tension, it typically fractures through the threaded portion (this is characteristically it's smallest area). The tensile stress area in thread is calculated through an empirical formula. The empirical formula and tables stating this area are provided in fastener standards (e.g. ISO 898-1).

Note:

For more information on tensile testing, please see ISO 6892-1, “Metallic materials - Tensile testing - Method of test at room temperature”.

Proof Load

Yield strengths of machined test specimens are easily determined because of their uniform cross-sectional area throughout the stressed length. It has been noted that the yield strength characteristics of test specimens do not always parallel those of the full size fastener from which they are taken. This is because the beneficial effects of cold working may be completely lost when the test piece is machined from the parent product. It is difficult to test full size fasteners for yield strength because of the different strain rates in areas such as: the fully threaded portion; the thread runout; and the unthreaded shank which comprises the stressed length. Because of this, the proof load test was introduced as an approved technique for testing a fastener’s deformation characteristics.

By definition, the proof load is an applied tensile load/force that the fastener (bolt/screw) must support without permanent (plastic) deformation. In other words, the material must remain in its elastic region when loaded up to its proof load and the bolt/screw returns to its original shape (or size) once the load is removed.

In most (but not all) bolting applications, it is important not to tension a bolt past its yield strength. If a threaded fastener has been tightened past its yield strength, it is no longer reusable and will have to be thrown away if loosened because if it is tightened past its yield strength, it will not return to its original shape on loosening. Proof load is the limit of the elastic range of the threaded fastener. Designing of threaded fasteners according to proof load can help prevent plastic deformation. As long as a fastener is never tensioned beyond its specified proof load, you can be assured that it has maintained its original shape, and may be reused safely. It may be noted that structural bolts are tensioned well beyond yield strength.

It may also be noted that proof load is a force measurement. The units are newton or pounds. Yield strength is a stress measurement. The units are MPa or psi. The stress under proof load (S_p) is typically 90% (between 85-95%) of the yield strength. Stress under proof load, for various materials is quoted in fastener standards (e.g. ISO 898-1).

In a proof load test, a headed bolt is placed in a testing machine with a nut on the threaded end, and a wedge under the head. The wedge varies from 4-10 degrees depending on the size and configuration of fastener, and serves to evaluate the ductility of the bolt. In a machine specimen test, you test ductility by measuring elongation and reduction of area, but those are impossible during a full size test, so head deflection is used in its place. Proof load testing is typically performed at 90% of the expected minimum yield strength and is a simple pass/fail test. The bolt length is measured, and after being subjected to the published proof load value for 10 seconds, if it has not elongated more than 0.0005″, it is deemed to have passed.

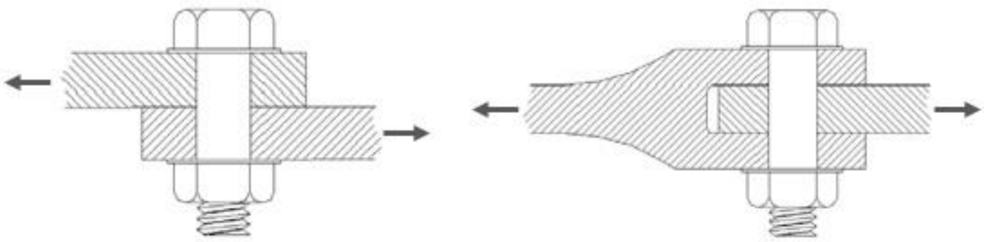
Hardness

Hardness is a measure of a material’s ability to resist abrasion and indentation. Generally speaking, hardness is the resistance which the material offers to the penetration of a test body under a defined load. It is measured by the Brinell (ISO 6506), Rockwell (ISO 6508) or Vickers (ISO 6507) methods.

For carbon steels, Brinell and Rockwell hardness testing can be used to estimate tensile strength properties of the fastener.

Shear Strength

Shear strength is defined as the maximum load that can be supported prior to fracture, when applied at a right angle to the fastener's axis.

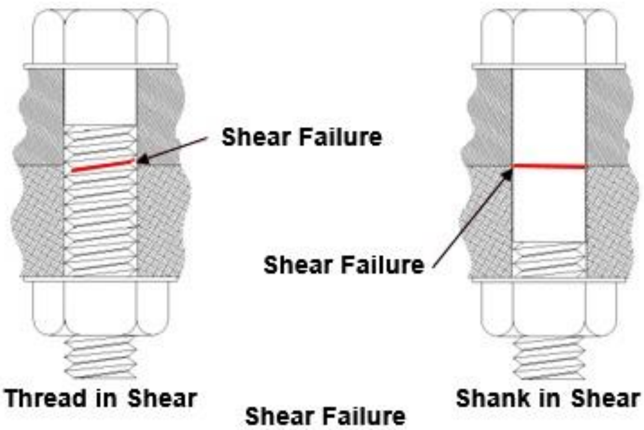


Single Shear Joint and Double Shear Joint

As shown in above figure, the joint design is said to be in single shear if the fastener would only need to shear in one plane for the joint to fail; whereas the joint design is said to be in double shear if the fastener would need to shear in two planes for the joint to fail. Obviously the double shear joint is stronger and more stable than the single shear joint, and should be used at every available opportunity when joint strength and reliability are of concern.

Since most bolts are used as clamps, not as shear pins, most bolting specifications and standards list only one or more forms of tensile strength (proof, yield, or ultimate) and not shear strengths.

When no shear strength is given for common carbon steels with hardness up to 40 HRC or so, 60 % of their ultimate tensile strength is often used as their shear strength. However, this should only be used as an estimation. The stainless steels are an exception to this rule of thumb; they have shear strengths which are about 55% of their ultimate tensile strengths.



Shear Failure

To determine the shear strength of the material, the total cross-sectional area of the shear plane is important. For shear planes through the threads, we could use the equivalent tensile stress area (A_s). However, to take full advantage of strength properties, the preferred design would be to position the full shank body in the shear plane as shown in above figure.

Fatigue Strength

A fastener subjected to repeated cyclic loads can suddenly and unexpectedly break, even if the loads are well below the strength of the material. The fastener fails in fatigue. The fatigue strength is the maximum stress a fastener can withstand for a specified number of repeated cycles prior to its failure.

Torsional Strength

Torsional strength is a load usually expressed in terms of torque, at which the fastener fails by being twisted off about its axis. Tapping screws and socket set screws require a torsional test.

Ductility

Ductility is a measure of the degree of plastic deformation that has been sustained at fracture. In other words, it is the ability of a material to deform before it fractures. A material that experiences very little or no plastic deformation upon fracture is considered brittle. A reasonable indication of a fastener's ductility is the ratio of its specified minimum yield strength to the minimum tensile strength. The lower this ratio, the more ductile the fastener will be.

Note

A maintenance engineer is required to know tensile strength (hardness can be used to estimate tensile strength), yield strength and proof load properties of fasteners because preloading / tightening of fasteners depend on these properties. In view of this, information about tensile strength, yield strength, proof load and hardness is given in various chapters. For information on other properties like elongation, reduction of area, etc. and chemical composition, please see the relevant standard/specification.

Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel as per ISO Standard (ISO 898)

ISO 898 consists of the following parts, under the general title Mechanical properties of fasteners made of carbon steel and alloy steel:

Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread

Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread

Part 5: Set screws and similar threaded fasteners with specified hardness classes - Coarse thread and fine pitch thread

Part 7: Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm

Some useful information about the mechanical properties as per the standard is given in this chapter. It may be noted that the information is given for education purpose only. For commercial use, please see the latest version of the standard.

ISO 898-1: Bolts, Screws and Studs with Specified Property Classes

ISO 898-1 specifies mechanical and physical properties of fasteners (the term used when bolts, screws and studs are considered all together) made of carbon steel and alloy steel when tested at an ambient temperature range of 10°C to 35°C. Fasteners conforming to the requirements of ISO 898-1 are used in applications ranging from −50°C to +150°C. They might not retain the specified mechanical and physical properties at elevated temperatures and/or lower temperatures.

ISO 898-1 is applicable to bolts, screws and studs made of carbon steel or alloy steel, having triangular ISO metric screw thread in accordance with ISO 68-1 with coarse pitch thread M1.6 to M39, and fine pitch thread M8×1 to M39×3.

Designation System for Property Classes

Property class defines the strength of a bolt or nut. For metric fasteners, property classes are designated by numbers where increasing numbers represent increasing tensile strengths. The symbol for property classes consists of two numbers, separated by a dot.

The number to the left of the dot consists of one or two digits and indicates 1/100 of the nominal tensile strength, $R_{m,nom}$, in megapascals (N/mm^2).

The number to the right of the dot indicates 10 times the ratio between the nominal yield strength and the nominal tensile strength, $R_{m,nom}$, (called yield strength ratio). The nominal yield strength is:

- lower yield strength $R_{eL,nom}$, or
- nominal stress at 0.2 % non-proportional elongation $R_{p0,2\ nom}$, or
- nominal stress at 0.0048d non-proportional elongation $R_{pf,nom}$.

Hence, yield strength ratio = $R_{eL,nom}$ / $R_{m,nom}$ or $R_{p0,2\ nom}$ / $R_{m,nom}$ or $R_{pf,nom}$ / $R_{m,nom}$.

An additional zero to the left of the property class designation indicates that fasteners have reduced loadability.

For example, in property classes 10.9 designation; the first number indicates 1/100 of the nominal tensile strength in N/mm^2. So, nominal tensile strength for property classes 10.9 designation is = 10 × 100 = 1000 N/mm^2. The second number indicates 10 times the ratio between lower yield strength and nominal tensile strength. So, $\frac{9}{10} = \frac{\text{lower yield strength}}{\text{nominal tensile strength}}$. As nominal tensile strength is 1000 N/mm^2, the lower yield strength is 900 N/mm^2.

It may be noted that the multiplication of the nominal tensile strength and the yield strength ratio gives the nominal yield strength.

A fastener with material properties of property class 8.8 but with reduced loadability is designated by 08.8.

Following table specifies the limits for the chemical composition of steels and minimum tempering temperatures for the different property classes of bolts, screws and studs.

<table>
<tr><th rowspan="3">Property Class</th><th rowspan="3">Material and Heat Treatment</th><th colspan="5">Chemical Composition Limit, %</th><th rowspan="3">Tempering Temperature °C min.</th></tr>
<tr><th colspan="2">C</th><th>P</th><th>S</th><th>B</th></tr>
<tr><th>min.</th><th>max.</th><th>max.</th><th>max.</th><th>max.</th></tr>
<tr><td>4.6</td><td rowspan="5">Carbon steel or carbon steel with additives.</td><td rowspan="2">-</td><td rowspan="2">0.55</td><td rowspan="2">0.050</td><td rowspan="2">0.060</td><td rowspan="5">Not Specified</td><td rowspan="5">-</td></tr>
<tr><td>4.8</td></tr>
<tr><td>5.6</td><td>0.13</td><td>0.55</td><td>0.050</td><td>0.060</td></tr>
<tr><td>5.8</td><td>-</td><td>0.55</td><td>0.050</td><td>0.060</td></tr>
<tr><td>6.8</td><td>0.15</td><td>0.55</td><td>0.050</td><td>0.060</td></tr>
<tr><td rowspan="3">8.8</td><td>Carbon steel with additives (e.g. Boron or Mn or Cr) quenched and tempered</td><td>0.15</td><td>0.40</td><td>0.025</td><td>0.025</td><td rowspan="3">0.003</td><td rowspan="3">425</td></tr>
<tr><td>or
Carbon steel quenched and tempered</td><td>0.25</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td>or
Alloy steel quenched and tempered</td><td>0.20</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td rowspan="3">9.8</td><td>Carbon steel with additives (e.g. Boron or Mn or Cr) quenched and tempered</td><td>0.15</td><td>0.40</td><td>0.025</td><td>0.025</td><td rowspan="3">0.003</td><td rowspan="3">425</td></tr>
<tr><td>or,
Carbon steel quenched and tempered</td><td>0.25</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td>or,
Alloy steel quenched and tempered</td><td>0.20</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td rowspan="3">10.9</td><td>Carbon steel with additives (e.g. Boron or Mn or Cr) quenched and tempered</td><td>0.20</td><td>0.55</td><td>0.025</td><td>0.025</td><td rowspan="3">0.003</td><td rowspan="3">425</td></tr>
<tr><td>or,
Carbon steel quenched and tempered</td><td>0.25</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td>or,
Alloy steel quenched and tempered</td><td>0.20</td><td>0.55</td><td>0.025</td><td>0.025</td></tr>
<tr><td>12.9</td><td>Alloy steel quenched and tempered</td><td>0.30</td><td>0.50</td><td>0.025</td><td>0.025</td><td>0.003</td><td>425</td></tr>
<tr><td><u>12.9</u></td><td>Carbon steel with additives (e.g. Boron or Mn or Cr or Molybdenum) quenched and tempered</td><td>0.28</td><td>0.50</td><td>0.025</td><td>0.025</td><td>0.003</td><td>380</td></tr>
</table>

Note: For remarks about the text of above table please see the specification (ISO 898-1).

The bolts, screws and studs of the specified property classes shall, at ambient temperature meet all the applicable mechanical and physical properties in accordance with the following table. They shall also meet the minimum ultimate tensile loads and proof loads as per the tables given in the specification.

No.	**Mechanical or Physical Property**		**Property Class**									
			4.6	4.8	5.6	5.8	6.8	8.8		9.8	10.9	12.9/ 12.9
								$d \le 16$ mm[a]	$d > 16$ mm[b]	$d \le 16$ mm		
1	Tensile strength, R_m, N/mm^2	nom.	400		500		600	800		900	1000	1200
		min.	400	420	500	520	600	800	830	900	1040	1220
2	Lower yield strength, R_{eL}, N/mm^2	nom.	240	-	300	-	-	-	-	-	-	-
		min.	240	-	300	-	-	-	-	-	-	-
3	Stress at 0.2 % non-proportional elongation, $R_{p0.2}$, N/mm^2	nom.	-	-	-	-	-	640	640	720	900	1080
		min.	-	-	-	-	-	640	660	720	940	1100
4	Stress under proof load, S_p, N/mm^2	nom.	225	310	280	380	440	580	600	650	830	970
5	Percentage elongation after fracture for machined test pieces, *A*, %	min.	22	-	20	-	-	12	12	10	9	8
6	Vickers hardness, HV F ≥ 98 N	min.	120	130	155	160	190	250	255	290	320	385
		max.	220				250	320	335	360	380	435
7	Brinell hardness, HBW F = 30 D^2	min.	114	124	147	152	181	245	250	286	316	380
		max.	209				238	316	331	355	375	429
8	Rockwell hardness, HRB	min.	67	71	79	82	89	-				
		max.	95.0				99.5	-				
	Rockwell hardness, HRC	min.	-					22	23	28	32	39
		max.	-					32	34	37	39	44
9	Impact strength, K_V, J	min.	-		27	-		27	27	27	27	[k]
10	Head soundness		No fracture									

d is the nominal thread diameter, mm
[a] - Values do not apply to structural bolting.
[b] - For structural bolting $d \ge$ M12.
[k] - Value for K_V is under investigation.

It may be noted that above table is incomplete (information on some mechanical or physical properties and some remarks for the table text are not given).

The minimum ultimate tensile load and proof load can be calculated using above table, and the following formulas.

Minimum ultimate tensile load, $F_{m,min} = A_{s,nom} \times R_{m,min}$, N

Proof load, $F_p = A_{s,nom} \times S_{p,nom}$, N

Nominal stress area in thread, $A_{s,nom} = \frac{\pi}{4}\left(\frac{d2+d3}{2}\right)^2$ mm^2

where,
d_2 is the basic pitch diameter of external thread in accordance with ISO 724
d_3 is the minor diameter of external thread
$d_3 = d_1 - \frac{H}{6}$
d_1 is the basic minor diameter of external thread in accordance with ISO 724
H is the height of the fundamental triangle of the thread in accordance with ISO 68-1

For ready reference, values of the nominal stress areas, $A_{s,nom}$, for ISO metric coarse pitch thread and ISO metric fine pitch thread are given in the following tables.

Nominal Stress Areas, $A_{s,nom}$, for ISO Metric Coarse Pitch Thread	
Thread, *d*	Nominal Stress Area, $A_{s,nom}$, mm^2
M3	5.03
M3.5	6.78
M4	8.78
M5	14.2
M6	20.1
M7	28.9
M8	36.6
M10	58
M12	84.3
M14	115
M16	157
M18	192
M20	245
M22	303
M24	353
M27	459
M30	561
M33	694
M36	817
M39	976

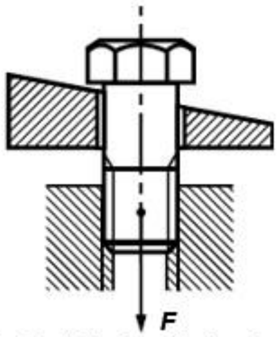
Note: Where no thread pitch is indicated in a thread designation, coarse pitch is specified.

Nominal Stress Areas, $A_{s,nom}$, for ISO Metric Fine Pitch Thread	
Thread, *d*	Nominal Stress Area, $A_{s,nom}$, mm^2
M8x1	39.2
M10x1.25	61.2
M10x1	64.5
M12x1.5	88.1
M12x1.25	92.1
M14x1.5	125
M16x1.5	167
M18x1.5	216
M20x1.5	272
M22x1.5	333
M24x2	384
M27x2	496
M30x2	621
M33x2	761
M36x3	865
M39x3	1030

For information on various test methods (for example, tensile test under wedge loading of finished bolts and screws; tensile test for finished bolts, screws and studs for determination of tensile strength, R_m; proof load test for finished bolts, screws and studs; tensile test for machined test pieces; head soundness test; hardness test; decarburization test; etc.) please see the specification. Following is the brief information on some of the test methods.

Tensile Test Under Wedge Loading of Finished Bolts and Screws (Excluding Studs)

The purpose of this tensile test is to determine simultaneously: the tensile strength on finished bolts and screws, R_m; and the integrity of the transition section between the head and the unthreaded shank or the thread.



Tensile Test Under Wedge Loading

For this test, tensile test is carried out after a wedge (as per test specification) is placed under the head of the bolt or screw as shown in above figure.

For integrity of transition section between head and unthreaded shank/thread: the fracture shall not occur in the head; for bolts and screws with unthreaded shank, the fracture shall not occur in the transition section between the head and the shank.

Proof Load Test for Finished Bolts, Screws and Studs

The proof load test consists of two main operations: application of a specified tensile proof load and measurement of permanent elongation, if any, caused by the proof load.

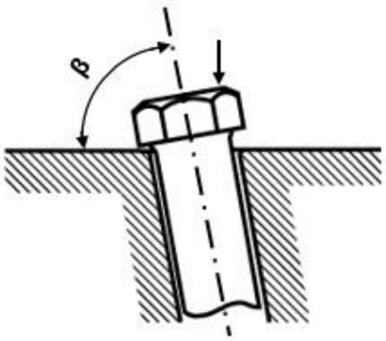
For applicability, apparatus, testing device and test procedure, please see the specification.

The test result requires that the total length of the fastener after unloading, l_1, shall be the same as before loading, l_0, within a tolerance of ± 12.5 μm allowed for uncertainty of measurement.

Some variables, such as straightness, thread alignment and uncertainty of measurement, can result in apparent elongation of the fastener when the proof load is initially applied. In such cases, the fastener shall be retested using a 3 % greater load than the proof load specified in the proof load tables.

The total length after the second unloading, l_2, shall be the same as before this loading, l_1, within a tolerance of ± 12.5 μm allowed for uncertainty of measurement.

Head Soundness Test



Testing Device for Head Soundness Test

The purpose of the head soundness test is to check the integrity of the transition section between the head and the unthreaded shank or the thread by striking the head of the fastener on a solid block to a given angle (β) as shown in above figure. A hammer shall be used to strike the head of the bolt or screw with several blows so that the head bends to an angle of 90° − β. Values of angle β are specified in the standard. The test requires no sign of cracking at the transition section between the head and the unthreaded shank shall be visible. For screws threaded to the head, this requirement is fulfilled even if a crack appears in the first thread, provided the head does not fracture off.

This test is generally used when the tensile test under wedge loading cannot be carried out due to the too short length of the fastener.

Hardness Test

The purpose of the hardness test is to determine the hardness of the fastener for all fasteners which cannot be tensile tested and to determine the hardness of the fastener which can be tensile tested in order to check that the maximum hardness is not exceeded.

Marking

The trade (identification) marking of the manufacturer is mandatory on all products which are marked with property classes.

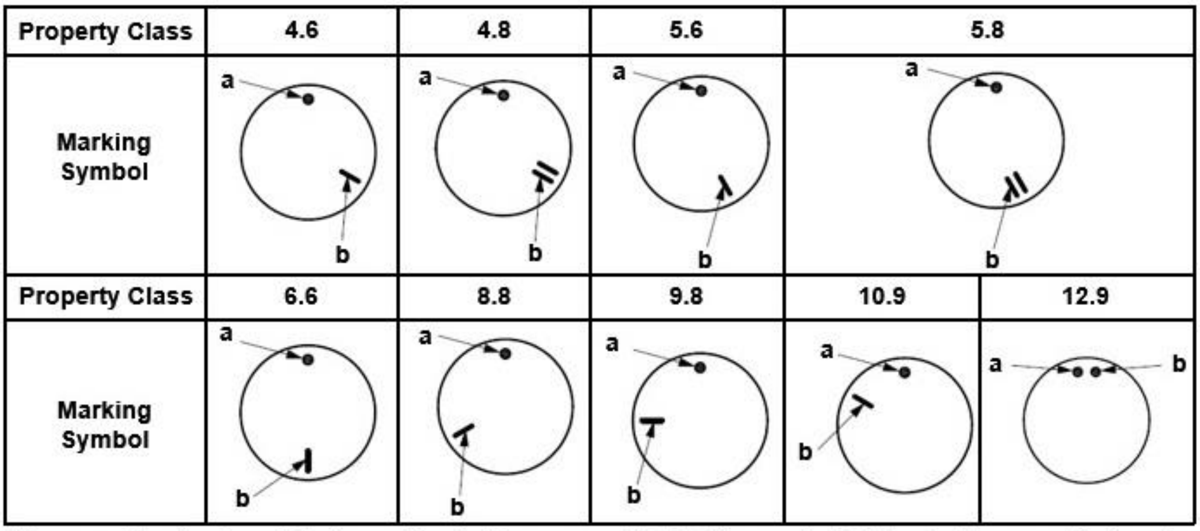
Marking symbols for property classes for fasteners with full loadability shall be as per the following table (It may be noted that due to their geometry, some fasteners are tested with reduced loadability. For more information on loadability, please see ISO 898-1).

Marking Symbols for Fasteners with Full Loadability

Property Class	**4.6**	**4.8**	**5.6**	**5.8**	**6.8**	**8.8**	**9.8**	**10.9**	**12.9**	**12.9**
Marking Symbol[a]	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9	12.9

[a] - The dot (full stop) in the marking symbol may be omitted.

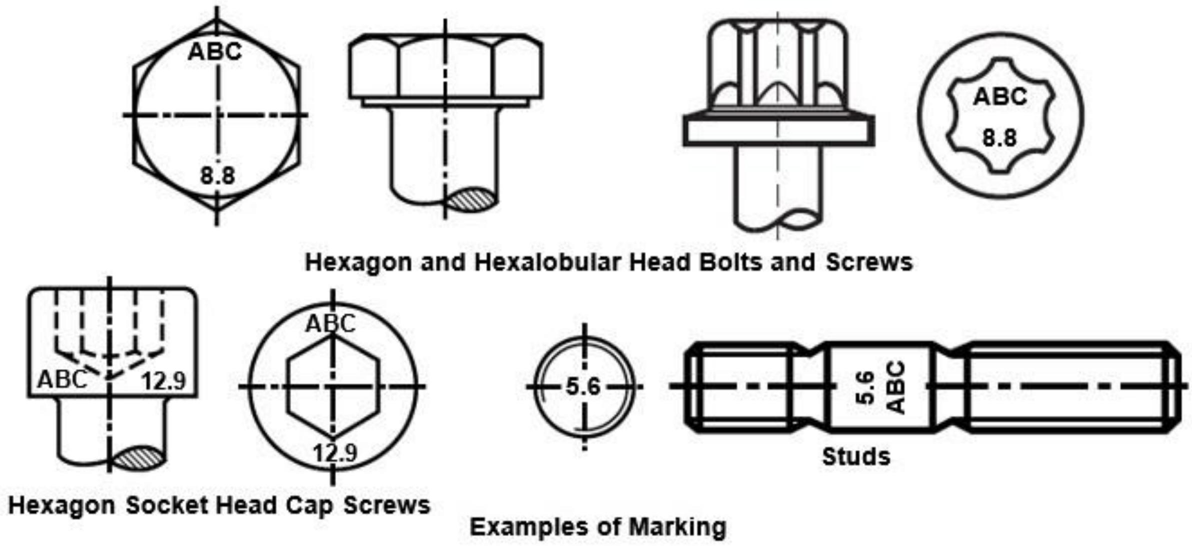
In the case of small screws, or when the shape of the head does not allow the marking in accordance with above table, the clock face marking symbols in accordance with the following figure may be used.



Where, a - The twelve o'clock position (reference mark) shall be marked either by the manufacturer's identification mark or by a dot.

b - The property class is marked by a dash or a double dash and, in the case of 12.9, by a dot.

Clock Face System for Marking Bolts and Screws



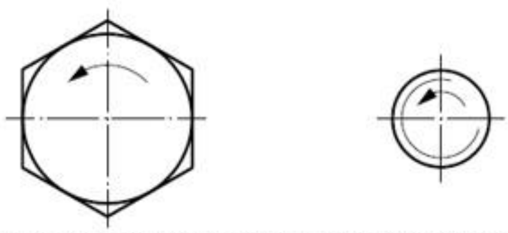
Examples of Marking

As shown in above figure, marking with the manufacturer's identification mark (for example: ABC in above figure) and the property class is mandatory for hexagon and hexalobular head bolts and screws; and hexagon and hexalobular socket head cap screws for all property classes and of nominal diameter *d* ≥ 5 mm. The marking shall be made preferably on the top of the head or on the side of the head.

Studs shall be marked with the manufacturer's identification mark and with the marking symbol of the property class or the alternative marking symbol specified in the following table. The marking is required for studs of property classes 5.6, 8.8, 9.8, 10.9 and 12.9/12.9, and of nominal diameter *d* ≥ 5 mm. The marking shall be on the unthreaded part of the stud. If this is not possible, marking of the property class shall be on the nut end, and the manufacturer's identification mark may be omitted. For studs with interference fit, the marking of property class shall be on the nut end, and the manufacturer's identification mark may be omitted.

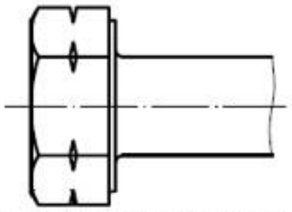
Property Class	5.6	8.8	9.8	10.9	12.9
Marking Symbol	–	○	+	□	△

Bolts and screws with left-hand thread and a nominal diameter of d ≥ 5 mm shall be marked with the symbol (left turning arrow) specified in the following figure, either on the top of the head or on the end of the fastener.



Marking of Bolts and Screws with Left-Hand Thread

Alternative marking for left-hand thread as specified in the following figure (with a groove halfway up the head height) may be used for hexagon bolts and screws.



Alternative Marking of Bolts and Screws with Left-Hand Thread

Fasteners with reduced loadability (fasteners. which due to their geometry, for examples - one having low head with or without external driving feature and one with waisted shank, do not fulfil the test requirements for loadability) manufactured to the requirements of ISO 898-1 shall be marked as detailed above, except that the marking symbol for property class shall be preceded by the digit “0” in accordance with the following table.

Marking Symbols for Fasteners with Reduced Loadability										
Property Class	**4.6**	**4.8**	**5.6**	**5.8**	**6.8**	**8.8**	**9.8**	**10.9**	**12.9**	**12.9**
Marking Symbol[a]	04.6	04.8	05.6	05.8	06.8	08.8	09.8	010.9	012.9	012.9
[a] - The dot (full stop) in the marking symbol may be omitted.										

Mechanical Properties of Fasteners at Elevated and Lower Temperatures

Up to typical service temperatures of 150°C, no detrimental effects due to a change of mechanical properties of fasteners are known. At temperatures over 150°C and up to a maximum temperature of 300°C, a progressive reduction of lower yield strength and tensile strength can be experienced.

The continuous operating of fasteners at elevated service temperatures can result in stress relaxation, which accompanies a loss of clamp force. For information on selection and application of steels for use at elevated temperatures, please see EN 10269 and ASTM F2281.

Following table may be used as a guide for properties at elevated temperatures. The table is not an integral part of standard ISO 898-1.

Property Class	**Temperature**				
	+ 20°C	**+ 100°C**	**+ 200°C**	**+ 250°C**	**+ 300°C**
	Lower yield stress, R_{el} or stress at 0.2 % non-proportional elongation, $R_{p0.2}$, N/mm^2				
5.6	300	270	230	215	195
8.8	640	590	540	510	480
10.9	940	875	790	745	705
12.9	1100	1020	925	875	825

Fasteners might not retain the specified mechanical properties at lower temperatures. For information on selection and application of steels for use at lower temperatures, please see ASTM A320/A320M.

ISO 898-2: Nuts with Specified Property Classes

ISO 898-2 specifies mechanical and physical properties of nuts with coarse thread and fine pitch thread made of carbon steel and alloy steel when tested at an ambient temperature range of 10°C to 35°C. It is possible that they do not retain the specified mechanical and physical properties at elevated and/or lower temperatures.

ISO 898-2 is applicable to nuts made of carbon steel or alloy steel; with coarse thread M5 ≤ *D* ≤ M39, and fine pitch thread M8×1 ≤ *D* ≤ M39×3; with triangular ISO metric thread according to ISO 68-1; with different nut styles: thin nuts, regular nuts and high nuts.

The following symbols apply to ISO 898-2.

D - nominal thread diameter of the nut, in millimetres
F - load, in newtons
m - height of the nut, in millimetres
P - pitch of the thread, in millimetres
s - width across flats, in millimetres

Designation of Nut Styles

ISO 898-2 specifies requirements for following three styles of nuts according to their height.

- Style 2: high nut with minimum height $m_{min} \approx 0.9D$ or $m_{min} > 0.9D$
- Style 1: regular nut with minimum height $m_{min} \geq 0.8D$
- Style 0: thin nut with minimum height $0.45D \leq m_{min} < 0.8D$

Minimum heights of style 1 (ISO 4032) and style 2 (ISO 4033) hexagon nuts shall be as per the following table. The table is not an integral part of standard ISO 898-2.

Thread *D*	**Width Across Flats** *s*, mm	**Minimum Height of Hexagon Nut**			
		Regular Nut (Style 1)		High Nut (Style 2)	
		m_{min}, mm	m_{min}/D	m_{min}, mm	m_{min}/D
M5	8	4.40	0.88	4.80	0.96
M6	10	4.90	0.82	5.40	0.90
M7	11	6.14	0.88	6.84	0.98
M8	13	6.44	0.81	7.14	0.90
M10	16	8.04	0.80	8.94	0.89
M12	18	10.37	0.86	11.57	0.96
M14	21	12.10	0.86	13.40	0.96
M16	24	14.10	0.88	15.70	0.98
M18	27	15.10	0.84	16.90	0.94
M20	30	16.90	0.85	19.00	0.95
M22	34	18.10	0.82	20.50	0.93
M24	36	20.20	0.84	22.60	0.94
M27	41	22.50	0.83	25.40	0.94
M30	46	24.30	0.81	2730	0.91
M33	50	27.40	0.83	30.90	0.94
M36	55	29.40	0.82	33.10	0.92
M39	60	31.80	0.82	35.90	0.92

Designation of Property Classes

The symbol for property classes of regular nuts (style 1) and high nuts (style 2) consists of one number. This number corresponds to the number to the left of the appropriate maximum property class of bolts, screws and studs with which they can be mated. A bolt or screw assembled with a nut (style 1 or style 2) of the appropriate property class is intended to provide an assembly which will lead to bolt breaking in case of over-tightening (overloading), i.e. without occurrence of thread stripping.

The symbol for property classes of thin nuts (style 0) consists of two numbers: the first number is zero, indicating that the loadability of the nut is reduced in comparison with the loadability of a regular nut or a high nut and therefore thread stripping can occur when overloaded; the second number corresponds to 1/100 of the nominal stress under proof load, in N/mm^2 (megapascals). Thin nuts are used with fasteners having reduced loadability.

Design of Bolted Joint

A bolted joint essentially consists of two pieces, which are clamped together using an externally threaded part (for example, a bolt or screw) on one side and an internally threaded part or a nut on the other side.

Nut thickness standards have been drawn up on the basis that the bolt/screw will always fail due to tension before thread strips. If the bolt breaks on tightening, it is obvious that a replacement is required. Thread stripping tends to be gradual in nature. If the thread stripping mode occurs, assemblies may enter into service which is partially failed. This may have disastrous consequences. Hence, the potential of thread stripping of both the internal and external threads must be avoided if a reliable design is to be achieved.

As per ISO 898-2, regular nuts (style 1) and high nuts (style 2) shall be mated with externally threaded fasteners according to the following table. However, nuts of a higher property class may replace nuts of a lower property class.

Combination of Regular Nuts and High Nuts with Bolt Property Classes	
Nut Property Class	**Maximum Property Class of Mating Bolt, Screw and Stud**
5	5.8
6	6.8
8	8.8
9	9.8
10	10.9
12	12.9/12.9

Thus a bolted joint design consisting of a bolt, screw or stud of a given property class according to ISO 898-1 assembled with a regular or high nut of the mating property class according to ISO 898-2 results in an optimized design because it is able to provide a maximum preload, using the full strength of the bolt. In the case of over-tightening, the fracture occurs in the loaded threaded part of the bolt, which gives an obvious indication of a tightening failure.

It may be noted that a decrease of thread stripping strength occurs for nuts with a fundamental deviation greater than zero for tolerance class 6H (such as hot dip galvanized nuts: 6AZ, 6AX). Thin nuts (style 0) have a reduced loadability compared to regular nuts or high nuts, and are not designed to provide resistance to thread stripping.

Thin nuts are generally used as jam nuts. Thin nuts used as jam nuts should be assembled together with a regular nut or a high nut. In assemblies with a jam nut, the jam nut is first tightened against the assembled parts and then the regular or high nut is tightened against the jam nut.

Mechanical Properties

When tested by the methods specified in the standard (ISO 898-2), the nuts of the specified property class shall meet, at ambient temperature, the requirements for the proof load test and for the hardness test.

The proof load test consists of application of a specified proof load by means of a test mandrel, and checking of the damage to the nut thread caused by the proof load, if any. For a nut to pass the test, the nut shall be removable using the fingers after the release of the proof load (and, if necessary, after a half turn maximum with a wrench) and it should have resisted the proof load without fracture by thread stripping or nut fracture.

The following table shows the proof load values for nuts with coarse thread.

Proof Load[a] Values for Nuts With Coarse Thread, N									
Thread	Pitch	Property Class							
D	*P*	04	05	5	6	8	9	10	12
M5	0.8	5400	7100	8250	9500	12140	13000	14800	16300
M6	1	7640	10000	11700	13500	17200	18400	20900	23100
M7	1	11000	14500	16800	19400	24700	26400	30100	33200
M8	1.25	13900	18300	21600	24900	31800	34400	38100	42500
M10	1.5	22000	29000	34200	39400	50500	54500	60300	67300
M12	1,75	32000	42200	51400	59000	74200	80100	88500	100300
M14	2	43700	57500	70200	80500	101200	109300	120800	136900
M16	2	59700	78500	95800	109900	138200	149200	164900	186800
M18	2.5	73000	96000	121000	138200	176600	176600	203500	230400
M20	2.5	93100	122500	154400	176400	225400	225400	259700	294000
M22	2.5	115100	151500	190900	218200	278800	278800	321200	363600
M24	3	134100	176500	222400	254200	324800	324800	374200	423600
M27	3	174400	229500	289200	330500	422300	422300	486500	550800
M30	3.5	213200	280500	353400	403900	516100	516100	594700	673200
M33	3.5	263700	347000	437200	499700	638500	638500	735600	832800
M36	4	310500	408500	514700	588200	751600	751600	866000	980400
M39	4	370900	488000	614900	702700	897900	897900	1035000	1171000

[a] - For the application of thin nuts, it should be considered that the stripping load is lower than the proof load of a nut with full loadability.

The following table shows the proof load values for nuts with fine pitch thread.

Proof Load[a] Values for Nuts with Fine Pitch Thread, N							
Thread	Property Class						
D×*P*	04	05	5	6	8	10	12
M8×1	14900	19600	27000	30200	37400	43100	47000
M10×1.25	23300	30600	44200	47100	58400	67300	73400
M10×1	24500	32200	44500	49700	61600	71000	77400
M12×1.5	33500	44000	60800	68700	84100	97800	105700
M12×1.25	35000	46000	63500	71800	88000	102200	110500
M14×1.5	47500	62500	86300	97500	119400	138800	150000
M16×1.5	63500	83500	115200	130300	159500	185400	200400
M18×2	77500	102000	146900	177500	210100	220300	-
M18×1.5	81700	107500	154800	187000	221500	232200	-
M20×2	98000	129000	185800	224500	265700	278600	-
M20×1.5	103400	136000	195800	236600	280200	293800	-
M22×2	120800	159000	229000	276700	327500	343400	-
M22×1.5	126500	166500	239800	289700	343000	359600	-
M24×2	145900	192000	276500	334100	395500	414700	-
M27×2	188500	248000	351100	431500	510900	535700	-
M30×2	236000	310500	447100	540300	639600	670700	-
M33×2	289200	380500	547900	662100	783800	821900	-
M36×3	328700	432500	622800	804400	942800	934200	-
M39×3	391400	515000	741600	957900	1123000	1112000	-

[a] - For the application of thin nuts, it should be considered that the stripping load is lower than the proof load of a nut with full loadability.

Hardness may be determined using the Vickers (ISO 6507-1), Brinell (ISO 6506-1) or Rockwell (ISO 6508-1) hardness test. The Vickers hardness test shall be carried out with a minimum load of 98 N. The Brinell hardness test shall be carried out with a load equal to $30D^2$, expressed in newtons.

The following table shows requirement of Vickers hardness for nuts with coarse thread.

Vickers Hardness for Nuts with Coarse Thread, HV																
Thread *D*	**Property Class**															
	04		**05**		**5**		**6**		**8**		**9**		**10**		**12**	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
M5 ≤ *D* ≤ M16	188	302	272	353	130	302	150	302	200	302	188	302	272	353	295[c]	353
M16 < *D* ≤ M39					146		170		233[a]	353[b]					272	

[a] - Minimum value for high nuts (style 2): 180 HV (171 HB).
[b] - Maximum value for high nuts (style 2): 302 HV (287 HB; 30 HRC).
[c] - Minimum value for high nuts (style 2): 272 HV (259 HB; 26 HRC).

The following table shows requirement of Vickers hardness for nuts with fine pitch thread.

Vickers Hardness for Nuts with Fine Pitch Thread, HV														
Thread *D* × *P*	**Property Class**													
	04		05		5		6		8		10		12	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
M8×1 ≤ *D* ≤ M16×1.5	188	302	272	353	175	302	188	302	250[a]	353[b]	295[c]	353	295	353
M16×1.5 < *D* ≤ M39×3					199		233		295	353	260		-	-

[a] - Minimum value for high nuts (style 2): 195 HV (185 HB).
[b] - Maximum value for high nuts (style 2): 302 HV (287 HB; 30 HRC).
[c] - Minimum value for high nuts (style 2): 250 HV (238 HB; 22,2 HRC).

For information on requirement of Brinell hardness (HB) and Rockwell hardness (HRC) values for various property classes, please see ISO 898-2.

Surface (bearing surface of the nut) hardness of quenched and tempered nuts shall meet the requirements specified in the standard.

Nuts which are not quenched and tempered shall not exceed the maximum hardness requirement specified in the standard. For nuts which are not quenched and tempered, if the minimum hardness requirement is not met when tested, it shall not be cause for rejection, provided the proof load requirements are met.

Marking

Hexagon nuts (including nuts with flange, prevailing torque type nuts, etc.) shall be marked with the identification mark of the manufacturer and with the marking symbol of the property class.

The marking symbols for property classes for regular nuts (style 1) and high nuts (style 2) shall be as per the following table.

Property Class Designation Symbol	5	6	8	9	10	12
Marking Symbol	5	6	8	9	10	12

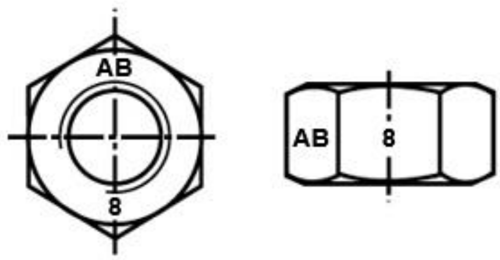
In the case of small nuts or where the shape of the nut does not allow that marking, the clock face marking symbols shall be used. As the alternative marking based on the clock face symbols did not find general acceptance, information on it is not given here.

Marking symbols for property classes for thin nuts (style 0) are specified in the following table.

Property Class	04	05
Marking Symbol	04	05

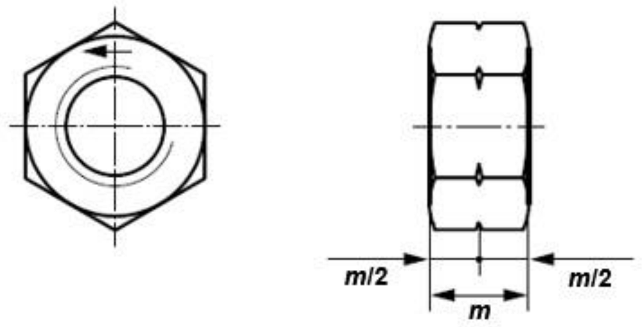
The alternative clock face marking symbols shall not be used for thin nuts.

The marking is required for nuts of all property classes. The marking shall be on the side or bearing surface as shown in the following figure.



Examples of Marking Symbol on Nuts

Nuts with left-hand thread shall be marked as shown in the following figure with a left turning arrow on one bearing surface of the nut or with a groove halfway up the nut height (alternative marking).



Marking Nuts with Left-Hand Thread

Nuts with Diameters *D* < M5 and *D* > M39

Mechanical properties of bolt and nut assemblies have been optimized for fasteners with threads from M5 to M39 inclusive, on the basis of hexagon nut dimensions specified in ISO 4032 (regular nuts, style 1) and ISO 4033 (high nuts, style 2). In general, the bolt and nut assemblies with smaller diameter need lower nut hardness and/or lower nut height proportion (*m*/*D*) due to the larger ratio of *P*/*D*. In view of this, minimum Vickers hardness suggested for regular nuts (style 1) with *D* < M5 is as per the following table. This suggestion is not an integral part of the standard ISO 898-2.

Minimum Vickers Hardness of Nuts (*D* < 5M), HV					
Thread	**Property Class**				
D	**5**	**6**	**8**	**10**	**12**
M3	151	178	233	284	347
M3.5	157	184	240	294	357
M4	147	174	228	277	337

Nuts with *D* > M39 specified in ISO 4032 have a minimum height of the nut, m_{min}, less than 0.8*D*, which is too low resulting in thread stripping instead of bolt/screw failure due to tension. Therefore, mechanical properties for these nuts are not defined in ISO 898-2. Hence, for nuts with *D* > M39, mechanical properties can be as per agreement between the purchaser and the supplier.

ISO 898-5: Set Screws and Similar Threaded Fasteners with Specified Hardness Classes

ISO 898-5 specifies mechanical and physical properties of set screws and similar threaded fasteners made of carbon steel or alloy steel having a triangular ISO metric screw thread in conformance with ISO 68-1, with a coarse pitch thread of M1.6 to M30, and a fine pitch thread of M8×1 to M30×2 when tested at an ambient temperature range of 10°C to 35°C.

Fasteners in conformance with this standard are classified to specified hardness classes and are intended for use under compressive stress only.

Designation System

The hardness classes are designated as specified in the following table. The number part of the designation represents 1/10 of the minimum Vickers hardness and the letter H refers to the hardness.

Hardness Class Designation	**14H**	**22H**	**33H**	**45H**
Vickers Hardness, HV min.	140	220	330	450

Mechanical and Physical Properties

The fasteners of the specified hardness classes shall, at ambient temperature, meet applicable mechanical and physical properties as per the following table.

No.	**Mechanical and Physical Properties**				**Hardness Class 14H**	**22H**	**33H**	**45H**
1	Performance hardness							
	1.1	Vickers hardness, HV 10		min.	140	220	330	450
				max.	290	300	440	560
	1.2	Brinell hardness HBW, $F = 30\ D^2$		min.	133	209	314	428
				max.	276	285	418	532
	1.3	Rockwell hardness	HRB	min.	75	95	-	-
				max.	105	*	-	-
			HRC	min.	-	*	33	45
				max.	-	30	44	53
2	Surface hardness HV 0.3			max.	-	320	450	580
3	Torque strength (Proof torque)				See the following table			

* - For Hardness Class 22H: if hardness is tested in Rockwell, it is necessary to test the minimum value in HRB and the maximum value in HRC.

Nominal Thread Diameter (coarse and fine pitch)	**Proof Torque, Nm**
3	0.9
4	2.5
5	5
6	8.5
8	20
10	40
12	65

16	160
20	310
24	520
30	860

For further details of the mechanical properties, please refer to ISO 898-5.

Marking

The manufacturer's identification mark is not required. Marking set screws with the hardness class is generally not required. If, in special cases, marking is agreed between the interested parties, the symbol of the hardness class should be used as the marking symbol.

ISO 898-7: Torsional Test and Minimum Torques for Bolts and Screws with Nominal Diameters 1 mm to 10 mm

ISO 898-7 specifies a torsional test for the determination of the breaking torque of bolts and screws with nominal diameters 1 mm to 10 mm with property classes 8.8 to 12.9 in accordance with ISO 898-1. The test applies to bolts and screws with thread less than M3 for which no breaking and proof loads are indicated in ISO 898-1, as well as to short bolts and screws with nominal diameters 3 mm to 10 mm which cannot be subjected to a tensile test. The minimum breaking torques are not valid for hexagon socket set screws.

Torsional Test

In the torsional test, the breaking torque of a bolt or screw is determined by clamping the bolt or screw to be tested into a test device.

As per the standard, the tested bolt or screw is regarded as having passed the torque/torsional test if no rupture occurs before the minimum breaking torques specified in the following table are reached.

Thread	Pitch mm	Minimum Breaking Torque*, Nm			
		Property Class			
		8.8	9.8	10.9	12.9
M1	0.25	0.033	0.036	0.040	0.045
M1.2	0.25	0.075	0.082	0.092	0.10
M1.4	0.3	0.12	0.13	0.14	0.16
M1.6	0.35	0.16	0.18	0.20	0.22
M2	0.4	0.37	0.40	0.45	0.50
M2.5	0.45	0.82	0.90	1.0	1.1
M3	0.5	1.5	1.7	1.9	2.1
M3.5	0.6	2.4	2.7	3.0	3.3
M4	0.7	3.6	3.9	4.4	4.9
M5	0.8	7.6	8.3	9.3	10
M6	1	13	14	16	17
M7	1	23	25	28	31
M8	1.25	33	36	40	44
M8 × 1	-	38	42	46	52
M10	1.5	66	72	81	90
M10 × 1	-	84	92	102	114
M10 × 1.25	-	75	82	91	102

* - These minimum breaking torques are valid for bolts and screws with the thread tolerances 6g, 6f and 6e.

Mechanical Properties of Steel Nuts as per DIN Standards

Relevant studies, experiments and calculations (e.g. Alexander) have shown that due to the higher proof loads of ISO 898-2 and the development of modern tightening techniques based on yield strength, the commonly used nuts with 0.8 *D* height (e.g. DIN 934) do not provide sufficient assurance that the assembly would resist thread stripping during tightening and that an increase of the nominal 0.8 *D* nut height is required. This statement is based on the traditional principle of bolted joints with full loadability, that - if over torqued, the bolt has to break and no thread stripping may occur.

However, the 0.8 *D* high nuts are so widely adopted in Europe, that a change-over on a short term could not be realized. This is why, besides the new ISO 898-2 with higher proof loads the existing DIN 267 Part 4 with lower proof loads has to be maintained temporarily for the 0.8 *D* high nuts. To prevent confusion, it has become necessary to add a vertical bar on either side of the code numbers in DIN 267 Part 4 e.g. I8I instead of 8, the latter being the symbol of the higher, so-called “ISO” nuts.

Because ISO 898-2 does not yet give information on nuts without defined proof load values (hardness classes), a new DIN-standard DIN 267 Part 24 had to be issued for the time being.

In view of above, information on DIN 267 Part 4 and DIN 267 Part 24 is given in this chapter.

DIN 267 Part 4: Fasteners; technical delivery conditions; property classes for nuts (previous classes)

This standard specifies the mechanical properties of nuts which have to withstand specified proof loads, with metric ISO thread, with tolerances 6G and 4H to 7H, with nominal thread diameters up to and including 39 mm, with width across flats or external diameters not less than 1.45 *D* and heights not less than 0.8 *D* (including the normal countersunk on the thread), made of carbon steel or low alloy steel and when tested at room temperature.

Furthermore, the standard only applies to the existing so-called “DIN”-nuts, where in the product standards for the mechanical properties reference is made to DIN 267 Part 4, e.g. the hexagon nuts, DIN 934.

This standard does not apply to nuts which have to meet special requirements, such as for weldability, corrosion resistance (see DIN 267 Part 11), ability to withstand temperatures above + 300°C or below − 50°C (See DIN 267 Part 13) or locking (see DIN 267 Part 15). The nuts made from free-cutting steel shall not be used above + 250°C.

Designation System of Property Classes

Nuts are assigned a code number to show their property class. The number indicates 1/100 of the proof load stress in N/mm^2. For example, property class 8 nut has a proof load stress of 8 × 100 = 800 N/mm^2. This proof load stress is equal to the minimum tensile strength of a bolt which can be loaded up to this value when mated with the nut concerned. Nuts of a higher property class can generally be used in the place of nuts of a lower class.

For identification of property classes, symbols are assigned to the property classes as shown in the following table. It may be noted that a vertical bar is added on either side of a code number of property class for its symbol.

Code Number for Property Class	4*	5	6	8	10	12
Symbol for Property Class	|4|	|5|	|6|	|8|	|10|	|12|

* - Only for sizes above M 16

Mechanical Properties

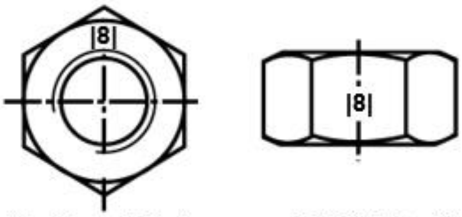
The properties listed in the following table shall apply for testing of nuts at room temperature.

Mechanical Properties	Property Class Symbol					
	|4|*	**|5|**	**|6|**	**|8|**	**|10|**	**|12|**
Proof load stress S_p N/mm^2	400	500	600	800	1000	1200
Vickers hardness HV 5 max.	302	302	302	302	353	353
Brinell hardness HB 30 max.	290	290	290	290	335	335
Rockwell hardness HRC max.	30	30	30	30	36	36
Widening	see DIN 267 Part 21					

* - Only for sizes above M 16

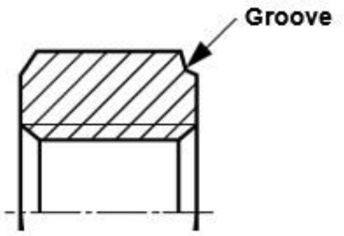
Marking of Nuts

For identification, hexagon nuts with nominal thread diameter $D \geq 5$ mm must be marked with the property class symbol on the bearing surface or on the side of the nut as shown in the following figure.



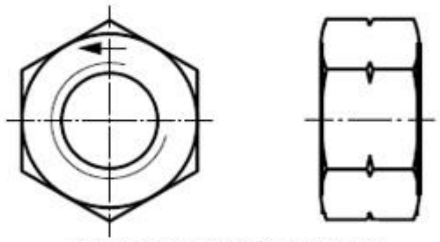
Marking of Nuts as per DIN 267 Part 4

For hexagon nuts according to DIN 934, DIN 935 and DIN 955, made from free-cutting steel, the marking must also include a groove on one face of the nut as shown in the following figure.



Marking of Free-cutting Steel Nuts

Left-hand thread shall be marked with a left turning arrow on one bearing surface, alternatively with a groove halfway up the nut height as shown in the following figure.



Left-hand Thread Marking

The trade (identification) marking of the manufacturer is mandatory on all nuts covered by the obligatory marking requirements for property classes, provided technical reasons do not preclude this.

DIN 267 Part 24: Fasteners; technical delivery conditions; property classes for nuts without specified proof load values (hardness classes)

This standard specifies the mechanical properties of nuts which, due to shape or dimensions cannot be tested by proof loads and cannot be defined on the base of proof load stresses.

This standard contains hardness classes for nuts which do not have to withstand specified proof loads. The hardness classes specified have been classified according to minimum hardness values from which, however, no conclusions can be drawn with regard to the loadability of the nuts or their resistance to stripping. The functional properties of nuts depend on their form.

This standard does not apply to nuts with special requirements, such as weldability, corrosion resistance, high-temperature strength (i.e. at temperatures over + 300°C) or low-temperature toughness (i.e. at temperatures below − 50°C).

It may be noted that nuts made of free-cutting steel shall not be used at temperatures over + 250 °C.

Designation System

The hardness classes for nuts according to the standard are denoted by a combination of numbers and letters as shown in the following table. The number indicates 1/10 of the minimum Vickers hardness; the letter H stands for hardness.

Hardness Class Symbol	11H	14H	17H	22H
Vickers Hardness HV 5 min.	110	140	170	220

Mechanical Properties

The mechanical properties given in the following table shall apply for testing of nuts at room temperature.

Mechanical Property		**Hardness Class**			
		11H	**14H**	**17H**	**22H**
Vickers Hardness HV 5	min.	110	140	170	220
	max.	185	215	245	300
Brinell Hardness HBW 30	min.	105	133	162	209
	max.	176	204	233	285

Marking of Hardness Class

For nuts ≥ M5 and the hardness class 22H, marking with the symbol denoting the hardness class is obligatory.

It is recommended that nuts with left-hand thread be marked with a left turning arrow on one bearing surface or a groove halfway up to the nut height.

Mechanical Properties of Corrosion-Resistant Stainless Steel Fasteners as per ISO Standard (ISO 3506)

ISO 3506 consists of the following parts, under the general title Mechanical properties of corrosion-resistant stainless steel fasteners:

Part 1: Bolts, screws and studs
Part 2: Nuts
Part 3: Set screws and similar fasteners not under tensile stress
Part 4: Tapping screws

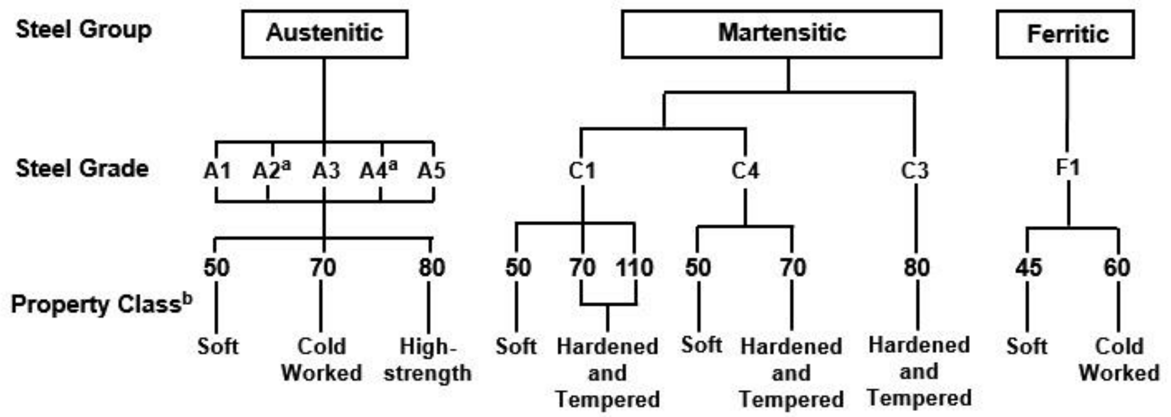
Some useful information about the mechanical properties as per the standard is given in this chapter. It may be noted that the information is given for education purpose only. For commercial use, please see the latest version of the standard.

ISO 3506-1: Bolts, Screws and Studs

ISO 3506-1 specifies the mechanical properties of bolts, screws and studs (called fasteners) made of austenitic, martensitic and ferritic steel grades of corrosion-resistant stainless steels, when tested over an ambient temperature range of 10°C to 35°C. Properties vary at higher or lower temperatures. The specification applies to fasteners with nominal thread diameter *d* ≤ 39 mm, of triangular ISO metric threads with diameters and pitches in accordance with ISO 68-1, ISO 261 and ISO 262.

Designation System

The designation system for stainless steel grades and property classes for bolts, screws and studs is shown in the following figure.



[a] - Low-carbon austenitic stainless steels with carbon content not exceeding 0.03 % may additionally be marked with an "L", Example: A4L-80.
[b] - Fasteners passivated in accordance with ISO 16048 may additionally be marked with a "P", Example: A4-80P.

Designation System for Stainless Steel Grades and Property Classes for Bolts, Screws and Studs

The designation of the material consists of two blocks, separated by a hyphen. The first block designates the steel grade and the second block, the property class.

The designation of the steel grade (first block) consists of one of the letters: A for austenitic steel, C for martensitic steel, or F for ferritic steel which indicates the group of steel and a digit, which indicates a range of chemical compositions within this steel group.

The designation of the property class (second block) consists of two or three digits representing 1/10 of the tensile strength of the fastener.

Example 1: A2-80 indicates, austenitic steel, high-strength, minimum 800 MPa (N/mm^2) tensile strength.

Example 2: C3-80 indicates, martensitic steel, hardened and tempered, minimum 800 MPa (N/mm^2) tensile strength.

Chemical Composition

The following table shows chemical compositions of stainless steels suitable for fasteners in accordance with ISO 3506-1.

Chemical Composition for Stainless Steel Grades										
Steel Group	**Steel Grade**	**Chemical Composition[a] - Mass Fraction, %**								
		C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Austenitic	A1	0.12	1.0	6.50	0.200	0.15 to 0.35	16 to 19	0.7	5 to 10	1.75 to 2.25
	A2	0.10	1.0	2.00	0.050	0.03	15 to 20	-[b]	8 to 19	4.0
	A3	0.08	1.0	2.00	0.045	0.03	17 to 19	-[b]	9 to 12	1.0
	A4	0.08	1.0	2.00	0.045	0.03	16 to 18.5	2 to 3	10 to 15	1.0
	A5	0.08	1.0	2.00	0.045	0.03	16 to 18.5	2 to 3	10.5 to 14	1.0
Martensitic	C1	0.09 to 0.15	1.0	1.00	0.050	0.03	11.5 to 14	-	1.0	-
	C3	0.17 to 0.25	1.0	1.00	0.040	0.03	16 to 18	-	1.5 to 2.5	-
	C4	0.08 to 0.15	1.0	1.50	0.060	0.15 to 0.35	12 to 14	0.6	1.0	-
Ferritic	F1	0.12	1.0	1.00	0.040	0.03	15 to 18	-[c]	1.0	-

[a] - Values are maximum, unless otherwise indicated.
[b] - Molybdenum may be present at the discretion of the manufacturer. However, if for some applications limiting of the molybdenum content is essential, this shall be stated at the time of ordering by the purchaser.
[c] - Molybdenum may be present at the discretion of the manufacturer.
Note: Information on only 3 footnotes ([a, b, c]) is given here. For information on other footnotes, please see the standard (ISO 3506-1).

In applications where risk of intergranular corrosion is present, testing in accordance with ISO 3651-1 or ISO 3651-2 is recommended. In such cases, stabilized stainless steels of grades A3 and A5 or stainless steels of grades A2 and A4 with carbon content not exceeding 0.03 % are recommended.

Mechanical Properties

The mechanical properties of bolts, screws and studs in accordance with ISO 3506-1 shall conform to the values given in the following tables.

It may be noted that even if the material of the fasteners meets all relevant requirements, it is possible that certain fasteners would not fulfil the tensile or torsional requirements because of the geometry of the head, which reduces the shear area in the head compared to the stress area in the thread such as countersunk, raised countersunk and cheese heads.

Mechanical Properties for Bolts, Screws and Studs - Austenitic Steel Grades					
Steel Group	Steel Grade	Property Class	Tensile Strength, R_m min. MPa (N/mm^2)	Stress at 0.2% permanent strain, $R_{p\,0.2}$ min. MPa (N/mm^2)	Elongation after fracture, A min. mm
Austenitic	A1, A2, A3, A4, A5	50	500	210	0.6 d
		70	700	450	0.4 d
		80	800	600	0.3 d

Mechanical Properties for Bolts, Screws and Studs - Martensitic and Ferritic Steel Grades								
Steel Group	Steel Grade	Property Class	Tensile Strength, R_m min. N/mm^2	Stress at 0.2% permanent strain, $R_{p\,0.2}$ min. N/mm^2	Elongation after fracture, *A* min. mm	Hardness		
						HB	HRC	HV
Martensitic	C1	50	500	250	0.2*d*	147 to 209	-	155 to 220
		70	700	410	0.2*d*	209 to 314	20 to 34	220 to 330
		110[a]	1100	820	0.2*d*	-	36 to 45	350 to 440
	C3	80	800	640	0.2*d*	228 to 323	21 to 35	240 to 340
	C4	50	500	250	0.2*d*	147 to 209	-	155 to 220
		70	700	410	0.2*d*	209 to 314	20 to 34	220 to 330
Ferritic	F1[b]	45	450	250	0.2*d*	128 to 209	-	135 to 220
		60	600	410	0.2*d*	171 to 271	-	180 to 285

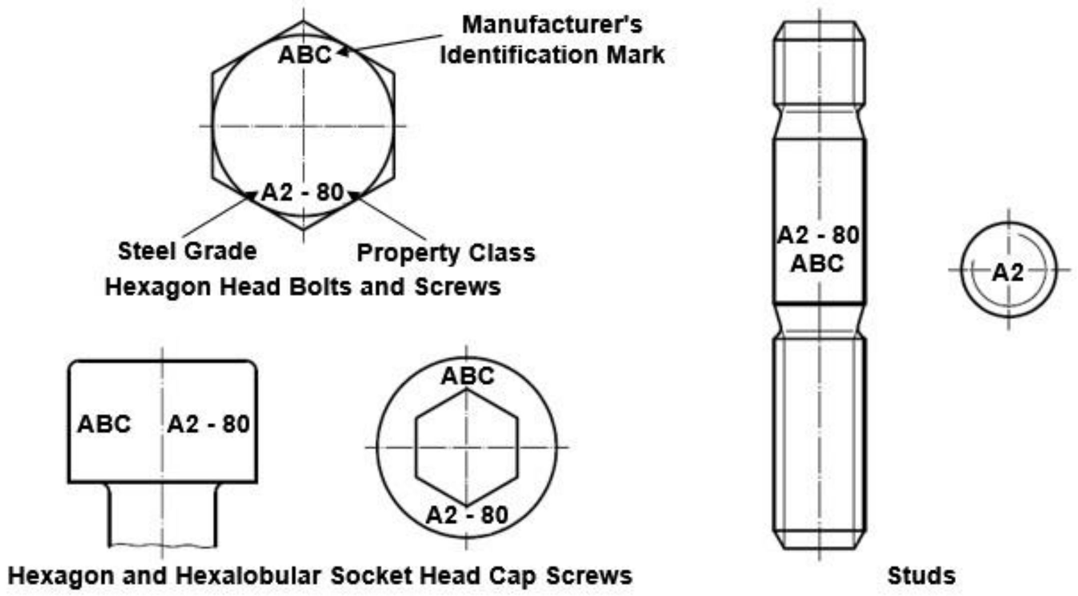
[a] - Hardened and tempered at a minimum tempering temperature of 275°C.
[b] - Nominal thread diameter $d \leq 24$ mm.

Minimum breaking torque, M_B, min., Nm, for austenitic steel grade bolts and screws M1.6 to M16 (coarse thread) shall be as per the following table.

Minimum Breaking Torque, M_B, min., Nm, for Austenitic Steel Grade Bolts and Screws			
Thread	**Property Class**		
	50	70	80
M1.6	0.15	0.2	0.24
M2	0.3	0.4	0.48
M2.5	0.6	0.9	0.96
M3	1.1	1.6	1.8
M4	2.7	3.8	4.3
M5	5.5	7.8	8.8
M6	9.3	13	15
M8	23	32	37
M10	46	65	74
M12	80	110	130
M16	210	290	330

Minimum breaking torque values for martensitic and ferritic steel grade fasteners shall be agreed upon between the manufacturer and the user.

Marking



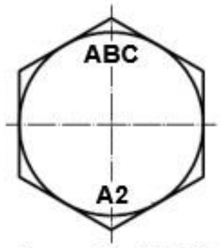
Marking of Stainless Steel Fasteners

Marking is mandatory for all hexagon head bolts and screws, and hexagon or hexalobular socket head cap screws of nominal thread diameter d ≥ 5 mm. The marking shall include the steel grade and property class and shall be marked as shown in above figure.

Studs of nominal thread diameter d ≥ 6 mm shall be marked as shown in above figure. The marking shall be on the unthreaded part of the stud and shall contain the steel grade and property class. If marking on the unthreaded portion is not possible, marking of steel grade only on the nut end of the stud is allowed.

A manufacturer's identification mark also shall be included on all fasteners which are marked with a property class symbol.

For marking of left-hand threads, please see ISO 898-1.



Marking of Fasteners Not Fulfilling Tensile or Torsional Requirements Because of Geometry

Fasteners that do not fulfil the tensile or torsional requirements because of the geometry may be marked with the steel grade, but shall not be marked with the property class as shown in above figure.

Description of Groups and Grades of Stainless Steels

In ISO 3506 (all parts), reference is made to steel grades A1 to A5, C1 to C4 and F1, covering steels of the following groups:

- Austenitic steel A1 to A5;
- Martensitic steel C1 to C4;
- Ferritic steel F1.

Information on the characteristics of the above-mentioned steel groups and steel grades mostly based on the informative Annex B of ISO 3506-1 is given in this section.

Steel Group A (Austenitic Structure)

Austenitic steels cannot be hardened and are usually non-magnetic. In order to reduce the susceptibility to work hardening, copper may be added to the steel grades A1 to A5, as specified in the chemical composition table.

Austenitic steels obtain their resistance to corrosion through a surface protective layer of chromic oxide. If this protective layer of chromic oxide gets damaged, it uses atmospheric oxygen to regenerate it. Hence, if access to atmospheric oxygen is blocked/prevented by an unfavourable style of construction or through dirt, then even these steels will corrode! As chromic oxide makes steel resistant to corrosion, low carbon content is of great importance to non-stabilized steel grades A2 and A4. Due to the high affinity of chrome to carbon, chrome carbide is obtained instead of chromic oxide, which is more likely at elevated temperature. For stabilized steel grades A3 and A5, either titanium (Ti) or niobium (Nb) or tantalum (Ta) is added to the steel. The elements Ti, Nb and Ta affect (react with) the carbon, and chromic oxide is produced to its full extent. Niobium (Nb) and Columbium (Cb) are alternate names for element 41 in the Periodic Table of the Elements. For offshore or similar applications, steels with Cr and Ni content of about 20 % and Mo of 4.5 % to 6.5 % are required. Fasteners from austenitic stainless steel shall be clean and bright. For maximum corrosion resistance passivation is recommended.

Steel Grade A1

Steels of grade A1 contains 0.15 to 0.35% sulfur. This makes the steel free machining for ease of manufacture. However, due to high sulfur content, the steels within this grade have lower resistance to corrosion than corresponding steels with normal sulfur content.

Steel Grade A2

Steels of grade A2 are the most frequently used stainless steels. They are used in the chemical industry and for kitchen equipment. Steels within this grade are not suitable for use in non-oxidizing acid and agents with chloride content, i.e. in swimming pools and sea water.

Steel Grade A3

Steels of grade A3 are stabilized “stainless steels” with properties of steels of grade A2.

Steel Grade A4

Steels of grade A4 are molybdenum alloyed and give a considerably better resistance to corrosion. A4 is used to a great extent by the cellulose industry, as this steel grade is developed for boiling sulfuric acid (hence, also called “acid proof steels”) and is, to a certain extent, also suitable in an environment with chloride content. A4 is frequently used by the food industry and by the shipbuilding industry.

Steel Grade A5

Steels of grade A5 are stabilized with properties of steels of grade A4.

Steel Group C (Martensitic Structure)

Martensitic steel grades C1, C3 and C4 can be hardened to an excellent strength. They are magnetic.

Steel Grade C1

Steels of grade C1 have limited resistance to corrosion. They are generally used in pumps and turbines.

Steel Grade C3

Steels of grade C3 have limited resistance to corrosion. However, the resistance to corrosion is better than C1. They are used in pumps and valves.

Steel Grade C4

Steels of grade C4 have limited resistance to corrosion. They are intended for machining (contains 0.15 to 0.35% sulfur), otherwise they are similar to steels of grade C1.

Steel Group F (Ferritic Structure)

One ferritic steel grade, F1, is included in ISO 3506 (all parts). The steels within F1 cannot normally be hardened and should not be hardened even if possible in certain cases. The F1 steels are magnetic.

Steels of grade F1 are normally used for simpler equipment with the exception of the superferrites, which have extremely low C and N contents. The steels within grade F1 can, if need be, replace steels of grades A2 and A3 and be used in an environment with a higher chloride content.

Steel Group FA (Ferritic-Austenitic Structure)

Steel group FA is not included in ISO 3506 (all parts), but will probably be included in a future edition.

Steels of this steel group are also called duplex steels. FA steels have better properties than steels of grades A4 and A5, especially where strength is concerned. They also exhibit superior resistance to pitting and crack corrosion.

Examples of ferritic-austenitic steel composition are given in the following table.

Examples of Composition of Steels with Ferritic-Austenitic Structure							
Steel Group	Chemical Composition, Mass Fraction, %						
	C max.	Si	Mn	Cr	Ni	Mo	N
Ferritic-Austenitic	0.03	1.7	1.5	18.5	5	2.7	0.07
	0.03	< 1	< 2	22	5.5	3	0.14

Mechanical Properties at Elevated Temperatures and Application at Low Temperatures

It may be noted that if the bolts, screws or studs are properly calculated, the mating nuts automatically meet the requirements. Therefore, in the case of application at elevated or low temperatures, it is sufficient to consider the mechanical properties of bolts, screws and studs only.

The values of mechanical properties given below are as per informative Annex F of ISO 3506-1 and is for guidance only.

% R_{eL} and $R_{p0.2}$ at Elevated Temperatures				
Steel Grade	**Temperature**			
	+100°C	+200°C	+300°C	+400°C
A2, A3, A4, A5	85	80	75	70
C1	95	90	80	65
C3	90	85	80	60
Note: This applies to property classes 70 and 80 only.				

Above table shows values for lower yield stress, R_{eL}, and stress at 0.2 % permanent strain, $R_{p0.2}$, at elevated temperatures in % of the values at room temperature.

Steel Grade	**Lower Limits of Operational Temperature at Continuous Operation**	
A2, A3	−200°C	
A4, A5	Bolts and Screws	−60°C
	Studs	−200°C

Above table shows application of stainless steel bolts, screws and studs at low temperatures.

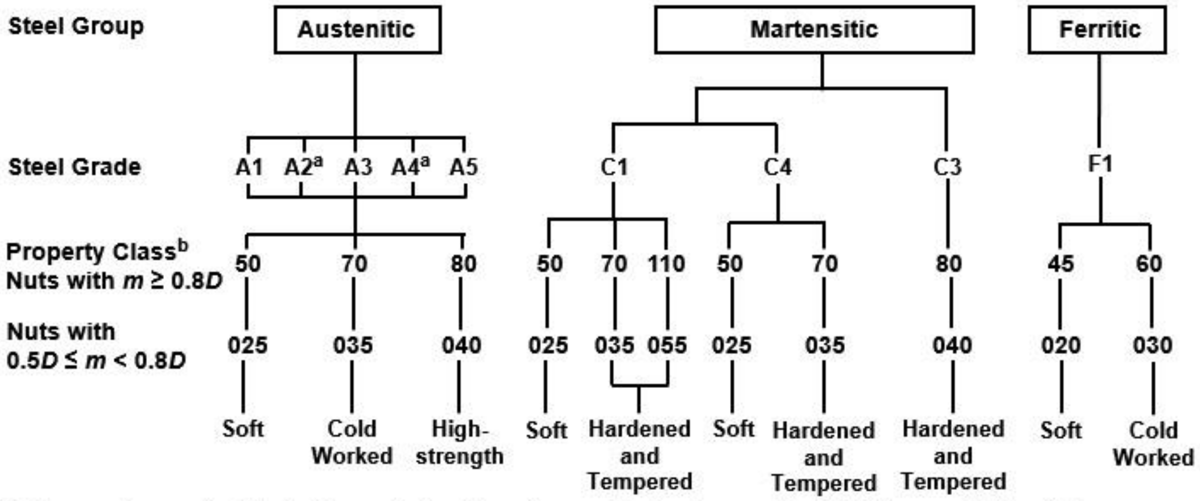
ISO 3506-2: Nuts

ISO 3506-2 specifies the mechanical properties of nuts made of austenitic, martensitic and ferritic steel grades of corrosion-resistant stainless steels, when tested over an ambient temperature range of 10°C to 35°C. Properties vary at higher or lower temperatures.

ISO 3506-2 applies to nuts with nominal thread diameter $D \leq 39$ mm; of triangular ISO metric threads with diameters and pitches in accordance with ISO 68-1, ISO 262; and ISO 261; with width across flats as specified in ISO 272 and with nominal heights $m \geq 0.5D$.

Designation System

The following figure shows the designation system for stainless steel grades and property classes for nuts.



[a] - Low-carbon austenitic stainless steels with carbon content not exceeding 0.03 % may additionally be marked with an "L", Example: A4L-80.
[b] - Fasteners passivated in accordance with ISO 16048 may additionally be marked with a "P", Example: A4-80P.

Designation System for Stainless Steel Grades and Property Classes for Nuts

The designation of the material consists of two blocks, which are separated by a hyphen. The first block designates the steel grade and the second block, the property class.

The designation of the steel grade (first block) consists of the letters:

- A for austenitic steel
- C for martensitic steel, or
- F for ferritic steel

which indicates the group of steel and a digit, which indicates a range of chemical compositions within the steel group.

The designation of the property class, second block consists of two digits for nuts with height $m \geq 0.8D$ (style 1 or style 2 or hexagon flange nuts), representing 1/10 of the stress under proof load; and three digits for nuts with height $0.5D \leq m < 0.8D$ (thin nuts/style 0), the first digit "0" indicating that the nut has a reduced loadability and the following digits representing 1/10 of the stress under proof load.

Mechanical Properties

The mechanical properties of nuts in accordance with ISO 3506-2 shall conform to the values given in the following tables.

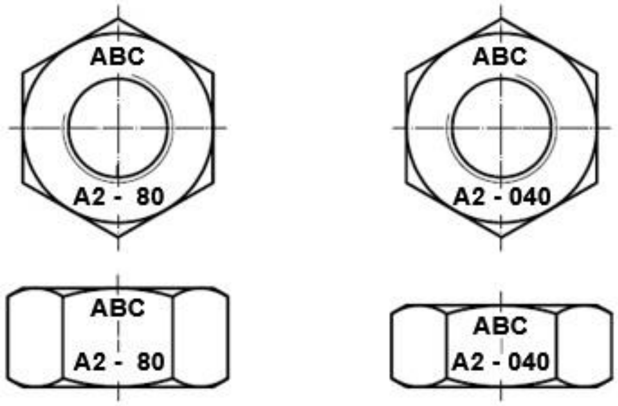
Mechanical Properties for Nuts - Austenitic Grades					
Group	**Grade**	**Property Class**		**Stress Under Proof Load S_p min. MPa (N/mm²)**	
		Nut Style 1 ($m \geq 0.8\ D$)	Thin Nuts ($0.5\ D \leq m < 0.8\ D$)	Nut Style 1 ($m \geq 0.8\ D$)	Thin Nuts ($0.5\ D \leq m < 0.8\ D$)
Austenitic	A1, A2, A3, A4, A5	50	025	500	250
		70	035	700	350
		80	040	800	400

Mechanical Properties for Nuts - Martensitic and Ferritic Grades								
Group	**Grade**	**Property Class**		**Stress Under Proof Load S_p min. MPa (N/mm²)**		**Hardness**		
		Nut Style 1 $m \geq 0.8D$	Thin Nuts $0.5D \leq m < 0.8D$	Nut Style 1 $m \geq 0.8D$	Thin Nuts $0.5D \leq m < 0.8D$	HB	HRC	HV
Martensitic	C1	50	025	500	250	147 to 209	-	155 to 220
		70	-	700	-	209 to 314	20 to 34	220 to 330
		110[a]	055[a]	1100	550	-	36 to 45	350 to 440
	C3	80	040	800	400	228 to 323	21 to 35	240 to 340
	C4	50	-	500	-	147 to 209	-	155 to 220
		70	035	700	350	209 to 314	20 to 34	220 to 330
Ferritic	F1[b]	45	020	450	200	128 to 209	-	135 to 220
		60	030	600	300	171 to 271	-	180 to 285

[a] - Hardened and tempered at a minimum tempering temperature of 275°C.
[b] - Nominal thread diameter $D \leq 24$ mm.

Marking

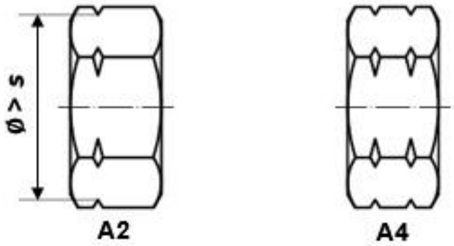
Marking is mandatory on all nuts of nominal thread diameter $D \geq 5$ mm and shall be marked with the steel grade and property class in accordance with the designation system described above. Nuts shall be also marked with the manufacturer's identification mark which are marked with a property class.



Marking of Stainless Steel Nuts

As shown in above figure, marking of only one nut face is acceptable and shall be only by indentation when applied to the bearing surface of the nuts. Alternatively, marking on the side of the nuts is permissible.

As shown in the following figure, when the marking is made with grooves, for steel grades A2 and A4 and the property class is not indicated, property class 50 or 025 will apply.



s is the width across flats

Alternative Groove Marking (for A2 and AA steel grades only)

For marking of left-hand threads, see ISO 898-2.

It is possible that certain nuts would not fulfil the proof load requirements because of fine pitch thread or the geometry of the nut. These nuts may be marked with the steel grade, but shall not be marked with the property class.

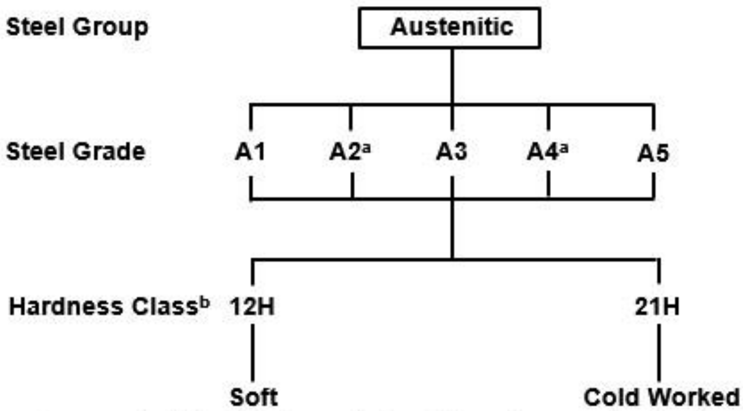
ISO 3506-3: Set Screws and Similar Fasteners Not Under Tensile Stress

ISO 3506-3 specifies the mechanical properties of set screws and similar fasteners not under tensile stress made of austenitic stainless steel, when tested over an ambient temperature range of 10°C to 35°C. Properties vary at higher or lower temperatures.

ISO 3506-3 applies to set screws and similar fasteners with nominal thread diameter 1.6 mm ≤ *d* ≤ 24 mm, of triangular ISO metric threads with diameters and pitches in accordance with ISO 68-1, ISO 261 and ISO 262.

The aim of ISO 3506-3 is the classification of corrosion-resistant stainless steel fasteners into hardness classes.

Designation System



[a] - Low-carbon austenitic stainless steels with carbon content not exceeding 0,03 % may additionally be marked with an "L". EXAMPLE A4L-21H

[b] - Set screws and similar fasteners passivated in accordance with ISO 16048 may additionally be marked with a "P". EXAMPLE A4-21HP

Designation System for Stainless Steel Grades and Hardness Classes for Set Screws and Similar Fasteners

Above figure shows the designation system for stainless steel grades and hardness classes for set screws and similar fasteners. The designation of the material consists of two blocks, which are separated by a hyphen. The first block designates the steel grade and the second block, the hardness class.

The designation of the steel grade, first block consists of the letter A for austenitic steel, which indicates the group of steel and a digit, which indicates a range of chemical compositions within this steel group.

The designation of the hardness class, second block consists of two digits representing 1/10 of the minimum Vickers hardness and the letter H, referring to hardness as per the following table.

Hardness Class	12H	21H
Vickers Hardness, HV min.	125	210

Example: A2-21H indicates: austenitic steel, cold worked, minimum hardness 210 HV.

Mechanical Properties

The mechanical properties of set screws and similar fasteners in accordance with ISO 3506-3 shall conform to the proof torque values and hardness values as per the following tables.

Proof Torque Requirements for Hexagon Socket Set Screws, min. Nm		
Nominal Thread Diameter	**Hardness Class**	
d	**12H**	**21H**
1.6	0.03	0.05
2	0.06	0.1
2.5	0.18	0.3
3	0.25	0.42
4	0.8	1.4
5	1.7	2.8
6	3	5
8	7	12
10	14	24
12	25	42
16	63	105
20	126	210
24	200	332

Hardness Requirements for Hexagon Socket Set Screws		
Test Method	**Hardness Class**	
	12H	**21H**
Vickers Hardness HV	125 to 209	210 min.
Brinell Hardness HB	123 to 213	214 min.
Rockwell Hardness HRB	70 to 95	96 min.

Marking

Marking of set screws and similar fasteners is not mandatory. However, when they are marked, the marking should include the steel grade, hardness class and manufacturer's identification mark.

ISO 3506-4: Tapping Screws

ISO 3506-4 specifies the mechanical properties of tapping screws made of austenitic, martensitic and ferritic steel grades of corrosion-resistant stainless steels, when tested over an ambient temperature range of 10°C to 35°C. It applies to tapping screws with threads from ST2.2 up to and including ST8, in accordance with ISO 1478. For more information, please see the standard.

ASTM Standards for Fasteners

The most widely used standards for materials in the United States are those published by ASTM (American Society for Testing and Materials, now ASTM International).

Every ASTM standard is identified by a unique designation. It includes a capital letter (A to H), followed by an arbitrary sequentially assigned number ranging from one to four digits, a dash, and finally the year of issue. For example, a common bolt specification is A449 - 14, although when specified the standard's year designation is usually not included.

The prefix alphabetical letters represent general classifications and correspond to the following subjects:

- A = Iron and Steel Materials
- B = Nonferrous Metal Materials
- C = Ceramic, Concrete, and Masonry Materials
- D = Miscellaneous Materials
- E = Miscellaneous Subjects
- F = Materials for Specific Applications
- G = Corrosion, Deterioration, and Degradation of Materials
- H = Joint Committee and District Recipients

These designations often apply to specific products, for example A574 is applicable to alloy steel socket-head cap screws.

Metric ASTM standards have a suffix letter M.

There are six types of ASTM standards: test method, specification, classification, practice, guide and terminology. Thus many of the ASTM standards are called specification. A specification has an explicit set of requirements to be satisfied by a material, product, system or service.

Information about important ASTM specifications for fastener materials is given in the following chapters. <u>It may be noted that the information is given for education purpose only.</u> For commercial use, please see the latest version of the standard.

Many of the ASTM specifications have been adopted by the American Society of Mechanical Engineers (ASME) with little or no modification; ASME uses the prefix S and the ASTM designation for these specifications. For example, ASME SA-962 and ASTM A962 are identical.

It may be noted that many ASTM specifications with fixed designation, (for example ASTM A962/A962M) are expressed in both inch-pound units and in SI units. In such specifications, unless the purchase order or contract specifies the applicable "M" specification designation (SI units) the inch-pound units shall apply. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. In case, a complete metric companion to a specification with fixed designation (for example, specification A563M, companion to the specification with fixed designation A563) has been developed, no metric equivalents are presented in the specification.

Definitions of Terms

Following are the definitions of terms specific to bolting material specification (A962/A962M).

Bolting

A general term which includes bolting materials which are manufactured into bolting components, including but not limited to, connectors, pins, restraining device components, shafts, bolts, nuts, screws, studs, and washers.

Bolting Materials

Bolting materials are starting materials used for the manufacture of bolting components, such as rolled or forged or threaded solid bars, blanks, wires, rods, or tubes or other hollow sections, that may be further processed by heat treatment, cold working, forging, threading, or machining.

Grade

Grade is used for an alloy described individually and identified by its own designation in a table of chemical requirements within any specification.

Class

Class is a term used to differentiate between different heat treatment conditions or strength levels, or both, often within the same grade but sometimes within the same family of materials. May also apply to work hardened condition or strength level, or both.

Strain Hardened Material

Strain hardened material is austenitic stainless steel material which has been subjected to cold working sufficient to cause a significant increase in strength.

Determination of Mechanical Properties

Fasteners are tested for mechanical properties like hardness, tensile properties (tensile strength and yield strength) and proof load. Tables are provided for the load to be applied during load testing in the specifications.

For information about procedures for conducting tests to determine the mechanical properties of externally and internally threaded fasteners, please see ASTM F606 / F606M: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets.

One can determine bolt / nut proof load in pounds by multiplying the appropriate bolt / nut proof load stress specified in the standard by the tensile stress area of the thread. The tensile stress area of the thread can be calculated by using the following equation.

$$A_s = 0.7854[D - (0.9743/n)]^2$$

where:
A_s = tensile stress area,
D = nominal diameter, and
n = threads per in.

For ready reference, tensile stress areas for UNC, UNF, and 8 UN thread series are given in the following table.

Tensile Stress Areas					
Nominal Size in. - Threads per Inch	**Tensile Stress Area, A_s in.^{2} for UNC**	**Nominal Size in. - Threads per Inch**	**Tensile Stress Area, A_s in.^{2} for UNF**	**Nominal Size in. - Threads per Inch**	**Tensile Stress Area, A_s in.^{2} for 8 UN**
0.073 - 64	0.00263	0.060 - 80	0.00180	-	-
0.086 - 56	0.00370	0.073 - 72	0.00278	-	-
0.099 - 48	0.00487	0.086 - 64	0.00394	-	-
0.112 - 40	0.00604	0.099 - 56	0.00523	-	-
0.125 - 40	0.00796	0.112 - 48	0.00661	-	-
0.138 - 32	0.00909	0.125 - 44	0.00830	-	-
0.164 - 32	0.0140	0.138 - 40	0.01015	-	-
0.190 - 24	0.0175	0.164 - 36	0.01474	-	-
0.216 - 24	0.0242	0.190 - 32	0.0200	-	-
¼ - 20	0.0318	¼ - 28	0.0364	-	-
5⁄16 - 18	0.0524	5⁄16 - 24	0.0580	-	-
⅜ - 16	0.0775	⅜ - 24	0.0878	-	-
7⁄16 - 14	0.1063	7⁄16 - 20	0.1187	-	-
½ - 13	0.1419	½ - 20	0.1599	-	-
9⁄16 - 12	0.182	9⁄16 - 18	0.203	-	-
⅝ - 11	0.226	⅝ - 18	0.256	-	-
¾ - 10	0.334	¾ - 16	0.373	-	-
⅞ - 9	0.462	⅞ - 14	0.509	-	-
1 - 8	0.606	1 - 12	0.663	1 - 8	0.606
1⅛ - 7	0.763	1⅛ - 12	0.856	1⅛ - 8	0.790
1¼ - 7	0.969	1¼ - 12	1.073	1¼ - 8	1.000
1⅜ - 6	1.155	1⅜ - 12	1.315	1⅜ - 8	1.233
1½ - 6	1.405	1½ - 12	1.581	1½ - 8	1.492
1¾ - 5	1.90	-	-	1¾ - 8	2.08
2 - 4½	2.50	-	-	2 - 8	2.77
2¼ - 4½	3.25	-	-	2¼ - 8	3.56
2½ - 4	4.00	-	-	2½ - 8	4.44
2¾ - 4	4.93	-	-	2¾ - 8	5.43
3 - 4	5.97	-	-	3 - 8	6.51
3¼ - 4	7.10	-	-	3¼ - 8	7.69
3½ - 4	8.33	-	-	3½ - 8	8.96
3¾ - 4	9.66	-	-	3¾ - 8	10.34
4 - 4	11.08	-	-	4 - 8	11.81

For Metric fasteners, the tensile stress area of the thread can be calculated by using the following equation.

$A_s = 0.7854\ (D - 0.9382P)^2$

where:
A_s = tensile stress area,
D = nominal diameter, and
P = threads pitch.

It may be noted that 1 ksi (1 ksi = 1000 psi) is equal to 6.895 MPa (N/mm^2).

ASTM Standards for Carbon and Alloy Steel Externally Threaded Fasteners

Information about ASTM standards for carbon and alloy steel externally threaded fasteners is given in this chapter.

ASTM F 568M - Standard Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

ASTM F 568M covers chemical and mechanical requirements for nine property classes of carbon and alloy steel externally threaded metric fasteners in nominal thread diameters M1.6 through M100 suited for use in general engineering applications.

Requirements for seven of the nine property classes, 4.6, 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9, are essentially identical with requirements given for these classes in ISO 898-1. The other two, 8.8.3 and 10.9.3, are not recognized in ISO standards.

Classes 8.8.3 and 10.9.3 bolts, screws, and studs have atmospheric corrosion resistance and weathering characteristics comparable to those of the steels covered in ASTM specification A 588 (Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance). The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

Significance of Property Class Designation

Property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol has the following significance:

- The one or two numerals preceding the first decimal point approximates $\frac{1}{100}$ of the minimum tensile strength in MPa.
- The numeral following the first decimal point approximates $\frac{1}{10}$ of the ratio, expressed as a percentage, between minimum yield stress and minimum tensile strength.
- The numeral 3, following the second decimal point, is an indicator that the material has atmospheric corrosion resistance and weathering characteristics comparable to steels covered in Specification A 588/A 588M.

As this specification (ASTM F 568M) was withdrawn in January 2012 because ISO 898-1 is the preeminent world standard for metric externally threaded fasteners more information on this specification is not given here except the conversion guidance as per appendix X1 of ASTM F 568M.

Appendix X1 (ASTM F 568M)

In appendix X1 of the specification (ASTM F 568M), for guidance purposes only, the following conversion guidance is provided to assist designers and purchasers in the selection of a property class.

- Class 4.6 mechanical properties are approximately equivalent to those of Specification A 307, Grade A.

- Class 8.8 mechanical properties are approximately equivalent to those of Specification A 449, and Specification A 325, Types 1 and 2.

- Class 8.8.3 mechanical properties are approximately equivalent to those of Specification A 325, Type 3.

- Class 9.8 mechanical properties are approximately 9 % higher than those of Specification A 449.

- Class 10.9 mechanical properties are approximately equivalent to those of Specification A 354, Grade BD and Specification A 490, Types 1 and 2.

- Class 10.9.3 mechanical properties are approximately equivalent to those of Specification A 490, Type 3.

- Class 12.9 mechanical properties are approximately equal to those of Specification A 574.

Information about various ASTM specifications mentioned above (Appendix X1 of ASTM Specification F 568M) is given in the following sections.

ASTM A307 - Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 PSI Tensile Strength

ASTM A307 covers the chemical and mechanical requirements of two grades of carbon steel bolts and studs in sizes ¼ in. through 4 in. The fasteners are designated by “Grade” denoting tensile strength and intended use, as follows:

Grade A - Bolts, studs, and threaded rod having a minimum tensile strength of 60 ksi (ksi = kilo psi) and intended for general applications.

Grade B - Bolts, studs, and threaded rod having a tensile strength of 60 to 100 ksi and intended for flanged joints in piping systems with cast iron flanges. Threaded rod is not usually produced to Grade B, but can be when specified by the purchaser.

This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

Hardness Requirements (Bolts, Studs, and Threaded Rod)

The fasteners shall conform to the hardness specified in the following table.

Grade	Nominal Length, in.	Hardness			
		Brinell		Rockwell B	
		min	max	min	max
A	Less than 3 × dia	121	241	69	100
	3 × dia and longer	-	241	-	100
B	Less than 3 × dia	121	212	69	95
	3 × dia and longer	-	212	-	95

Tensile Properties (Full-Size Bolts, Studs, and Threaded Rod)

The fasteners shall conform to the tensile strength as per following stress values.

Grade A, min: 60 ksi
Grade B: min = 60 ksi and max = 100 ksi

Product Marking

All bolt heads, one end of studs ⅜ in. and larger, and whenever feasible studs less than⅜ in. shall be marked with a grade marking as follows:

Grade A shall be marked as 307A
Grade B shall be marked as 307B

In addition to grade marking, bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate.

All markings shall be located on the top of the bolt head or stud end and shall be raised or depressed at the option of the manufacturer.

Suitable Nuts

Suitable nuts are covered in specification ASTM A563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	ASTM A563 Nut Grade and Style[A]
A ¼ to 1½ in.	A, hex
A over 1½ to 4 in.	A, heavy hex
B, ¼ to 4 in.	A, heavy hex

[A] - Nuts of other grades and styles having specified proof load stresses (as per ASTM A563) greater than the specified grade and style of nut are also suitable.

For information on materials, manufacturing, chemical composition, dimensions, etc. please see the specification.

ASTM A449 - Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use

ASTM A449 covers quenched and tempered steel hex cap screws, bolts, and studs having a minimum tensile strength of 120 ksi for diameters 1.0 in. and smaller; 105 ksi for diameters over 1.0 in. to 1½ in.; and 90 ksi for diameters 1¾ in. to 3.0 in. inclusive. The term "fasteners" in this specification denotes hex cap screws, bolts, and studs. The fasteners are intended for general engineering use.

The fasteners are furnished in diameters ¼ to 3.0 in. inclusive. They are designated by type denoting chemical composition as follows:

Type 1 - Plain carbon steel, carbon boron steel, alloy steel, or alloy boron steel
Type 2 - Withdrawn 2003
Type 3 - Weathering steel

Hardness Requirements

The fasteners shall conform to the hardness specified in the following table.

Nominal Diameter, in.	Length, in.	Brinell		Rockwell C	
		Min	Max	Min	Max
¼ to 1, inclusive	Less than 2*D*[A]	253	319	25	34
	2*D* and over	-	319	-	34
Over 1 to 1½ , inclusive	Less than 3*D*[A]	223	286	19	30
	3*D* and over	-	286	-	30
Over 1½ to 3, inclusive	Less than 3*D*[A]	183	235	-	-
	3*D* and over	-	235	-	-

[A] - Hex cap screws and bolts larger than 1.00 in. diameter and shorter than 3*D* and all studs shorter than 3*D* are subject only to minimum and maximum hardness.
D = Nominal diameter or thread size

Tensile Properties (Full-Size Hex Cap Screws, Bolts and Studs)

Bolts shall conform to the tensile load and proof load (Length Measurement Method) or alternative proof load (Yield Strength Method, 0.2 % Offset) as per stress values given in the following table.

Bolt Size, in.	Tensile Load, min, psi	Proof Load (Length Measurement), psi	Alternative Proof Load, Yield Strength (0.2 % Offset), psi
¼ to 1, incl	120 000	85 000	92 000
1⅛ to 1½, incl	105 000	74 000	81 000
1¾ to 3, incl	90 000	55 000	58 000

The load applied during proof load testing shall be equal to or greater than the proof load as per stress values shown in the above table.

Product Marking

Type 1 hex cap screws and bolts and one end of Type 1 studs ⅜ in. and larger, and whenever feasible studs smaller than ⅜ in., shall be marked “A449.”

All Type 3 hex cap screws, blots, and studs shall be marked to indicate that they are produced from weathering steel. Heads of type 3 hex cap screws and bolts shall be marked “A449” underlined (“A449”) Type 3 studs ⅜ in. and larger, and whenever feasible studs smaller than ⅜ in., shall be marked “A449” underlined on at least one end.

In addition to marking for the type as above, they shall be also marked with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

All markings shall be located on the top of a hex cap screw and bolt heads and on one end of studs and shall be either raised or depressed at the manufacturer’s option.

Suitable Nuts and Washers

Suitable nuts are covered in Specification A563. Unless otherwise specified, the grade and style of nut shall be as follows:

Fastener Size and Surface Finish	ASTM A563 Nut Grade and Style[A]
¼ to 1½ in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	B, hex
Over 1½ to 3 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	A, heavy hex
¼ to 3 in., zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
¼ to 3 in., Type 3	C3, DH3, heavy hex

[A] - Nuts of other grades and styles having specified proof load stresses (as per ASTM A563) greater than the specified grade and style of nut are suitable.

Unless otherwise specified, washers ordered with fasteners shall be furnished to the requirements of ASTM F436, Type 1 or ASTM F436, Type 3. Washers for A449 Type 3 fasteners shall conform to ASTM F436 Type 3.

It may be noted that ASTM A449 is virtually identical in chemistry and strength to ASTM A325 and SAE J429 grade 5. However, A449 is more flexible in the sense that it covers a larger diameter range and is not restricted by a specific configuration.

ASTM A325: Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength (Withdrawn 2016)

In May 2016, ASTM A325 was officially withdrawn and replaced by ASTM F3125/F3125M, in which A325 now becomes a grade under the F3125 specification. The F3125 specification is a consolidation and replacement of six ASTM standards; A325, A325M, A490, A490M, F1852, and F2280. Technical information about the now obsolete ASTM A325 specification is given here for reference and informational purposes only.

ASTM A325 covers two types of quenched and tempered steel heavy hex structural bolts having a minimum tensile strength of 120 ksi for sizes 1.0 in. and less and 105 ksi for sizes over 1.0 to 1½ in., inclusive. The bolts are intended for use in structural connections.

The bolts are furnished in sizes ½ to 1½ in., inclusive. They are designated by type, denoting chemical composition as follows:

Type 1 - Medium carbon, carbon boron, or medium carbon alloy steel.
Type 2 - Withdrawn in November 1991.
Type 3 - Weathering steel.

Hardness Requirements

The bolts shall conform to the hardness specified in the following table.

Bolt Size, in.	Nominal Length, in.	Brinell		Rockwell C	
		Min	Max	Min	Max
½ to 1, incl	Less than 2*D*	253	319	25	34
	2*D* and over	-	319	-	34
1⅛ to 1½ , incl	Less than 3*D*	223	286	19	30
	3*D* and over	-	286	-	30

D = Nominal diameter or thread size.

Tensile Properties (Full-Size Bolts)

The bolts shall conform to the minimum tensile load and proof load or alternative proof load as per stress specified in the following table.

Bolt Size, in.	Tensile Stress, min,	Proof Stress, Length Measurement Method	Alternative Proof Stress, Yield Strength Method
½ to 1, incl	120 000 psi	85 000 psi	92 000 psi
1⅛ to 1½ , incl	105 000 psi	74 000 psi	81 000 psi

The load achieved during proof load testing shall be equal to or greater than the specified proof load.

Product Marking

For grade identification, Type 1 bolts shall be marked "A325" and Type 3 bolts shall be marked "A325" ("A325" underlined).

For manufacturer's identification, all Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

Recommended Nuts and Washers

Nuts conforming to the requirements of ASTM A563 are the recommended nuts for use with ASTM A325 heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Nut Class and Finish
Type 1, plain (noncoated)	A563 - C, C3, D, DH, DH3, plain
Type 1, zinc coated	A563 - DH, zinc coated
Type 1, coated in accordance with ASTM Specification F1136, Grade 3	A563 - DH coated in accordance with ASTM Specification F1136, Grade 5
Type 3, plain	A563 - C3, DH3, plain

Alternatively, nuts conforming to ASTM A194/A194M Gr. 2H are considered a suitable substitute for use with A325 Type 1 heavy hex structural bolts.

Washers conforming to ASTM F436 are the recommended washers for use with A325 heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Washer Finish
Type 1, plain (uncoated)	Plain (uncoated)
Type 1, zinc coated	Zinc coated
Type 1, coated in accordance with ASTM F1136, Grade 3	Coated in accordance with ASTM F1136, Grade 3
Type 3, plain	Weathering steel, plain

When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to ASTM F959, Type 325.

ASTM A490: Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength (Withdrawn 2016)

ASTM A490 was withdrawn in May 2016 and replaced by Specification F3125/F3125M. In view of this, technical information about the now obsolete ASTM A490 specification is given here for reference and informational purposes only.

ASTM A490 covers two types of quenched and tempered, alloy steel, heavy hex structural bolts having a tensile strength of 150 to 173 ksi. These bolts are intended for use in structural connections.

The bolts are furnished in sizes ½ to 1½ in., inclusive. They are designated by type denoting chemical composition as follows:

Type	Description
Type 1	Medium carbon alloy steel
Type 2	Withdrawn in 2002
Type 3	Weathering steel

Hardness Requirements

The bolts shall conform to the hardness specified in the following table.

Bolt Size, in.	Bolt Length, in.	Brinell		Rockwell C	
		Min	Max	Min	Max
½ to 1, incl	Less than 2*D*[A]	311	352	33	39
	2*D*[A] and longer	-	352	-	39
1 to 1½ , incl	Less than 3*D*[A]	311	352	33	39
	3*D*[A] and longer	-	352	-	39

[A] - Heavy hex structural bolts 1 in. and smaller and shorter than 2*D* are subject only to minimum and maximum hardness. Heavy hex structural bolts larger than 1 through 1½, incl., in diameter and shorter than 3*D* are subject only to minimum and maximum hardness.

Tensile Properties (Full-Size Bolts)

The bolts shall conform to the minimum tensile load and proof load or alternative proof load as per following stress values.

Tensile Load: 150 000 psi (min) and 173 000 psi (max)
Proof Load (Length Measurement Method): 120 000 psi
Alternative Proof Load (Yield Strength Method): 130 000 psi

Product Marking

For grade identification, Type 1 bolts shall be marked "A 490" and Type 3 bolts shall be marked "A 490" (A 490 underlined).

In addition to grade identification as above, All Type 1 and Type 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

Recommended Nuts and Washers

Nuts conforming to the requirements of ASTM A563 are the recommended nuts for use with ASTM A490 heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Nut Class and Finish
Type 1, plain (uncoated)	ASTM A563 - DH, DH3 plain (uncoated)
Type 3, weathering steel	ASTM A563 - DH3, weathering steel

Alternatively, nuts conforming to ASTM A194, Gr. 2H plain (uncoated) are considered a suitable substitute for use with ASTM A490 Type 1 heavy hex structural bolts.

Washers conforming to ASTM F436 are the recommended washers for use with ASTM A490 heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Washer Finish
Type 1, plain (uncoated)	Plain (uncoated)
Type 3, weathering steel	Weathering steel

When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to ASTM F959 Type 490.

As ASTM A490 is applicable to heavy hex structural bolts only, the thread length shall not be changed from that specified in ASME B18.2.6 for heavy hex structural bolts. Bolts requiring thread lengths other than those required by this specification (ASTM A490) shall be ordered under **ASTM A354 Gr. BD** (this specification is having mechanical properties similar to ASTM A490).

ASTM A490 bolts are similar in application and dimensions to ASTM A325 heavy hex structural bolts but are made from an alloy steel rather than a medium carbon steel, resulting in a higher strength fastener.

ASTM A354: Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

ASTM A354 covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature. For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, please see ASTM A193/A193M. Two levels of bolting strength are covered, Grades BC and BD.

Grade BD bolts are higher in strength than grade BC, and equal in strength to ASTM F3125 grade A490 bolts. Unlike A490 however, the A354 standard is unrestricted in its configuration. Also, since A490 bolts are for structural use and do not exceed 1½" in diameter, A354 grade BD should be considered for anchor bolts, threaded rods, other styles of headed bolts, and bolts larger than 1½" diameter where similar mechanical properties are desired. A354 grade BD does not require a magnetic particle test like A490, except when called out as a supplemental requirement.

Grade BC is lower in strength than BD. It should be considered in lieu of F3125 grade A325 bolts when configuration and size conflicts occur with A325 as described above for grade BD and A490 bolts.

Hardness Requirements

Fasteners (Full-Size Fasteners) shall not exceed the maximum hardness specified in the following table.

Size, in.	Grade	Brinell		Rockwell C	
		Minimum	Maximum	Minimum	Maximum
¼ to 2½	BC	255	331	26	36
Over 2½	BC	235	311	22	33
¼ to 2½	BD	311	363	33	39
Over 2½	BD	293	363	31	39

Fasteners less than three diameters in length and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in above table, as hardness is the only requirement.

Tensile Properties (All Full-Size Fasteners)

The bolts shall conform to the minimum tensile load and proof load or alternative proof load as per following stress values.

For Grade BC

Tensile Load, min: 125 000 psi for sizes ¼ to 2½ in., inclusive, and 115 000 psi for sizes over 2½ to 4 in., inclusive.
Proof Load (Length Measurement Method), min: 105 000 psi for sizes ¼ to 2½ in., inclusive, and 95 000 psi for sizes over 2½ to 4 in., inclusive.
Alternative Proof Load (Yield Strength Method), min: 109 000 psi for sizes ¼ to 2½ in., inclusive, and 99 000 psi for sizes over 2½ to 4 in., inclusive.

For Grade BD

Tensile Load, min: 150 000 psi for sizes ¼ to 2½ in., inclusive, and 140 000 psi for sizes over 2½ to 4 in., inclusive.
Proof Load (Length Measurement Method), min: 120 000 psi for sizes ¼ to 2½ in., inclusive, and 105 000 psi for sizes over 2½ to 4 in., inclusive.
Alternative Proof Load (Yield Strength Method), min: 130 000 psi for sizes ¼ to 2½ in., inclusive, and 115 000 psi for sizes over 2½ to 4 in., inclusive.

Product Marking

For grade identification, all grade BC products shall be marked "BC" and all grade BD products shall be marked "BD". In addition to the "BD" marking, the product may be marked with 6 radial lines 60° apart if manufactured from alloy steel conforming to the requirements of this specification.

In addition to grade identification as above, all products shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

Recommended Nuts

Nuts are covered in ASTM A563. Unless otherwise specified, the ASTM A563 grade and style of nut for each grade of fastener shall be as follows:

Grade of Fastener and Surface Finish	Nut Grade and Style
BC, plain (or with a coating of insufficient thickness to require over-tapped nuts)	C, heavy hex
BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
BD, all finishes	DH, heavy hex

ASTM F3125: Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions

ASTM F3125covers chemical, physical and mechanical requirements for quenched and tempered bolts manufactured from steel and alloy steel, in inch and metric dimensions, in two strength grades, two types and two styles. This specification is a consolidation and replacement of six ASTM standards, including; A325, A325M, A490, A490M, F1852 and F2280.

Bolts manufactured under this specification are intended for use in structural connections covered in the Specification for Structural Joints Using High-Strength Bolts, as approved by the Research Council on Structural Connections. Bolts in this specification are furnished in sizes from ½ to 1½ in. inclusive and from M12 to M36 inclusive.

Classification

For classification, bolts are designated as given below.

Bolts are designated by grade or property class, which indicates inch or metric respectively.
Bolts are designated by type denoting raw material chemical composition.
Bolts are designated by style denoting Heavy Hex bolts or "Twist-Off" Style assemblies.

Grade	Min. Strength	Type		Style
A325	120 ksi	1	3	Heavy Hex Head
A325M	830 MPa	1	3	Heavy Hex Head
F1852	120 ksi	1	3	Twist-Off
A490	150 ksi	1	3	Heavy Hex Head
A490M	1040 MPa	1	3	Heavy Hex Head
F2280	150 ksi	1	3	Twist-Off

Type 1 - 120 ksi (830 MPa) - carbon steel, carbon boron steel, alloy steel or alloy steel with boron addition
Type 3 - 120 ksi (830 MPa) or 150 ksi (1040 MPa) - weathering steel
Type 1 - 150 ksi (1040 MPa) - alloy steel or alloy steel with boron addition

Hardness Requirements

Bolts shall conform to the hardness as per the following table. For lots on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

Nom. Dia.	Length	120 ksi/830 MPa Tensile, Grade A325, A325M, F1852				150 ksi/1040 MPa Tensile Grade A490, A490M, F2280			
		Brinell HB		Rockwell HRC		Brinell HB		Rockwell HRC	
		Min	Max	Min	Max	Min	Max	Min	Max
Up to 1 in., M24 inclusive	Less than 2D	253	319	25	34	311	352	33	38
	2D and longer	-	319	-	34	-	352	-	38
Over 1 in., M24	Less than 3D	253	319	25	34	311	352	33	38
	3D and longer	-	319	-	34	-	352	-	38

Tensile Properties (Full-Size Bolts)

Diameters 1 in./M24 and smaller having a nominal length of 2¼ D and longer, and sizes over 1 in./M24 having a nominal length of 3D and longer, shall be wedge tested full size to F606/F606M and shall conform to the minimum wedge tensile strength and proof load (stress) or alternative proof load (stress) specified in the following table.

Sizes 1 in./M24 and smaller having a nominal length shorter than 2¼ D down to 2D, inclusive, that cannot be wedge tensile tested, shall be axially tension tested full size to F606/F606M and shall conform to the minimum tensile strength and poof load (stress) or alternate proof load (stress) specified in the following table.

Sizes 1 in./M24 and smaller having a nominal length shutter than 2D and sizes larger than 1 in./M24 with nominal lengths shorter than 3D that cannot be axially tensile tested shall be qualified on the basis of hardness.

Bolt Classification	Tensile Strength min.	Tensile Strength max.	Proof Load (stress), Length Measurement, min.	Alternative Proof Load (stress), Yield Strength Method, min.
120 ksi - A325, F1852	120000	-	85000	92000
150 ksi - A490, F2280	150000	173000	120000	130000
830 MPa - A325M	830 MPa	-	600 MPa	660 MPa
1040 MPa - A490M	1040 MPa	1210 MPa	830 MPa	940 MPa

Product Marking and Matching Components (Nuts and Washers)

Product marking shall be as per the following table. The table also shows recommended nuts and washers.

Product	120 ksi Min Tensile (Inch)		830 MPa Min Tensile (Metric)		150 ksi Min Tensile (Inch)		1040 MPa Min Tensile (Metric)	
	Type 1	Type 3	Type 1	Type 3	Type 1	Type 3	Type 1	Type 3
Grade Marking for Heavy Hex Bolts	A325	A325	A325M	A325M	A490	A490	A490M	A490M
Grade Marking for Twist-Off Bolts	A325TC	A325TC			A490TC	A490TC		
Alt. Grade Marking for Twist-Off Bolts	A325	A325			A490	A490		
Recommended Nut and Washer								
Plain Nut	A563 DH	A563 DH3	A563M 10S	A563M 10S3	A563 DH	A563 DH3	A563M 10S	A563M 10S3
Suitable Alternative[A]	DH3, D, C, C3	C3	8S, 8S3, 10S3	8S3	-	-	10S3	-
Coated Nut	A563 DH	A563 DH3	A563M 10S	A563M 10S3	A563 DH	A563 DH3	A563M 10S	A563M 10S3
Flat, Bevel or Thick Washer if used.	F436-1	F436-3	F436M-1	F436M-3	F436-1	F436-3	F436M-1	F436M-3

[A] - ASTM A194/A194M 2H heavy hex inch nuts may be used in place of A563 DH nuts on type 1 A325, A490, F1852 and F2280 bolts. 2H heavy hex metric nuts may be used in place of A563M 10S nuts on type 1 A325M and A490M bolts. When coated 2H nuts are used in place of DH or 10S nuts, the same requirements of A563, A563M, and this specification, including Annex A1, shall apply. These include, but are not limited to, overtap amount, coating grade, lubrication requirements, and proof load testing.

For supplementary requirements, please see the specification. It may be noted that Grade A490 is stronger than Grade A325, but it cannot be hot dip or mechanical galvanized because these coatings have not been qualified and accepted by ASTM committee.

ASTM A574: Standard Specification for Alloy Steel Socket-Head Cap Screws

ASTM A574 covers the requirements for quenched and tempered alloy steel hexagon socket-head cap screws, 0.060 through 4 in. in diameter where high strength is required.

Mechanical Properties

Different tests shall be conducted in order to determine the mechanical properties of the screws and they shall meet the mechanical requirements as per the following table.

Property (for full-size screws)	≤0.5 in. Nom. Dia.	>0.5 in. and <1.0 in. Nom. Dia.	≥1.0 in. Nom. Dia.
Tensile or wedge tensile strength, min, ksi	180	170	170
Proof load (stress), ksi	140	135	135
Product hardness: Rockwell (HRC)	39-45	37-45	37-45

Product Marking

All screws with nominal diameters of ¼ in. and larger manufactured to this revision shall be permanently marked to identify the manufacturer’s or private label distributor’s identification symbol. Marking for “Socket Head Cap Screws” shall be on the side of the head or on top.

ASTM F1554: Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

ASTM F1554 covers straight, bent, headed, and headless anchor bolts (also known as anchor rods) made of carbon, medium carbon boron, alloy, or high-strength low alloy steel. The specification provides for anchor bolts in three strength grades and two thread classes.

Anchor bolts are intended for anchoring structural supports to concrete foundations. Such structural supports include building columns, column supports for highway signs, street lighting and traffic signals, steel bearing plates, and similar applications.

Threads can be rolled, cut, or ground at the option of the manufacturer. Grade 36 anchor bolts are considered weldable. At the manufacturer's option, a weldable Grade 55 may be supplied when Grade 36 is specified.

Classification

Anchor bolts may be furnished in three grades (denoting minimum yield strength) and two classes (denoting thread class) as follows:

Grade	Diameter Range, in.	Tensile Strength, ksi (MPa)	Yield Strength, min, ksi (MPa)
36	½ - 4	58 - 80 (400 - 558)	36 (248)
55	½ - 4	75 - 95 (517 - 655)	55 (380)
105	½ - 3	125 - 150 (862 - 1034)	105 (724)

1A: anchor bolts with Class 1A threads
2A: anchor bolts with Class 2A threads

Nuts

Recommended nuts from ASTM Specification A563 for each grade and diameter of the anchor bolt are as follows:

Anchor Bolt Grade and Diameter, in.		Plain		Hot-Dip or Mechanical Zinc-coated	
Grade	Diameter, in.	Grade	Style	Grade	Style
36	½ - 1½	A	Hex	A	Hex
	over 1½	A	Heavy Hex	A	Heavy Hex
55	½ - 1½	A	Hex	A	Heavy Hex
	over 1½ - 4	A	Heavy Hex	A	Heavy Hex
105	All	DH	Heavy Hex	DH	Heavy Hex

The availability of A563 grade DH nuts in nominal sizes 1″ and larger is very limited and generally available only on large orders. For smaller quantities, ASTM A194 grade 2H should be considered.

Washers

Unless the washer material and dimensions are otherwise specified in the inquiry and the order, washers conforming to the requirements of ASTM Specification F436, Type 1 shall be furnished.

Unless otherwise specified, when zinc-coated anchor bolts are specified, the washers shall be zinc coated.

Product Marking

Unless otherwise specified, the end of each anchor bolt intended to project from the concrete shall be color coded to identify the grade as follows:

Grade	Color
36	Blue
55	Yellow
55 - Weldable	Yellow (projecting end) & White (encased end)
105	Red

Instead of color coding as specified above, as per supplementary requirement S3, the end of the anchor bolt intended to project from the concrete shall be steel die stamped with the grade identification as follows:

Grade	Identification
36	AB36
55	AB55
105	AB105

Other supplementary requirements provided in the specification are for:
S1 - Weldable Grade 55 Bars and Anchor Bolts,
S2 - Permanent Manufacturer's Identification and
S4 - Grades 55 and 105 Charpy Absorbed-Energy Requirements.

Orders should include grade and class; size and dimensions; coatings detail if required; number of nuts; number of washers; etc.

ASTM A394: Standard Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare

ASTM A394 covers the chemical and mechanical requirements of hexagon and square-head zinc-coated steel bolts and atmospheric corrosion-resistant bolts, in nominal thread diameters of ½, ⅝, ¾, ⅞ and 1 in. for use in the construction of transmission towers, substations, and similar steel structures. The various types of bolts covered in this specification are:

Type 0 - Hot-dip zinc-coated bolts made of low or medium carbon steel.
Type 1 - Hot-dip zinc-coated bolts made of medium carbon steel, quenched and tempered.
Type 2 - Withdrawn in 2005.
Type 3 - Bare (uncoated), quenched and tempered bolts made of weathering steel.

Mechanical Properties

Types 0, 1 and 3 bolts having a length equal to or more than 3 diameters shall be wedge tension tested and shall conform to the tensile strength requirements as per the following table. Zinc-coated bolts shall be tested after coating.

Nominal Size, in.	Minimum Tensile Load, lbf	
	Type 0[A]	Type 1 and 3[B]
½	10500	17050
⅝	16700	27100
¾	24700	40100
⅞	34200	55450
1	44850	72700

[A] Based on 74000 psi unit tensile strength.
[B] Based on 120000 psi unit tensile strength.

Bolts too short for full size testing or for other reasons not subject to tension tests, shall meet the following hardness requirements:

Type 0 - Rockwell B: 80 (Min) - 100 (Max)
Type 1 and 3 - Rockwell C: 25 (Min) - 34 (Max)

Marking

Bolt heads shall be marked to identify the bolt type as per the following.

Bolt Type	Head Marking
0	T-0
1	T-1
3	T-3

Bolt heads shall be also marked with the manufacturer or private label distributor, as appropriate.

Type and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

Recommended Nuts

Unless otherwise specified, all nuts on these bolts shall be hex style and conform to the requirements of Specification A563 as follows.

Bolt Type	Nut Grade	Finish
0	A	hot-dip zinc-coated
1	DH	hot-dip zinc-coated
3	DH3	plain

Recommended Washers

Suitable washers for use with Type 0 are hot-dip zinc-coated carbon-steel washers with dimensions that are in accordance with ASTM Specification F436. Suitable washers for use with Type 1 bolts are hot-dip zinc-coated Type 1 hardened-steel washers that are in accordance with ASTM Specification F436. Suitable washers for use with Type 3 bolts are Type 3 hardened-steel washers that are in accordance with ASTM Specification F436.

ASTM F835: Alloy Steel Socket Button and Flat Countersunk Head Cap Screws

ASTM F835 covers the requirements for quenched and tempered alloy steel hexagon socket button (SBHCS) 0.060 through 0.625 thread sizes and flat countersunk (SFHCS) 0.060 through 1.5 thread sizes head cap screws having material properties for high-strength requirements.

Fasteners meeting this specification are intended for shear-type applications and have tensile requirements ranging from 122 to 150 ksi.

Mechanical Properties

The finished screws shall conform to the mechanical requirements as per the following table.

Mechanical Requirement	Nominal Thread Size, in.	
	0.500 and smaller	Over 0.500
Full-size Screws		
Tensile, min, ksi	145	135
Machined Test Specimen		
Yield strength at 0.2 % offset, min, ksi	[A]	153
Tensile strength, min, ksi	[A]	170
Elongation in 4*D*, min, %	[A]	8
Reduction of area, min, %	[A]	35
Product Hardness		
Rockwell C	39 - 44	37 - 44
Vickers DPH	382 - 434	363 - 434

[A] - Not applicable.

ASTM F912: Alloy Steel Socket Set Screws

ASTM F912 covers the requirements for quenched and tempered alloy steel socket-set screws (SSS) 0.060 through 2.000 in. sizes having hardnesses 45 to 53 HRC. These set screws are intended for compression applications only.

Mechanical Properties

Socket set screws when subjected to a torque test in accordance with the specification shall withstand application of the test tightening torque specified in the following table without evidence of the socket reaming or the screw bursting.

Nominal Size	Test Torque in.-lb, min	Nominal Size	Test Torque in.-lb, min	Nominal Size	Test Torque in.-lb, min
0 (0.060)	1.1	10 (0.190)	40	⅞ (0.875)	5750
1 (0.073)	2.1	¼ (0.250)	94	1 (1.000)	8000
2 (0.086)	2.1	5⁄16 (0.312)	183	1⅛ (1.125)	8000
3 (0.099)	6.0	⅜ (0.375)	317	1¼ (1.250)	11000
4 (0.112)	6.0	7⁄16 (0.437)	502	1⅜ (1.375)	11000
5 (0.125)	11	½ (0.500)	750	1½ (1.500)	18100
6 (0.138)	11	⅝ (0.625)	1460	1¾ (1.750)	38000
8 (0.164)	23	¾ (0.750)	2520	2 (2.000)	38000

Socket set screws shall have a hardness of 45 to 53 HRC. The hardness limits shall apply throughout the screw from core to surface.

Packets containing SBHCS, SFHCS and SSS are marked with ASTM designation, size, brand name or trademark of the manufacturer, number of pieces, purchase order number, and country of origin.

ASTM Standards for Carbon and Alloy Steel Nuts

There are two ASTM standards for carbon and alloy steel nuts: A563 and A563M. A563M is the metric companion of A563. Information about these standards is given in this chapter.

ASTM A563: Standard Specification for Carbon and Alloy Steel Nuts

ASTM A563 covers chemical and mechanical requirements for eight grades (O, A, B, C, D, DH, C3 and DH3) of carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts.

According to the A563 specification, "The requirements for any grade of nut may, at the supplier's option, and with notice to the purchaser, be fulfilled by furnishing nuts of one of the stronger grades specified herein unless such substitution is barred in the inquiry and purchase order". This is important because some nut grades are not readily available in certain sizes and finishes.

Grades C3 and DH3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in specifications A242/A242M, A588/A588M, and A709/A709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assemblability.

Manufacturing

Nuts may be made cold or hot by forming, pressing, or punching or may be machined from bar stock. Threads shall be formed by tapping or machining.

Hot-dip zinc-coated nuts shall be tapped after zinc coating. Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize prior to zinc coating and need not be retapped afterwards.

Nuts to be used on bolts with Class 2A threads before hot-dip zinc coating, and then hot-dip zinc coated in accordance with Specification F2329, shall be tapped oversize after coating,

Hot-dip and mechanically deposited zinc-coated Grade DH nuts shall be provided with an additional lubricant which shall be clean and dry to the touch.

Mechanical Properties

The hardness of nuts of each grade shall not exceed the maximum hardness specified for the grade in the following table.

Nuts of each grade, shall withstand the proof load stress specified for the grade, size, style, thread series, and surface finish of the nut in the following table.

Nuts with UNC, 8 UN, 6 UN and Coarser Pitch Threads								
Grade of Nut	Nominal Nut Size, in.	Style of Nut	Proof Load Stress, ksi[A]		Hardness			
			Non-Zinc-Coated Nuts	Zinc-Coated Nuts	Brinell		Rockwell	
					min	max	min	max
O	¼ to 1½	hex	69	52	103	302	B55	C32
A	¼ to 1½	hex	90	68	116	302	B68	C32
B	¼ to 1	hex	120	90	121	302	B69	C32
B	1⅛ to 1½	hex	105	79	121	302	B69	C32
D[B]	¼ to 1½	hex	135	135	159	352	B84	C38
DH[C]	¼ to 1½	hex	150	150	248	352	C24	C38
DH3	½ to 1	hex	150	150	248	352	C24	C38
A	¼ to 4	heavy hex	100	75	116	302	B68	C32
B	¼ to 1	heavy hex	133	100	121	302	B69	C32
B	1⅛ to 1½	heavy hex	116	87	121	302	B69	C32
C[B]	¼ to 4	heavy hex	144	144	143	352	B78	C38
C3	¼ to 4	heavy hex	144	144	143	352	B78	C38
D[B]	¼ to 4	heavy hex	150	150	159	352	B84	C38
DH[C]	¼ to 4	heavy hex	175	150	248	352	C24	C38
DH3	¼ to 4	heavy hex	175	150	248	352	C24	C38
Nuts with UNF, 12 UN, and Finer Pitch Threads								
O	¼ to 1½	hex	65	49	103	302	B55	C32
A	¼ to 1½	hex	80	60	116	302	B68	C32
B	¼ to 1	hex	109	82	121	302	B69	C32
B	1⅛ to 1½	hex	94	70	121	302	B69	C32
D[B]	¼ to 1½	hex	135	135	159	352	B84	C38
DH[C]	¼ to 1½	hex	150	150	248	352	C24	C38
A	¼ to 4	heavy hex	90	68	116	302	B68	C32
B	¼ to 1	heavy hex	120	90	121	302	B69	C32
B	1⅛ to 1½	heavy hex	105	79	121	302	B69	C32
D[B]	¼ to 4	heavy hex	150	150	159	352	B84	C38
DH[C]	¼ to 4	heavy hex	175	150	248	352	C24	C38

[A] - To determine nut proof load in pounds, multiply the appropriate nut proof load stress by the tensile stress area of the thread.

[B] - Nuts made in accordance to the requirements of Specification A194/A194M, Grade 2 or Grade 2H, and marked with their grade symbol are acceptable equivalents for Grades C and D nuts. When A194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A563.

[C] - Nuts made in accordance with the requirements of Specification A194/A194M, Grade 2H, and marked with its grade symbol are an acceptable equivalent for Grade DH nuts. When A194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A563.

Jam nuts, slotted nuts, nuts smaller in width across flats or thickness than standard hex nuts (ANSI B18.2.2), and nuts that would require a proof load in excess of 160000 lbf may be furnished on the basis of minimum hardness requirements specified for the grade in above table, unless proof load testing is specified in the inquiry and purchase order.

Product Marking

Nuts made to the requirements of Grades O, A, and B are not required to be marked unless individual marking is specified in the inquiry and order. When individual marking is required, the mark shall be the grade letter symbol on one face of the nut.

Heavy hex nuts made to the requirements of Grade C (see Note X given below) shall be marked on one face with three circumferential marks 120° apart.

Heavy hex nuts made to the requirements of Grade C3 shall be marked on one face with three circumferential marks 120° apart and the numeral 3.

Nuts made to the requirements of Grade D shall be marked with the grade symbol, D (Note X) on one face.

Nuts made to the requirements of Grade DH shall be marked with the grade symbol, DH (Note X) on one face.

Heavy hex nuts made to the requirements of Grade DH3 shall be marked with the grade symbol DH3 on one face. Hex nuts made to the requirements of DH3 shall be marked with the symbol HX3 on one face.

In addition, nuts of Grades C, C3, D, DH, and DH3 and hex nuts made to the requirements of DH3, shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate.

Note X: See above table ([C] in Table for Mechanical Properties) for marking of equivalent nuts made in accordance with requirements of Specification A194/A194M.

Nut and Bolt Suitability Guide

Following table, nut and bolt suitability guide (Appendix X1 of ASTM A563), gives additional information for the intended application of nuts.

Nut and Bolt Suitability Guide								
Grade of Bolt[D]	**Surface Finish[E]**	**Nominal Size, in.**	**Grade and ANSI Nut Style[A]**					
			Recommended[B]		**Suitable[C]**			
			Hex	Heavy Hex	Square	Hex	Heavy Hex	Hex Thick
A 307 Grade A	non-zinc coated and zinc-coated	¼ to 1½	A	-	A	B,D,DH	A,B,C,D,DH,DH3	A,B,D,DH
		>1½ to 2	-	A	-	A[F]	C,D,DH,DH3	-
		> 2 to 4	-	A	-	-	C,D,DH,DH3	-
A 307 Grade B	non-zinc coated and zinc-coated	¼ to 1½	-	A	A	B,D,DH	B,C,D,DH,DH3	A,B,D,DH
		>1½ to 2	-	A	-	A[F]	C,D,DH,DH3	-
		> 2 to 4	-	A	-	-	C,D,DH,DH3	-
A 325 Type 1	non-zinc coated	½ to 1½	-	C	-	-	C3,D,DH,DH3	-
	zinc-coated	½ to 1½	-	DH	-	-	-	-
A 325 Type 3	non-zinc coated	½ to 1½	-	C3	-	-	DH3	-
A 354 Grade BC	non-zinc coated	¼ to 1½	-	C	-	D,DH	C3,D,DH,DH3	D,DH
		>1½ to 4	-	C	-	-	C3,D,DH,DH3	-
	zinc-coated	¼ to 1½	-	DH	-	-	-	DH
		>1½ to 4	-	DH	-	-	-	-
A 354 Grade BD	non-zinc coated	¼ to 1½	-	DH	-	DH	D,DH,DH3	D,DH
		>1½ to 4	-	DH	-	-	DH3	-
A 394 Type 0	zinc-coated	½ to 1	A	-	-	B,D	-	-
A 394 Type 1 and 2	zinc-coated	½ to 1	DH	-	-	D	-	-
A 394 Type 3	non-zinc coated	½ to 1	DH3	-	-	-	C3	-
A 449 Type 1 and 2	non-zinc coated	¼ to 1½	B	-	-	D,DH	B,C,C3,D,DH,DH3	B,D,DH
		>1½ to 3	-	A	-	-	C,C3,D,DH,DH3	-
	zinc-coated	¼ to 1½	-	DH	-	D,DH	D	D,DH
		>1½ to 3	-	DH	-	-	D	-
A 490 Type 1 and 2	non-zinc coated	½ to 1½	-	DH	-	-	DH3	-
A 490 Type 3	non-zinc coated	½ to 1½	-	DH3	-	-	-	-
A 687	non-zinc coated	1¼ to 3	-	D	-	-	DH,DH3	-
	zinc-coated	1¼ to 3	-	DH	-	-	-	-

[A] - The availability of DH nuts in nominal sizes ¾ in. and larger is very limited and generally available only on special orders for 50000 pieces or more. For smaller quantities A194 Gr. 2H nuts should be considered.
[B] - "Recommended" denotes a commercially available nut having the most suitable mechanical properties and dimensional configuration (style) that will make it possible to torque the bolt to the required load when used in combination with the nut.
[C] - "Suitable" denotes nuts having mechanical properties that will make it possible to torque the bolt to the required load when used in combination with the nut; but, which require consideration of dimensional configuration (style) suitability and availability. Others are not suitable.

[D] - The term "bolt" includes all externally threaded types of fasteners.
[E] - Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners, which have a plain (nonplated or noncoated) finish or a have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assembiability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are not hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assembiability.
[F] - Hex nuts in nominal sizes over 1½ to 2 in. inclusive are not covered in the tables of tabulated sizes in ANSI B18.2.2 but are commercially available [having dimensions conforming to ANSI B18.2.2 calculated using the formulas for the 1¼ through 1½-in. size range in Appendix III (Formulas for Nut Dimensions) of ANSI B18.2.2]. Such nuts are suitable.

ASTM A563M: Standard Specification for Carbon and Alloy Steel Nuts (Metric)

ASTM A563M covers chemical and mechanical requirements for eight property classes of hex and hex-flange carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts. This specification is the metric companion of ASTM A563.

Requirements for the four classes 5, 9, 10, and 12 are essentially identical with requirements given for these classes in ISO 898-2. Requirements for Classes 8S and 10S are essentially identical with requirements in an ISO 4775 (withdrawn) Hexagon Nuts for High-Strength Structural Bolting with Large Width Across Flats, Product Grade B, Property Classes 8 and 10. Classes 8S3 and 10S3 are not recognized in ISO standards.

Classes 8S3 and 10S3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to those of the steels covered in Specification A588/A588M.

For mechanical properties, please see the standard.

Product Marking

Nuts of all classes, in nominal thread diameters M5 and larger, shall be marked with the property class designation (5, 9, 10, 12, 8S, 10S, 8S3, or 10S3) on the top or bearing surface, on the top of flange, or on one of the wrenching flats of the nut.

Additionally, nuts of Classes 10, 12, 8S, 8S3, 10S, and 10S3 shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate.

Nut/Bolt Suitability Guide

Following table (Appendix X1, Intended Application) presents guidance on the strength suitability of nuts for use in combination with various property classes of metric bolts, screws and studs.

In the following table,

The term "bolt" includes all types of externally threaded products.

"Plain" applies to any bolt that is non-coated or non-plated, or that has a coating or plating of insufficient thickness to require that the nut be overtapped. "Zinc-coated" applies to any bolt that is hot-dip or mechanically zinc-coated or otherwise coated or plated with a coating or plating of sufficient thickness to require the use of overtapped nuts.

G indicate recommended nut class and style.
H indicate non-suitable nut.
I indicate suitable nut class and style.

Nut/Bolt Suitability Guide

Class of Bolt, Screw or Stud	Nominal Diameter of Bolt/Nut	Surface Finish of Bolt	Property Class and Dimensional Style of Nut													
			5		9			10		12			8S	8S3	10S	10S3
			H1[A]	HH[B]	H2[C]	HF[D]	HH[B]	H1[A]	HF[D]	H2[C]	HF[D]	HH[B]	HH[B]	HH[B]	HH[B]	HH[B]
F568, Class 4.6	M5 to M36	plain	*G*	*H*	*I*	*I*	*H*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*	*I*
		zinc-coated	*G*	*H*	*H*	*H*	*H*	*H*	*H*	*I*	*I*	*H*	*H*	*H*	*I*	*H*
	M42 to M100	plain	*H*	*G*	*H*	*H*	*I*	*H*	*H*	*H*	*H*	*I*	*H*	*H*	*H*	*H*
		zinc-coated	*H*	*G*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*I*	*H*	*H*	*H*	*H*
F568, Class 4.8	M1.6 to M16	plain	*G*	*H*	*I*	*I*	*H*	*I*	*I*	*I*	*I*	*H*	*H*	*H*	*H*	*H*
		zinc-coated	*G*	*H*	*H*	*H*	*H*	*H*	*H*	*I*	*I*	*H*	*H*	*H*	*I*	*H*
F568, Class 5.8	M5 to M24	plain	*G*	*H*	*I*	*I*	*H*	*I*	*I*	*I*	*I*	*H*	*I*	*I*	*I*	*I*
		zinc-coated	*G*	*H*	*H*	*H*	*H*	*H*	*H*	*I*	*I*	*H*	*H*	*H*	*I*	*H*
F568, Class 8.8	M16 to M36	plain	*H*	*H*	*G*	*I*	*H*	*I*	*I*	*I*	*I*	*H*	*I*	*I*	*I*	*I*
		zinc-coated	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*H*	*H*	*H*	*I*	*H*
	M42 to M100	plain	*H*	*H*	*H*	*H*	*G*	*H*	*H*	*H*	*H*	*I*	*H*	*H*	*H*	*H*
		zinc-coated	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*	*H*	*H*	*H*
F568, Class 8.8.3	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*	*I*
F568, Class 9.8	M1.6 to M16	plain	*H*	*H*	*G*	*I*	*H*	*I*	*I*	*I*	*I*	*H*	*H*	*H*	*H*	*H*
		zinc-coated	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*H*	*H*	*H*	*I*	*H*
F568, Class 10.9	M5 to M36	plain	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*I*	*I*	*H*	*I*	*I*	*I*	*I*
	M42 to M100		*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*	*H*	*H*	*H*
F568, Class 10.9.3	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*
F568, Class 12.9	M1.6 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*H*	*H*	*H*	*I*	*I*
	M42 to M100		*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*	*H*	*H*	*H*
A325M, Types 1 and 2	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*I*	*I*
		zinc-coated	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*
A325M, Types 3	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*H*	*I*
A490M, Types 1 and 2	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*
A490M, Types 3	M16 to M36	plain	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*
A394, Grade A	M12 to M24	zinc-coated	*G*	*H*	*H*	*H*	*H*	*H*	*H*	*I*	*I*	*H*	*H*	*H*	*I*	*H*
A394, Grade B	M12 to M24	zinc-coated	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*G*	*I*	*H*	*H*	*H*	*I*	*H*

[A] - H1: ANSI B 18.2.4.1M hex nut, Style 1.
[B] - HH: ANSI B 18.2.4.6M heavy hex nut.
[C] - H2: ANSI B 18.2.4.2M hex nut, Style 2.
[D] - HF: ANSI B 18.2.4.4M hex flange nut.

Various nut styles (H1, H2, HH, and HF) have different dimensions (width across flats, thickness, flange diameter). Purchasers are cautioned to consider the dimensional requirements of the application when selecting the most appropriate nut.

For information on slotted hex nuts and hex jam nuts, please see Appendix X2 of the standard.

ASTM Standards for Alloy Steel, Stainless Steel and Nickel Alloy Threaded Fasteners

ASTM A962/A962M titled "Standard Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range", covers a group of common requirements that shall apply to carbon, alloy, stainless steel, and nickel alloy bolting under any of the following ASTM Specifications.

- A193/A193M: Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
- A194/A194M: Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A320/A320M: Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
- A437/A437M: Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service
- A453/A453M: High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels
- A540/A540M: Alloy-Steel Bolting for Special Applications
- A1014/A1014M: Precipitation-Hardening Bolting (UNS N07718) for High Temperature Service

In view of above, information about above standards used for special applications is given in this chapter. For the common requirements that shall apply to them, please see ASTM A962/A962M. ASTM A1082/A1082M: High Strength Precipitation Hardening and Duplex Stainless Steel Bolting for Special Purpose Applications also require conformation to ASTM specification A962/A962M. Information on ASTM standards ASTM F593, ASTM F594 and ASTM F837 for stainless steel fasteners intended for general purpose usage is also given in this chapter to cover all commonly used standards for bolting materials.

ASTM A193/A193M: Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

ASTM A193/A193M covers alloy and stainless steel bolting for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. This specification is heavily utilized in petroleum, chemical and power industries. It may be noted that information about only inch-pound units is given here.

Several grades of ferritic steels and austenitic stainless steels as per the following list are covered by the standard. Selection of a grade will depend upon design, service conditions, mechanical properties, and high temperature characteristics. It may be noted that for grades of alloy-steel bolting suitable for use at the lower range of high temperature applications, reference should be made to ASTM A354.

Type	Grade	UNS Designation
Ferritic Steel, 5% Chromium	B5	-
Ferritic Steel, 12 % Chromium	B6 and B6X	S41000 (410)
Ferritic Steel, Chromium-Molybdenum[A]	B7, B7M	-
Ferritic Steel, Chromium-Molybdenum-Vanadium	B16	-
Austenitic Steels[B], Classes 1, 1A, 1D, and 2	B8, B8A	S30400 (304)
	B8C, B8CA	S34700 (347)
	B8M, B8MA, B8M2, B8M3	S31600 (316)
	B8P, B8PA	S30500

Austenitic Steels[B], Classes 1A, 1B, 1D, and 2	B8N, B8NA	S30451 (304N)
	B8MN, B8MNA	S31651 (316N)
	B8MLCuN, B8MLCuNA	S31254
Austenitic Steels[B], Classes 1, 1A, and 2	B8T, B8TA	S32100 (321)
Austenitic Steels[B], Classes 1C and 1D	B8R, B8RA	S20910
	B8S, B8SA	S21800
Austenitic Steels[B], Classes 1, 1A and 1D	B8LN, B8LNA	S30453
	B8MLN, B8MLNA	S31653

[A] - Typical steel compositions used include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
[B] - Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

For information on chemical requirements (composition) of each grade (alloy), please see the specification (ASTM A193).

Mechanical Requirements - Inch Products

Mechanical requirements for common grades (for inch products) is given in the following table. For information on other grades, please see the specification (ASTM A193).

Grade	Diameter, in.	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Hardness, max
B7	2½ and under	125	105	321 HB or 35 HRC
	over 2½ to 4	115	95	321 HB or 35 HRC
	over 4 to 7	100	75	321 HB or 35 HRC
Class 1: B8, B8M	all diameters	75	30	223 HB or 96 HRB
Class 2: B8	¾ and under	125	100	321 HB or 35 HRC
	over ¾ to 1, incl	115	80	321 HB or 35 HRC
	over 1 to 1¼ , incl	105	65	321 HB or 35 HRC
	over 1¼ to 1½ , incl	100	50	321 HB or 35 HRC
Class 2: B8M	¾ and under	110	95	321 HB or 35 HRC
	over ¾ to 1, incl	100	80	321 HB or 35 HRC
	over 1 to 1¼ , incl	95	65	321 HB or 35 HRC
	over 1¼ to 1½ , incl	90	50	321 HB or 35 HRC

Product Marking

The marking symbol shall be as shown in the following tables.

Marking of Ferritic Steels	
Grade	**Marking Symbol**
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M	<u>B7M</u>
B16	B16
B16 + Supplement S12 (Stress Rupture Testing of Grade B16)	B16R

Marking of Common Austenitic Steels		
Class	**Grade**	**Marking Symbol**
Class 1	B8	B8
	B8M	B8M
Class 2	B8	<u>B8SH</u>
	B8M	<u>B8MSH</u>

Note: For marking symbol of other Classes and Grades of Austenitic Steels, please see the specification (ASTM A193).

Nuts

Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A194/A194M.

Supplementary Requirements

Supplementary requirements of the A193 specification shall not apply unless specified in the purchase order or contract. There are fourteen supplementary requirements under the A193 specification that include special testing, processing, marking, and coating of fasteners.

Strain Hardening of Austenitic Steels (Based on Appendix X1)

Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). Strain hardening is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The amount of strain hardening that can be produced is limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. It may be noted that in large diameter bars, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. The smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

Coatings and Application Limits (Based on Appendix X2)

Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. For example, the melting point of elemental zinc is approximately 780°F [415°C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390°F [210°C].

ASTM A194/A194M: Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

ASTM A194/A194A covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

Note

Though this specification gives information for both inch-pound units and SI units, information about only inch-pound units is given here. For other ASTM specification also information about only inch-pound units is given in this booklet.

Terminology

In this specification, following terminology is used for the various graded.

Austenitic Grades—All grades with a prefix of “8” or “9”.
Ferritic Grades—Grades 1, 2, 2H, 2HM, 3, 6, 6F, 7, 7M, and 16.

Nut Grades

Nuts are made in many grades (following table) to suit variety of bolting material.

Grade Symbol	Material	UNS Number
1	Carbon	-
2, 2HM and 2H	Carbon	-
3	Type 501	-
6	Type 410	S41000
6F	Type 416	S41600
6F	Type 416 Se	S41623
7[A], 7M[A]	Type 4140 / AISI 4142 / AISI 4145, 4140H, 4142H, 4145H	-
8, 8A	Type 304	S30400
8C, 8CA	Type 347	S34700
8CLN, 8CLNA	Type 347LN	S34751
8M, 8MA	Type 316	S31600
8T, 8TA	Type 321	S32100
8F, 8FA	Type 303	S30300
8F, 8FA	Type 303Se	S30323
8P, 8PA	Type 305	S30500
8N, 8NA	Type 304N	S30451
8LN, 8LNA	Type 304LN	S30453
8MN, 8MNA	Type 316N	S31651
8MLN, 8MLNA	Type 316LN	S31653
8R, 8RA	XM19	S20910
8S, 8SA	-	S21800
8MLCuN, 8MLCuNA	S31254	S31254
B8ML4CuN	S31730	S31730
9C, 9CA	N08367	N08367
16	Chromium Molybdenum Vanadium	-

[A] - Grade 4 has been withdrawn (in 2017). Grade 7 is an acceptable substitute for Grade 4.

For information on chemical requirements (chemical composition) of various grades, please the specification.

Hardness Requirements

All nuts shall meet the hardness requirements (for completed nuts) as per the following table.

Grade and Type	Brinell Hardness	Rockwell Hardness	
		C Scale	B Scale
1	121 min	-	70 min
2	159 to 352	-	84 min
2H to 1½ in. or M36, incl.	248 to 327	24 to 35	-
2H over 1½ in. or M36	212 to 327	35 max	95 min
2HM and 7M	159 to 235	-	84 to 99
3, 7, and 16	248 to 327	24 to 35	-
6 and 6F	228 to 271	20 to 28	-

8, 8C, 8CLN, 8M, 8T, 8F, 8P, 8N, 8MN, 8LN, 8MLN, 8MLCuN, 8ML4CuN, and 9C	126 to 300	32 max	60 min
8A, 8CA, 8CLNA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, 8MLCuNA, 8ML4CuNA, and 9CA	126 to 192	-	60 to 90
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min

Note: Where dash (-) appear in above, table there is no requirement.

Proof Load Test

The nuts shall be capable of withstanding the proof loads as per stress specified in the following table. It may be noted that proof loads are not design loads.

Grade	Proof Load Stress, psi	
	Heavy Hex	Hex
1	130 000	120 000
2, 2HM, 6, 6F, 7M	150 000	135 000
2H, 3, 7, 16	175 000	150 000
All Types of Grade 8, Grades 9C and 9CA	80 000	75 000

Note: For proof loads of various nominal size of nuts, please see the specification.

Product Marking

Nuts shall be legibly marked on one face with marking representing the grade, type, and applicable manufacturing process as per the following table (only common nut grades are shown in the table). Other less common grades exist, but are not listed here.

Marking of Common Nut Grades - ASTM A194/A194M			
Grade and Type	Nuts Hot Forged or Cold Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6#
2	2	2B	-
2H[A]	2H	2HB	-
2HM[A]	2HM	2HMB	-
7	7	7B	-
7M[A]	7M	7MB	-
8	8	8B	8A
8M[A]	8M	8MB	8MA

[A] The letters H and M indicate heat-treated nuts.

As per section 6.6 of the specification (ASTM A194/A194M), grades 8A, 8CA, 8CLNA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, 8ML4CuNA and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

Nuts coated with zinc shall have ZN marked after the grade symbol. Nuts coated with cadmium shall have CD marked after the grade symbol. As an example, the marking for zinc-coated 2H bolting components will be 2HZN rather than 2H.

In addition to marking for grade, type, and applicable manufacturing, all nuts shall bear the manufacturer's identification mark.

Dimensions

Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ASME B 18.2.2, ASME B 18.2.4.6M, and ISO 4033. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used. Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished.

It may be noted that ASTM A194 grade 2H nuts are common in the marketplace and are often substituted for ASTM A563 grade DH nuts due to the limited availability of DH nuts in certain diameters and finishes.

Supplementary Requirements

Supplementary requirements of an optional nature are provided in the specification. For information on them, please see the specification. These shall apply only when specified in the inquiry, contract, and order.

ASTM A320/A320M: Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

ASTM A320/A320M covers alloy steel bolting materials and bolting components for pressure vessels, valves, flanges, and fittings for low-temperature service. Several grades are covered, including both ferritic and austenitic steels. Selection will depend on design, service conditions, mechanical properties, and low-temperature characteristics.

Mechanical Properties

Following table indicate the diameters for which the minimum mechanical properties apply to the various grades and classes.

Mechanical Requirements				
Class and Grade	**Diameter, in [mm]**	**Tensile Strength, min, ksi [MPa]**	**Yield Strength, min, ksi [MPa] (0.2 % offset)**	**Hardness max**
Ferritic Steels				
L7, L7A, L7B, L7C, L70, L71, L72, L73	2½ [65] and under	125 [860]	105 [725]	321 HBW or 35 HRC
L43	4 [100] and under	125 [860]	105 [725]	321 HBW or 35 HRC
L7M	2½ [65] and under	100 [690]	80 [550]	235 HBW[A] or 99 HRB
L1	1 [25] and under	125 [860]	105 [725]	-
Austenitic Steels[B]				
Class 1: B8, B8C, B8M, B8P, B8F, B8T, B8LN, B8MLN,	All Diameters	75 [515]	30 [205]	223 HBW[C] or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, B8MLNA,	All Diameters	75 [515]	30 [205]	192 HBW or 90 HRB
Class 2: B8, B8C, B8P, B8F, B8T:	¾ [20] and under	125 [860]	100[690]	321 HBW or 35 HRC
	over ¾ to 1 [20 to 25], incl	115 [795]	80 [550]	321 HBW or 35 HRC
	over 1 to 1¼ [25 to 32], incl	105 [725]	65 [450]	321 HBW or 35 HRC
	over 1¼ to 11⁄2 [32 to 40], incl	100 [690]	50 [345]	321 HBW or 35 HRC
Class 2: B8M:	¾ [20] and under	110 [760]	95 [655]	321 HBW or 35 HRC
	over ¾ to 1 [20 to 25], incl	100 [690]	80 [550]	321 HBW or 35 HRC
	over 1 to 1¼ [25 to 32], incl	95 [655]	65 [450]	321 HBW or 35 HRC
	over 1¼ to 11⁄2 [32 to 40], incl	90 [620]	50 [345]	321 HBW or 35 HRC

[A] - To meet the tensile requirements, the Brinell hardness shall not be less than 200 HBW or 93 HRB.
[B] - Class 1 products are made from solution-treated material. Class 1A products are solution treated in the finished condition for corrosion resistance; heat treatment is critical for enhancing this physical property and meeting the mechanical property requirements. Class 2 products are made from solution-treated material that has been strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the cross section, particularly in sizes over ¾ in. [20 mm] in diameter.
[C] - For sizes ¾ in. [20 mm] in diameter and smaller, a maximum hardness of 241 HBW (100 HRB) is permitted.

The following table shows type, grade and description / UNS designation of various alloys.

Type	Grade	Description / UNS Designation
Ferritic Steels	L7, L7M, L70	Chromium-Molybdenum[A]
	L7A, L71	Carbon-Molybdenum (AISI 4037)
	L7B, L72	Chromium-Molybdenum (AISI 4137)
	L7C, L73	Nickel-Chromium-Molybdenum (AISI 8740)
	L43	Nickel-Chromium-Molybdenum (AISI 4340)
	L1	Low-Carbon Boron
Austenitic Steels, Classes 1, 1A, and 2	B8, B8A	S 30400 (304)
	B8C, B8CA	S 34700 (347)
	B8T, B8TA	S 32100 (321)
	B8P, B8PA	S 30500
	B8F, B8FA	S 30300 (303) and S 30323 (303Se)
	B8M, B8MA	S 31600 (316)
Austenitic Steels, Classes 1 and 1A	B8LN, B8LNA	S 30453
	B8MLN, B8MLNA	S 31653

[A] - Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

For information on chemical composition, please see the specification.

Impact tests are required for the grades shown in above table. However, Class 1, 1A, and 2 austenitic steels for temperatures above −325 °F [−200 °C]; Class 1 and 1A austenitic Grades B8, B8A, B8P, B8PA, B8C, B8CA, B8LN, and B8LNA above −425 °F [−255 °C]; and ferritic or austenitic bolting ½ in. (12.5 mm) and smaller, are exempt from impact testing, unless Supplementary Requirement S1 is specified in the purchase order. All other material furnished under this specification shall be tested. Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft lbf [54 J] at the test temperature when tested by the procedure specified in the applicable portions of Sections 19 to 28 of ASTM A 370: Standard Test Methods and Definitions for Mechanical Testing of Steel Products.

The hardness shall conform to the requirements prescribed in the Table for Mechanical Requirements.

Product Marking

The grade symbol of above table shall be used as the identification symbol. In the case of Class 2, Grades B8, B8C, B8M, B8P, B8F, and B8T strain hardened (as provided in the Table for Mechanical Requirements), a line shall be stamped under the grade symbol in order to distinguish it from Class 1 and Class 1A bolting which has not been strain hardened.

In the case of Class 1A, the marking B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA identifies the material as being in the solution-treated condition in the finished state.

Grade L7M shall be 100 % evaluated in conformance with this specification (As per the specification the maximum hardness of Grade L7M shall be 235 HBW or 99 HRB. Minimum hardness shall not be less than 200 HBW or 93 HRB. Conformance to this hardness shall be ensured by testing each bolt or stud by Brinell or Rockwell B methods.) and shall have a line under the grade symbol.

Nuts from materials that have been impact tested shall be marked with the letter “L.”

Nuts and Washers

Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with ferritic alloy nuts conforming to Grade 7 of specification A194/A194M or a grade of steel similar to the studs.

Grade 7M nuts at a hardness not exceeding 235 HBW (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts.

Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for specification A194/A194M.

Washers for use with ferritic steel bolting shall conform to ASTM F436.

Washers for use with austenitic steel bolting shall be made of austenitic steel as agreed upon between the manufacturer and purchaser.

Washer dimensions shall be in accordance with requirements of ASME B18.22.1, unless otherwise specified in the purchase order.

Supplementary Requirements

The supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. For information on supplementary requirements, please see the specification.

ASTM A437/A437M: Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service

ASTM A437/A437M covers stainless and alloy-steel bolting specially heat treated for high-temperature service, such as steam turbine, gas turbine, and similar uses. The high-temperature properties of the bolting covered by this specification are dependent upon special heat treatment, which is required. Three levels of bolting strength are covered, designated Grades B4B, B4C, and B4D.

Mechanical Properties

Material shall conform to the requirements as to tensile properties, impact requirements and hardness as pre the following tables at room temperature after heat treatment.

Grade	Diameter, in. [mm]	Tensile Strength, min, ksi [MPa]	Yield Strength (0.2 % offset) min, ksi [MPa]
B4B	-	145 [1000]	105 [720]
B4C	-	115 [790]	85 [585]
B4D	2½ [65] and under	125 [860]	105 [720]
	over 2½ to 4 [65 to 100]	110 [760]	95 [655]
	over 4 to 7 [100 to 180]	100 [690]	85 [585]

Grade	Minimum Impact Value, ft·lbf [J]
B4B	10 [14]
B4C	25 [34]
B4D, for bars over 5-in. [127-mm] diameter only	25 [34]

Grade	Bolts and Studs	Nuts and Washers	
	Brinell Hardness Number, max	Brinell Hardness Number	Rockwell Hardness Number
B4B	331	293 to 341	C 31 to 37
B4C	277	229 to 277	C 21 to 29
B4D	302	263 to 311	C 27 to 33

Threads

All threads shall be formed after heat treatment.

Nondestructive Inspection

Each bar or forged blank of starting material shall be subjected to NDE following final heat treatment and shall fulfill inspection requirements as per the specification.

Product Marking

The grade symbol shown in the above table shall be used for the product marking.

Supplementary Requirements

Supplementary requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

ASTM A453/A453M: High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels

ASTM A453/A453M covers four grades of bolting materials with ten classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service such as fasteners for pressure vessel and valve flanges.

The bolting materials shall conform to the room-temperature tensile and hardness requirements as per the following table. For approximate Rockwell Hardness and stress-rupture requirements, please see the specification.

Grade	Class	Tensile strength, min ksi [MPa]	Yield Strength (0.2 % Offset), min ksi [MPa]	Brinell Hardness Number
660	A, B and C	130 [895]	85 [585]	248 - 341
	D	130 [895]	105 [725]	248 - 321
651	A	100 [690]	70[A] [485] 60[B] [415]	217 - 277
	B	95 [655]	60[A] [415] 50[B] [345]	212 - 269
662	A	130 [895]	85 [585]	248 - 321
	B	125 [860]	80 [550]	248 - 321
665	A	170 [1170]	120 [830]	311 - 388
	B	155 [1070]	120 [830]	311 - 388

[A] - Material sizes 3 in. [76 mm] and under in diameter.
[B] - Material sizes over 3 in. [76 mm] in diameter.

Marking

Product shall be marked by grade and class shown in above table. The type designation (for finishing process - for detail see the specification) shall also appear on all bolting material. Grade 660 Class D does not require stress-rupture and shall be additionally stamped NR.

ASTM A540/A540M: Alloy-Steel Bolting for Special Applications

ASTM A540/A540M covers regular and special-quality alloy steel bolting that may be used for nuclear and other special applications. There are five grades of bolting materials with twenty-three classes of yield strength ranging from 105 to 150 ksi as per the following table.

Grade Symbol	Description	Class
B21 (Cr-Mo-V)	Chromium-Molybdenum-Vanadium	1 to 5
B22 (4142-H)	Chromium-Molybdenum	1 to 5
B23 (E-4340-H)	Chromium-Nickel-Molybdenum	1 to 5
B24 (4340 Mod.)	Chromium-Nickel-Molybdenum	1 to 5
B24V (4340V Mod.)	Chromium-Nickel-Molybdenum-Vanadium	1 to 3

ASTM A1014/A1014M: Precipitation-Hardening Bolting (UNS N07718) for High Temperature Service

ASTM A1014/A1014M covers precipitation hardening bolting material (UNS N07718) and bolting components for high temperature service.

Tensile and hardness testing shall be performed after aging. The test specimens shall meet the tensile and hardness requirements as per the following.

Tensile strength, min, ksi [Mpa]: 185 [1275]
Yield Strength, min, ksi, [Mpa] 0.2 % offset: 150 [1035]
Hardness, Brinell: 331 - 444

For information on requirements of other mechanical properties (stress rupture requirements and elevated tensile requirements) and metallography, please see the specification.

Bolting components shall be marked with “718” and the manufacturer’s identification symbol.

ASTM A1082/A1082M: High Strength Precipitation Hardening and Duplex Stainless Steel Bolting for Special Purpose Applications

ASTM A1082/A1082M covers high strength stainless steel bolting materials and bolting components for special purpose applications such as pressure vessels. Several grades of precipitation-hardened and duplex (ferritic-austenitic) stainless steels are covered as listed below. Selection will depend upon design, service conditions, mechanical properties and characteristics related to the application.

Duplex (Ferritic-Austenitic) Grades, UNS Designation (Type):

S31100
S31260
S31803
S32101
S32202
S32205 (2205)
S32304 (2304)
S32506
S32550 (255)
S32750 (2507)
S32760
S32906

S32950
S39277

Precipitation Hardening Grades, UNS Designation (Type):

S15700 (632)
S17400 (630)
S17600 (635)
S17700 (631)
S35500 (634)

For information on chemical composition, heat treatment, mechanical properties and product marking, please see the specification.

Many stainless steel bolts and nuts are simply marked "304" or "316". These markings do not indicate compliance with any particular industrial standard. They do not assure the purchaser of any chemistry, strength, or performance characteristics as are spelled out in the ASTM standards. The markings imply that the chemistry meets the requirements of the UNS S30400 or S31600 material, but that is not assured or mandated by any standards body like SAE or ASTM. Bolts and nuts marked in this way may meet all of the requirements of one or more of the ASTM standards, but since these are not the markings required by ASTM, there is no indication or assurance of such compliance. In view of this, to assure that ordered stainless steel fasteners intended for general purpose usage will provide specific chemistry and physical characteristics, it is recommended that ASTM F593 should be specified for bolts and ASTM F594 should be specified for nuts.

ASTM F593: Stainless Steel Bolts, Hex Cap Screws, and Studs

ASTM F593 covers the requirements for stainless steel bolts, hex cap screws, and studs 0.25 to 1.50 in., inclusive, in nominal diameter in a number of alloys in common use and intended for service applications requiring general corrosion resistance (general purpose usage).

Seven groups of stainless steel alloys are covered, including thirteen austenitic, two ferritic, four martensitic, and one precipitation hardening as shown in the following table.

It may be noted that unless otherwise specified on the inquiry and order, the choice of an alloy from within a group shall be at the discretion of the fastener manufacturer.

Group	Alloys	Condition Furnished Unless Otherwise Specified	Optional Conditions (must be specified)
1	304, 305, 384, 304 L, 18-9LW, 302HQ[B]	(CW) cold worked[A]	AF, A, SH
2	316, 316 L	(CW) cold worked[A]	
3	321, 347	(CW) cold worked[A]	
4	430	(CW) cold worked[A]	A
5	410[D]	(H) hardened and tempered	HT
6	431	(H) hardened and tempered	HT
7	630	(AH) age hardened	none

[A] - Sizes 0.75 in. and larger may be hot worked and solution annealed, provided the bolts comply with the cold worked (CW) mechanical property requirements.
[B] - When approved by the purchaser, Alloys 303, 303Se, or XM1 may be furnished.
[C] - When approved by the purchaser, Alloy 430F may be furnished.
[D] - When approved by the purchaser, Alloys 416 or 416Se may be furnished.

Where (Legend for optional conditions),

A - Machined from annealed or solution-annealed stock thus retaining the properties of the original material; or hot-formed and solution annealed.
AF - Headed and rolled from annealed stock and then reannealed.
AH - Solution-annealed and age-hardened after forming.
CW - Headed and rolled from annealed stock thus acquiring a degree of cold work. Sizes 0.75 in. and larger may be hot-worked and solution annealed.
H - Hardened and tempered at 1050°F (565°C) minimum.
HT - Hardened and tempered at 525°F (274°C) minimum.
SH - Machined from strain-hardened stock or cold-worked to develop the specific properties.

Supplementary requirements of an optional nature are provided in the specification and are applicable only when agreed upon between the manufacturer and the purchaser at the time of the inquiry and order.

Suitable nuts for use with bolts, hex cap screws, and studs included in this specification are covered by ASTM F594. Unless otherwise specified, all nuts used on these fasteners shall conform to the requirements of ASTM F594 and shall be of the same alloy group.

Following table shows UNS designation for the alloys covered by this specification.

Alloy Group	Alloy	UNS Designation	Alloy Type
1	303	S30300	Austenitic Alloy
1	303 Se	S30323	
1	304	S30400	
1	304 L	S30403	
1	305	S30500	
1	384	S38400	
1	XM1	S20300	
1	18–9LW	S30430	
1	302HQ	S30433	
2	316	S31600	
2	316 L	S31603	
3	321	S32100	
3	347	S34700	
4	430	S43000	Ferritic Alloy
4	430F	S43020	
5	410	S41000	Martensitic Alloy
5	416	S41600	
5	416 Se	S41623	
6	431	S43100	
7	630	S17400	Precipitation Hardening Alloy

Mechanical Properties

The finished fasteners shall meet the applicable mechanical property and test requirements of as appropriate for the specified alloy group and condition and shall be tested for conformance to the mechanical property requirements as specified in the specification.

Following table shows tensile strength, yield strength and hardness requirements (full-size tests) for commonly used alloy groups 1 and 2. Information about mechanical property marking is also included in the table. For information on other groups of alloys, please see the specification.

Alloy Group (Alloys)	Condition	Alloy Mechanical Property Marking	Nominal Diameter, in.	Tensile Strength ksi	Yield Strength, (0.2 % Offset), ksi	Rockwell Hardness
1 (303, 304, 304 L, 305, 384, XM1, 18-9LW, 302HQ, 303Se)	AF	F593A	¼ to 1½, incl	65 to 85	20	B85 max
	A	F593B	¼ to 1½, incl	75 to 100	30	B65 to 95
	CW1	F593C	¼ to ⅝, incl	100 to 150	65	B95 to C32
	CW2	F593D	¾ to 1½, incl	85 to 140	45	B80 to C32
	SH1	F593A	¼ to ⅝, incl	120 to 160	95	C24 to C36
	SH2	F593B	¾ to 1, incl	110 to 150	75	C20 to C32
	SH3	F593C	1⅛ to 1¼, incl	100 to 140	60	B95 to C30
	SH4	F593D	1⅜ to 1½, incl	95 to 130	45	B90 to C28
2 (316, 316L)	AF	F593E	¼ to 1½, incl	65 to 85	20	B85 max
	A	F593F	¼ to 1½, incl	75 to 100	30	B65 to 95
	CW1	F593G	¼ to ⅝, incl	100 to 150	65	B95 to C32
	CW2	F593H	¾ to 1½, incl	85 to 140	45	B80 to C32
	SH1	F593E	¼ to ⅝, incl	120 to 160	95	C24 to C36
	SH2	F593F	¾ to 1, incl	110 to 150	75	C20 to C32
	SH3	F593G	1⅛ to 1¼, incl	100 to 140	60	B95 to C30
	SH4	F593H	1⅜ to 1½, incl	95 to 130	45	B90 to C28

Product Marking

All products except studs ⅜ in. in diameter and smaller shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking in accordance with above table.

ASTM F594: Stainless Steel Nuts

ASTM F594 covers the requirements for stainless steel nuts 0.25 to 1.50 in., inclusive, in nominal diameter in a number of alloys in common use and intended for service applications requiring general corrosion resistance (general purpose usage). Seven groups of stainless steel alloys are covered, as per the following table.

These nuts are for use with fasteners conforming to ASTM F593.

Alloy Group	Alloys	Alloy Type
1	303, 304, 304L, 305, 384, XM1, 18-9LW, 302HQ, 303 Se	Austenitic
2	316, 316L	Austenitic
3	321, 347	Austenitic
4	430, 430F	Ferritic
5	410, 416, 416 Se	Martensitic
6	431	Martensitic
7	630	Precipitation Hardening

It may be noted that unless otherwise specified on the inquiry and order, the choice of an alloy from within a group shall be at the discretion of the fastener manufacturer.

Mechanical Properties

Following table shows mechanical property requirements for commonly used alloy groups 1 and 2. Information about mechanical property marking is also included in the table. For information on other groups of alloys, please see the specification.

Alloy Group	Condition	Mech. Property Marking	Nominal Diameter, in.	Proof Stress, Hex Nuts, ksi, min	Proof Stress, Heavy Hex Nuts, ksi, min	Rockwell Hardness
1	AF	F594A	¼ to 1½, incl	70	76	B85 max
	A	F594B	¼ to 1½, incl	75	81	B65 to 95, incl
	CW1	F594C	¼ to ⅝, incl	100	108	B95 to C35, incl
	CW2	F594D	¾ to 1½, incl	85	92	B80 to C35, incl
	SH1	F594A	¼ to ⅝, incl	120	130	C24 to C36, incl
	SH2	F594B	¾ to 1, incl	110	119	C20 to C32, incl
	SH3	F594C	1⅛ to 1¼, incl	100	108	B95 to C30, incl
	SH4	F594D	1⅜ to 1½, incl	85	92	B90 to C28, incl
2	AF	F594E	¼ to 1½, incl	70	76	B85 max
	A	F594F	¼ to 1½, incl	75	81	B65 to 95, incl
	CW1	F594G	¼ to ⅝, incl	100	108	B95 to C35, incl
	CW2	F594H	¾ to 1½, incl	85	92	B80 to C35, incl
	SH1	F594E	¼ to ⅝, incl	120	130	C24 to C36, incl
	SH2	F594F	¾ to 1, incl	110	119	C20 to C32, incl
	SH3	F594G	1⅛ to 1¼, incl	100	108	B95 to C30, incl
	SH4	F594H	1⅜ to 1½, incl	85	92	B90 to C28, incl

Note: For legend of conditions please see the specification.

Product Marking

All products shall be marked with a symbol identifying the manufacturer. In addition, they shall be marked with the alloy/mechanical property marking as per above table. The marking shall be on the top of the nut or on one of the wrenching flats.

ASTM F837: Stainless Steel Socket Head Cap Screws

ASTM F837 covers the chemical and mechanical requirements for stainless steel inch socket head cap screw (SHCS) with nominal thread 0.060 through 1.500 in. and intended for use in applications requiring general corrosion resistance.

Three groups of stainless steel alloys are covered, austenitic Group 1 and 2 and martensitic Group 5.

Four property conditions are covered: austenitic Alloy Groups 1 and 2 in an annealed condition (AF) at 85 ksi maximum, in two cold worked conditions (CW) at 80 ksi minimum, (CW1) at 102 ksi minimum, and martensitic Alloy Group 5 in a heat treated condition (HT) at 160 ksi minimum.

Classification

The austenitic stainless steel socket head cap screw shall be designated F837 Group 1 or 2 Condition AF, F837 Group 1 or 2 Condition CW, or F837 Group 1 or 2 Condition CW1.

The martensitic stainless steel socket head cap screw shall be designated F837 Group 5 Condition HT.

Mechanical Properties

Screws shall meet the mechanical requirements as per the following table. Marking for alloy mechanical property is also shown in the table.

Alloy Group	Condition	Alloy Mech. Property Marking	Nominal Thread Diameter	Full-Size Product	Machine Specimen		Core Hardness[A] Rockwell
				Tensile Strength, ksi	Tensile Strength, ksi	Yield Strength, ksi	
1	AF	F837A	0.060–1.500	85 max	85 max	55 max	95 HRB max
1	CW	F837B	0.060–0.750	80 min	80 min	40 min	50 HRA min
1	CW1	F837C	0.060–0.750	102 min	87 min	65 min	59 HRA min
2	AF	F837D	0.060–1.500	85 max	85 max	55 max	95 HRB max
2	CW	F837E	0.060–0.750	80 min	80 min	40 min	50 HRA min
2	CW1	F837F	0.060–0.750	102 min	87 min	65 min	59 HRA min
5	HT	F837G	0.060–0.190	180 min	-	-	36 - 43 HRC
5	HT	F837H	0.250–1.500	180 min	160 min	120 min	36 - 43 HRC

[A] - Core hardness is only required when full-size product tensile testing cannot be accomplished.

ASTM F879: Stainless Steel Socket Button and Flat Countersunk Head Cap Screws

ASTM F879 covers the chemical and mechanical requirements for stainless steel inch hexagon socket button (SBHCS) and flat countersunk (SFHCS) head cap screws with nominal thread 0.060 through 0.625 in. intended for use in applications requiring general corrosion resistance. Three conditions of austenitic stainless steel alloys covered are:

1. Austenitic alloy group 1 AF in an annealed condition at 85 ksi maximum,
2. Austenitic alloy group 1 CW in a cold-worked condition at 80 ksi minimum, and
3. Austenitic alloy group 1 condition CW1 in a cold worked condition at 102 ksi minimum.

For more information, please see the specification.

ASTM F880: Stainless Steel Socket, Square Head, and Slotted Headless-Set Screws

This specification covers the requirements for austenitic grade stainless steel socket-set screws (SSS) sizes 0.060 through 1.000 in. square head set screws (SHSS) sizes 0.190 through 1.500 in., and slotted headless set screws (HSS) 0.060 through 0.750 in., in two conditions, AF (solution annealed) and CW (cold worked). For more information on them, please see the specification.

ASTM F2281: Standard Specification for Stainless Steel and Nickel Alloy Bolts, Hex Cap Screws, and Studs, for Heat Resistance and High Temperature Applications

ASTM F2281 covers the chemical and mechanical requirements for stainless steel and nickel alloy bolts, hex cap screws, and studs, ¼ in. diameter and larger, intended for use in applications where resistance to heat and the effects of high temperature are to be considered. Three types of materials covered in this specification are: Type I-heat resisting alloys for continuous service applications; Type II-heat resisting alloys for continuous and intermittent service applications; and Type III-high temperature alloys for continuous and intermittent service applications. Type I is classified further into Class A-austenitic grades, Class B-martensitic grades, and Class C-ferritic grades. Type III is also classified further into Class A-nickel based alloy, Class B-precipitation hardened alloy, and Class C-precipitation hardened alloy. For the chemical and mechanical requirements, please see the specification.

Threaded Fasteners as per SAE International

Information about two SAE International (Society of Automotive Engineers) standards on threaded fasteners, SAE J429 and SAE J995 is given in this chapter.

SAE J429: Mechanical and Material Requirements for Externally Threaded Fasteners

SAE J429 covers the mechanical and material requirements for inch-series steel bolts, screws, studs, sems, and U-bolts used in automotive and related industries in sizes to 1-1/2 in inclusive.

Designations and Mechanical Requirements

Designation System: Grades are designated by numbers where increasing numbers represent increasing tensile strength and by decimals of whole numbers where decimals represent variations at the same strength level. The grade designations and important mechanical properties are given in the following table.

Grades: Bolts and screws are normally available only in Grades 1, 2, 5, 5.2, 8, and 8.2. Studs are normally available only in Grades 1, 2, 4, 5, 8 and 8.1. Grade 5.1 is applicable to sems (screw and washer assemblies) which may be heat treated following assembly of the washer on the screw and to products without assembled washer.

Grade Designation	Products	Nominal Size, Diameter, in.	Full Size[1] Fasteners Proof Load (Stress) psi	Full Size Fasteners Tensile Strength (Stress) Min, psi	Machine Test Specimens Yield Strength[2] (Stress) Min, psi	Core Hardness Rockwell	
						Min	Max
1	Bolts, Screws, Studs	¼ thru 1½	33000	60000	36000	B70	B100
2	Bolts, Screws, Studs	¼ thru ¾	55000	74000	57000	B80	B100
		Over ¾ thru 1½	33000	60000	36000	B70	B100
4	Studs	¼ thru 1½	65000	115000	100000	C22	C32
5	Bolts, Screws, Studs	¼ thru 1	85000	120000	92000	C25	C34
		Over 1 thru 1½	74000	105000	81000	C19	C30
5.1	Sems	No. 4 thru ⅝	85000	120000	-	C25	C40
5.2	Bolts, Screws	¼ thru 1	85000	120000	92000	C26	C36
8	Bolts, Screws, Studs	¼ thru 1½	120000	150000	130000	C33	C39
8.1	Studs	¼ thru 1½	120000	150000	130000	C33	C39
8.2	Bolts, Screws	¼ thru 1	120000	150000	130000	C33	C39

[1] - "Full Size" means a tension test specimen consisting of a completed fastener for testing in the ready to use condition without alteration.
[2] - Yield strength is stress at which a permanent set of 0.2% of gage length occurs.

The hardness of bolts, screws, studs, and sems shall be determined at mid-radius of a transverse section through the threaded portion of the product taken at a distance of one diameter from the end of the product. The reported hardness shall be the average of four hardness readings located at 90 degrees to one another. The preparation of test specimens and the performance of hardness tests shall be in conformity with the requirements of SAE J417.

Product Marking - Bolts and Screws

Internal drive screws of all sizes and other screws and bolts of sizes smaller than ¼ in. need not be marked. All other screws and bolts of sizes ¼ in. and larger shall be marked permanently and clearly to identify the strength grade and the manufacturer.

Grade Identification Marking Symbols as per SAE J429

The grade identification symbols shall be as shown in above figure. Markings shall be located on the top of the head and may be either raised or depressed. For hex head products, the markings may be indented on the side of the head. Studs need not be marked.

Alternate Grades

For fasteners larger than 1½ in. diameter, it is recommended to consider the following ASTM grades.

SAE Grade	ASTM Equivalent
1	ASTM A307 Grade A or B
2	ASTM A307 Grade A or B
5	ASTM A449
8	ASTM A354 Grade BD

SAE J995: Mechanical and Material Requirements for Steel Nuts

SAE J995 covers the mechanical and material requirements for three grades of steel nuts suitable for use in automotive and related engineering applications, in sizes ¼ to 1½ in, inclusive, and with dimensions conforming with the requirements of the latest issue of SAE J482 or ASME B18.2.2, except for machine screw nuts which are not covered in the standard. The three grades of nuts are designated Grades 2, 5 and 8.

Mechanical Requirements

The nuts shall withstand the proof load stress specified in the following table for the nut grade, size, and thread series.

Nut Grade	2		5				8	
Nut Size	¼ thru 1½	¼ thru 1½	¼ thru 1	¼ thru 1	Over 1 thru 1½	Over 1 thru 1½	¼ thru 1½	¼ thru 1½
Thread Series	UNC and 8UN	UNF, 12UN and Finer	UNC and 8UN	UNF, 12UN and Finer	UNC and 8UN	UNF, 12UN and Finer	UNC and 8UN	UNF, 12UN and Finer
Nut Type	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi	Proof load stress, psi
Hex	90000	80000	120000	109000	105000	94000	150000	150000
Hex Flange	90000	80000	120000	109000	105000	94000	150000	150000
Hex Jam	54000	48000	72000	65000	63000	57000	90000	90000
Heavy Hex Jam	54000	48000	72000	65000	63000	57000	90000	90000
Hex Slotted	71000	65000	96000	87000	84000	75000	120000	120000
Heavy Hex	100000	90000	133000	120000	116000	105000	165000	150000
Heavy Thick	100000	90000	133000	120000	116000	105000	165000	150000
Heavy Thick Slotted	79000	71000	105000	96000	92000	84000	132000	120000
Hex High	100000	90000	133000	120000	116000	105000	165000	150000
Hex High Slotted	79000	71000	105000	96000	92000	84000	132000	120000
Square	90000	80000	105000	96000	92000	84000	132000	120000
Heavy Square	100000	90000	133000	120000	116000	105000	165000	150000

The proof load in pounds for nuts is computed by multiplying the proof load stress, in psi (lbf/in^2), for the nut grade, size, thread series, and type, as shown in above table, and tensile stress area in square in (in^2), for the applicable size and thread series.

Nuts shall have hardness within the limits specified in the following table.

Nut Grade	Nominal Size	Hardness
2	¼ thru 1½	32 HRC max
5	¼ thru 1½	32 HRC max
8	¼ thru ⅝	24 - 32 HRC
	Over ⅝ thru 1	26 - 34 HRC
	Over 1 thru 1½	26 - 36 HRC

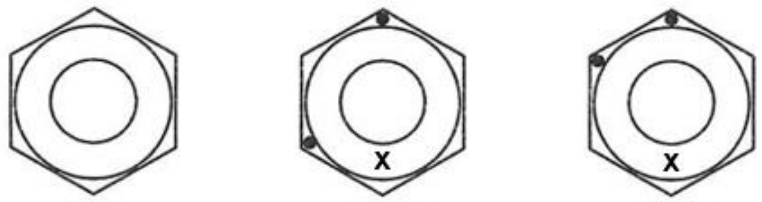
Marking

Three "styles" of grade marking are acceptable. Style A is applicable to all types and sizes of nuts. Style B is applicable to hex nuts of sizes ⅝ in. and larger; but may be used for smaller sizes or other types of nuts only when authorized by the purchaser. Style C is applicable to nuts that are fabricated by cutting from hex bar. In the following figures, manufacturer's mark is represented by "X".

Grade 2 Grade 5 Grade 8

Style A Marking for SAE J995 Nuts

Style A marking shall be depressed on the top surface of the nut on a circular line or path approximately midway between hole diameter and hex flat diameter, or, for hex flange nuts at the supplier's option, raised or depressed on top of the flange, and shall consist of no marks (a single circumferential line if specified by purchaser) for Grade 2 nuts; two circumferential lines 120 degrees apart for Grade 5 nuts; and two circumferential lines 60 degrees apart for Grade 8 nuts as shown in above figure.

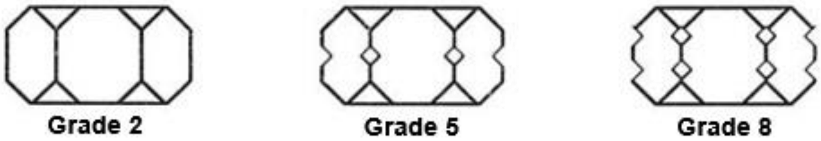


Grade 2 Grade 5 Grade 8

Style B Marking for SAE J995 Nuts

Style B marking shall be raised or depressed on the chamfer surface of the top of the nut corners, and shall consist of no marks (one circumferential line on one corner if specified by purchaser) on Grade 2 nuts; one circumferential line on each of two corners 120 degrees apart for grade 5 nuts; and one circumferential line on each of two corners 60 degrees apart for Grade 8 nuts as shown in above figure.

Style C marking shall consist of notches at the hexagon corners, one notch at each corner for Grade 5 nuts, and two notches at each corner for Grade 8 nuts as shown in the following figure.



Style C Marking for SAE J995 Nuts

Grade 2 nuts are not required to be marked for grade or source identification.

Grade 5 and Grade 8 hex and hex flange nuts, sizes ¼ through 1½, shall be marked for grade identification and for source identification. Grade 5 and Grade 8 hex jam, heavy hex jam, hex slotted, heavy hex slotted, hex thick slotted, hex thick and heavy hex nuts are not required to be marked for grade or source identification, unless specified by the purchaser. If marked, Grade 5 and Grade 8 hex jam, heavy hex jam, hex slotted, heavy hex slotted, hex thick slotted, hex thick and heavy hex nuts shall be marked with grade and source identification marks.

SAE Grade 8 and ISO Class 8.8

Please note that ISO Class 8.8 bolt DOES NOT have the same strength as a SAE Grade 8 bolt because minimum tensile strength of SAE Grade 8 bolt is 150000 psi (1034 N/mm^2) whereas tensile strength of ISO Class 8.8 bolt is 800 N/mm^2.

In view of above, if one wants to use bolt as per ISO class, class 10.9 bolt having minimum tensile strength of 1040 N/mm^2 (Nominal tensile strength of 1000 N/mm^2) may be used as a substitute for SAE Grade 8 bolt.

ASTM Standards for Nonferrous Threaded Fasteners

Nonferrous materials are those materials that do not contain any significant amounts of iron, except in trace amounts that are unintentionally present. There are many nonferrous fastener materials which can provide outstanding corrosion resistance in applications which would rapidly destroy more common ferrous materials. Super alloys, or high performance alloys are used in wide range of environments and applications like corrosion and oxidation resistance in both aqueous and high temperature, excellent strength at elevated temperature, and ductility and toughness at low temperatures. Following materials are used for nonferrous fasteners.

Copper and its alloys are designated by the prefix letter C in the UNS (Unified Numbering System). There are many alloys of copper, ranging from brass, bronze, silicon bronze and cupro-nickel. For example, Brass alloy 260 has a UNS number of C26000. Copper is mainly alloyed with zinc. Some alloys include aluminum, manganese, silicon, nickel and lead. These alloys have excellent corrosion resistance to sea water. Silicon bronze 651 is most frequently used for general fasteners.

The UNS designation for nickel begins with the prefix letter N such as N04400 for alloy 400. Nickel is a versatile element that when alloyed with other elements such as chromium (Cr), molybdenum (Mo), copper (Cu), aluminum (Al), cobalt (Co) or tungsten (W), it generates a category called “super alloys.” The term "super alloy" was first used shortly after World War II to describe a group of alloys developed for use in turbo superchargers and aircraft turbine engines that required high performance at elevated temperatures. However, it should be noted that these super alloys, for examples Inconel® and Hastelloy® are for highly specialized applications and are very expensive. See Specification B574 for nickel alloys.

Aluminum has a UNS designation of the prefix A, such as A 92024 for alloy 2024. Aluminum has good electrical and thermal conductivity. It is resistant to oxidation and is lightweight but not strong. It is used to join other aluminum parts to avoid galvanic corrosion with dissimilar metals.

Titanium is recognized by the UNS prefix of R, such as R56401 for alloy 23, which is Ti-6Al-4V ELI (extra low interstitials). Lower interstitials provide improved ductility and better fracture toughness. Titanium has the highest strength to weight ratio of any metal. Without any benefit of an alloy, it is as strong as most steels but 45 percent lighter. Alloys can achieve tensile strengths of 200ksi (1400 Mpa) but will begin to lose strength when exposed to temperatures above 800°F (430°C). Titanium has excellent corrosion and fatigue resistance, along with high crack resistance. It also has the ability to withstand moderate temperature increases without experiencing creep. Besides being able to withstand elevated temperatures, it also exhibits excellent cryogenic properties.

ASTM has two standards for nonferrous threaded fasteners intended for general service applications. ASTM F468 and F468M, inch and metric, respectively are Standard Specification for Nonferrous Bolts, Hex Cap Screws, Socket Head Cap Screws, and Studs for General Use and ASTM F467 and F467M, inch and metric, respectively are Standard Specification for Nonferrous Nuts for General Use.

Following table gives UNS Designation Number, Alloy, General Name, Tensile Strength, Yield Strength and Hardness for nonferrous threaded fasteners as per ASTM F468. For information on Chemical Composition, Mechanical Property Marking, Ordering Information, Supplementary Requirements, etc. please see ASTM F468. For information on nonferrous nuts, please see ASTM F467.

UNS Designation Number	Alloy	General Name	Full - Size Tests		Hardness
			Tensile Strength, ksi	Yield Strength, min, ksi	
Copper and Copper-Base Alloys					
C11000	Cu 110	ETP copper	30–50	10	65 - 90 HRF
C26000	Cu 260	brass	60–90	50	55–80 HRF
C27000	Cu 270	brass	60–90	50	55–80 HRF
C46200	Cu 462	naval brass	50–80	25	65–90 HRB
C46400	Cu 464	naval brass	50–80	15	55–75 HRB
C51000	Cu 510	phosphor bronze	60–90	35	60–95 HRB
C61300	Cu 613	aluminum bronze Dia., 0.250 - 0.500 in.	80–110	50	70–95 HRB
		aluminum bronze Dia., 0.625 - 1.500 in.	75–105	45	70–95 HRB
C61400	Cu 614	aluminum bronze	75–110	35	70–95 HRB
C63000	Cu 630	aluminum bronze	100–130	50	85 - 100 HRB
C64200	Cu 642	aluminum silicon bronze	75–110	35	75–95 HRB
C65100	Cu 651	silicon bronze Dia., 0.250 - 0.750 in.	70–100	55	75–95 HRB
		silicon bronze Dia., 0.875 - 1.500 in.	55–90	40	70–95 HRB
C65500	Cu 655	silicon bronze	50–80	20	60–80 HRB
C66100	Cu 661	silicon bronze	70–100	35	75–95 HRB
C67500	Cu 675	manganese bronze	55–85	25	60–90 HRB
C71000	Cu 710	cupro-nickel	45–75	15	50–85 HRB
C71500	Cu 715	cupro-nickel	55–85	20	60–95 HRB
Nickel and Nickel-Base Alloys					
N06059	Ni 59 Grade 1	Ni-Cr-Mo	120–165	85	21–45 HRC
	Ni 59 Grade 2		135–185	125	23–47 HRC
	Ni 59 Grade 3		160–200	150	25–49 HRC
	Ni 59 Grade 4		100–145	45	80 HRB - 25 HRC
N10001	Ni 335	Ni-Mo	115–145	45	20–32 HRC
N10276	Ni 276	Ni-Mo-Cr	110–140	45	20–32 HRC
N04400	Ni 400	Ni-Cu Class A Dia., 0.250 to 0.750 in.	80–130	40	75 HRB–25 HRC
	Ni 400	Ni-Cu Class A Dia., 0.875 to 1.500 in.	70–130	30	60 HRB–25 HRC
	Ni 400 HF	Ni-Cu Class A, hot-formed	70–120	30	60–95 HRB
N04405	Ni 405	Ni-Cu Class B	70–125	30	60 HRB–20 HRC
N05500	Ni 500	Ni-Cu-Al Dia., 0.250 to 0.875 in.	130–180	90	24–37 HRC
	Ni 500	Ni-Cu-Al Dia., 1.000 to 1.500 in.	130–180	85	24–37 HRC
N06625	Ni 625	Ni-Cr-Mo-Cb	120	60	85 HRB–35 HRC
N06686	Ni 686 Grade 1	Ni-Cr-Mo-W	120–165	85	21–45 HRC
	Ni 686 Grade 2		135–185	125	23–47 HRC
	Ni 686 Grade 3		160–200	150	25–49 HRC
	Ni 686 Grade 4		100–145	45	65 HRB–25 HRC
Aluminum-Base Alloys					
A92024	Al 2024–T4	Aluminum 2024	55–70	36	70–85 HRB
A96061	Al 6061–T6	Aluminum 6061	37–52	31	40–50 HRB
A97075	Al 7075–T73	Aluminum 7075	61–76	50	80–90 HRB
Titanium and Titanium-Base Alloys					
R50250	Ti 1	Titanium Gr 1	35–70	30	140–160 HV
R50400	Ti 2	Titanium Gr 2	50–85	45	160–180 HV
R50700	Ti 4	Titanium Gr 4	80–115	75	200–220 HV
R56400	Ti 5 Class A	Titanium Gr 5	130–165	125	30–39 HRC
	Ti 5 Class B		130–165	125	30–39 HRC
R52400	Ti 7	Titanium Gr 7	50–85	45	160–180 HV
R58640	Ti 19	Titanium Ti-38-6-44	115–150	115	24–38 HRC
R56401	Ti 23	Titanium Ti-6Al-4V ELI	120–165	110	25–36 HRC
R55111	32	Titanium Ti-5-1-1-1	105–150	90	24–38 HRC

Washers

Many times a washer is used either under the head of the fastener, bolt or screw, or under the nut. A washer is used to spread the clamp load over a larger surface area, to cover an oversize or elongated hole, to reduce the friction of the rotated component and to protect the work piece surface from damage by the rotated component. Information about requirement of mechanical properties of washers as per ASTM specifications and ISO specifications is given in this chapter.

ASTM F 436

ASTM F 436 covers the chemical, mechanical, and dimensional requirements for hardened steel washers for use with fasteners having nominal thread diameters of ¼ through 4 in. These washers are intended for general-purpose mechanical and structural use with bolts, nuts, studs, and other internally and externally threaded fasteners. These washers are suitable for use with fasteners covered in Specifications A 354, A 449, A563 and F3125. Additionally, they are used with bolts as per A193, A320, F1554 and whenever specified. ASTM specification F 436M is the metric counterpart of ASTM F 436.

The washers are designated by type denoting the material and by style denoting the shape.

The types of washers covered are:

- Type 1 - Carbon steel and
- Type 3 - Weathering steel.

The styles of washers covered are:

- Circular - Circular washers in nominal bolt sizes ¼ through 4 in.
- Beveled - Beveled washers are square or rectangular, in nominal sizes ½ through 1½ in., with a beveled slop 1 in 6 for use with American standard beams and channels.
- Clipped - Clipped washers are circular or beveled for use where space limitations necessitate that one side be clipped.

Orders for hardened steel washers under this specification shall include the zinc coating process if required, for example, hot-dip, mechanically deposited, or no preference.

Mechanical Properties

Through hardened washers shall have a hardness of 38 to 45 HRC, except when zinc-coated by the hot-dip process, in which case they shall have a hardness of 26 to 45 HRC.

Product Marking

Washers shall be marked with a symbol, or other distinguishing marks, to identify the manufacturer or private label distributor, as appropriate. Additionally, Type 3 weathering steel washers shall be identified with the symbol “3”.

ASTM F 844

ASTM F 844 covers round and miscellaneous shape steel plain (flat) washers furnished in an unhardened condition. These washers typically have a larger outside diameter than F436 structural washers and are for general purpose use. They are suitable for use with A307 fasteners and whenever specified.

Unless otherwise specified, the washers are furnished plain, with no protective finish other than oil to minimize rusting. When coated washers are required, the purchaser shall specify the protective coating and coating process.

Mechanical Properties

Unless otherwise specified, the washers are not furnished to mechanical requirements. When required and specified, the washers shall conform to the specified hardness.

Individual washers are not required to be marked.

ISO 7089

ISO 7089: Plain washers - Normal series - Product grade A, specifies the characteristics of normal-series, product-grade-A plain washers in the 200 HV and 300 HV hardness classes and of nominal sizes (nominal thread diameters) ranging from 1.6 mm to 64 mm inclusive.

Washers of hardness class 200 HV are suitable for hexagon bolts and screws of product grades A and B in property classes up to and including 8.8; hexagon nuts of product grades A and B in property classes up to and including 8; hexagon bolts, screws and nuts of stainless steel of similar chemical composition and case-hardened thread rolling screws.

Washers of hardness class 300 HV are suitable for hexagon bolts and screws of product grades A and B in property classes up to and including 10.9 and hexagon nuts of product grades A and B in property classes up to and including 10.

Mechanical Properties

Washers shall meet the mechanical requirements as per the following table.

Material[A]		Steel		Stainless Steel
	Grade			A2, A4, F1 C1, C4
	International Standard			ISO 3506-1
Mechanical Properties	Hardness Class	200 HV	300 HV[B]	200 HV
	Hardness Range	200 HV to 300 HV	300 HV to 370 HV	200 HV to 300 HV

[A] Other metallic materials as agreed between customer and supplier.
[B] Hardened and tempered.

Designation Example

A normal-series, product-grade-A plain washer made of grade A4 stainless steel, of nominal size 8 mm and hardness class 200 HV is designated as: Washer ISO 7089-8-200 HV-A4.

Note: Type 1 - washers as per ASTM F 436M may be used with property class 12.9 fasteners.

ISO 7091

ISO 7091: Plain washers - Normal series - Product grade C, specifies the characteristics of normal-series, product-grade-C plain washers in the 100 HV hardness class and of nominal sizes (nominal thread diameters) ranging from 1.6 mm to 64 mm inclusive.

Washers of hardness class 100 HV are suitable for hexagon bolts and screws of product grade C in property classes up to and including 6.8; hexagon nuts of product grade C in property classes up to and including 6 and case-hardened thread rolling screws.

Mechanical Properties

Hardness: 100 HV minimum.

Following are other ISO standards on washers.

ISO 7090: Plain washers, chamfered - Normal series - Product grade A
ISO 7092: Plain washers - Small series - Product grade A
ISO 7093-1: Plain washers - Large series - Part 1: Product grade A
ISO 7093-2: Plain washers - Large series - Part 2: Product grade C
ISO 7094: Plain washers - Extra large series - Product grade C

Note
It may be noted that though information on washer dimensions is given in above washer specifications, information about requirement of mechanical properties of washers is only given in this chapter. Information on washer dimensions is covered in the product standards for fasteners.

IS 1367: Technical Supply Conditions for Threaded Steel Fasteners

Indian Standard, IS 1367: Technical Supply Conditions for Threaded Steel Fasteners is published in many parts. Part 1 of it deals with general requirements for bolts, screws, studs and nuts. In view of this, information on general requirements for Part 1 of IS 1367 is given in this chapter. Many parts of this standard are adopted from standards issued by the International Organization for Standardization (ISO). Information about most of these ISO standards is already given in this booklet. In view of this, all other parts of IS 1367 are only listed in this chapter. The list will be helpful to specify various specific requirements for fasteners as per IS standard.

IS 1367: Part 1: 2014/ISO 8992: 2005

As shown in the standard number, ISO 8992: 2005 is adopted by the Bureau of Indian Standards for the Part 1 of IS 1367.

This International Standard specifies the general requirements for standardized bolts, screws, studs and nuts, but is also recommended for these non-standardized fasteners. It is intended to be used with reference to the related International Standards (ISO Standards) on tolerances, mechanical and performance characteristics, geometrical features (thread, driving features, ends of parts, countersunk head, other features), surface discontinuities, surface finishes and quality aspects. For information on the various ISO Standards to be used, please see the standard.

General Requirements

Standardized bolts, screws, studs and nuts are defined by the following elements:

- Mechanical properties (property class, material);
- Product grade (tolerances);
- Standardized geometrical features (if any);
- Surface coatings (if required);
- Special requirements (if agreed).

All information relates to fully manufactured products. The product shall have intact surfaces and edges and shall be free of burrs consistent with the manufacturing methods used. It is not generally required that small burrs due to manufacturing be removed. However, any burr which influences the performance of the product or would be a safety hazard when handled shall be removed.

Unless a surface coating is agreed, the surface finish of the products shall be as processed for steel products, or plain for products made of stainless steel or non-ferrous metal. Bolts, screws, studs and nuts shall be delivered in a clean condition and lightly oiled, if no other conditions have been agreed.

Parts of IS 1367

Following table lists the various parts of IS 1367. The list gives information on the ISO Standard adopted for the various parts of IS 1367. The list will be helpful in identification of a standard to be referred to specify technical supply condition for threaded steel fasteners.

IS Number	Title
IS 1367: Part 1: 2014/ISO 8992: 2005	Technical supply conditions for threaded steel fasteners: Part 1 general requirements for bolts, screws, studs and nuts (Fourth Revision)
IS 1367: Part 2: 2002/ISO 4759-1:2000	Technical supply conditions for threaded steel fasteners: Part 2 tolerances for fasteners - Bolts, screws, studs and nuts - Product grades A, B and C (Third Revision)
IS 1367: Part 3:2017/ISO 898-1: 2013	Technical supply conditions for threaded steel fasteners: Part 3 mechanical properties of fasteners made of carbon steel and bolts, screws and studs (Fifth Revision)
IS 1367: Part 5: 2018/ISO 898-5: 2012	Technical supply conditions for threaded steel fasteners: Part 5 mechanical properties of fasteners made of carbon steel and alloy steel - Set screws and similar threaded fasteners with specified hardness classes - Coarse thread and fine pitch thread (Fourth Revision)
IS 1367: Part 6: 2018/ISO 898-2: 2012	Technical supply conditions for threaded steel fasteners: Part 6 mechanical properties of fasteners made of carbon steel and alloy steel - Nuts with specified property classes - Coarse thread and fine pitch thread (Fourth Revision)
IS 1367: Part 7: 1980	Technical supply conditions for threaded steel fasteners: Part 7 mechanical properties and test methods for nuts without specified proof loads (Second Revision)
IS 1367: Part 8: 2014/ISO 2320: 2015	Technical supply conditions for threaded steel fasteners: Part 8 prevailing torque type steel nuts - Mechanical and performance properties (Fourth Revision)
IS 1367: Part 9: Sec 1: 1993/ISO 6157-1:1988	Technical supply conditions for threaded steel fasteners: Part 9 surface discontinuities Section 1 bolts, screws and studs for general applications (Third Revision)
IS 1367: Part 9: Sec 2: 1993/ISO 6167-3: 1988	Technical supply conditions for threaded steel fasteners: Part 9 surface discontinuities Section 2 bolts, screws and studs for special applications (Third Revision)
IS 1367: Part 10: 2002/ISO 6157-2: 1995	Technical supply conditions for threaded steel fasteners: Part 10 surface discontinuities - Nuts (Third Revision)
IS 1367: Part 11: 2002/ISO 4042: 2018	Technical supply conditions for threaded steel fasteners: Part 11 electroplated coatings (Third Revision)
IS 1367: Part 12: 1981	Technical supply conditions for threaded steel fasteners: Part 12 phosphate coatings on threaded fasteners (Second Revision)
IS 1367: Part 13: 1983/ISO 10684: 2004	Technical supply conditions for threaded steel fasteners: Part 13 hot - dip galvanized coatings on threaded fasteners (Second Revision)
IS 1367: Part 14: Sec 1: 2018/ISO 3506-1: 2009	Technical supply conditions for threaded steel fasteners: Part 14 mechanical properties of corrosion resistant stainless steel fasteners Section 1 bolts, screws and studs (Fourth Revision)
IS 1367: Part 14: Sec 2: 2018/ISO 3506-2: 2009	Technical supply conditions for threaded steel fasteners Part 14 mechanical properties of corrosion resistant stainless steel fasteners Section 2 Nuts (Fourth Revision)
IS 1367: Part 14: Sec 3: 2018/ISO 3506-3: 2009	Technical supply conditions for threaded steel fasteners: Part 14 mechanical properties of corrosion resistant stainless steel fasteners Section 3 set screws and similar fasteners not under tensile stress (Fourth Revision)
IS 1367: Part 16: 2002/ISO 8991: 1986	Technical supply conditions for threaded steel fasteners: Part 16 designation system for fasteners (Third Revision)
IS 1367: Part 17: 2005/ISO 3269: 2000	Technical supply conditions for threaded steel fasteners: Part 17 inspections, sampling and acceptance procedure (Fourth Revision)
IS 1367: Part 18: 1996	Industrial fasteners - Threaded steel fasteners - Technical supply conditions: Part 18 packaging (Third Revision)
IS 1367: Part 19: 1997/ISO 3800: 1993	Industrial fasteners - Threaded steel fasteners - Technical supply conditions: Part 19 axial load fatigue testing of bolts, screws and studs
IS 1367: Part 20 : 1996/ISO 896-7: 1992	Industrial fasteners - Threaded steel fasteners - Technical supply conditions - Mechanical properties: Part 20 Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm

Selection of Fastener Material

Fasteners are manufactured from a variety of materials such as steel, stainless steel, aluminum, brass, bronze, copper, nickel, titanium and other non-ferrous metals and plastics. For selecting the right fastener material from the vast array of materials available, careful consideration should be given to strength, brittleness, temperature, corrosion, fatigue, weight, cost and many other variables. In view of this information about various materials is given in this chapter.

Carbon Steel

Over 90% of fasteners are made from carbon steel because of its inherent strength properties, excellent workability and relative cheapness as compared to other materials. The mechanical properties of carbon steel are sensitive to the carbon content, which is normally less than 1.0%. The more common steels used to manufacture fasteners are generally classified into 3 types: low carbon, medium carbon and alloy steel.

Low Carbon Steels

Low carbon steels generally contain less than 0.25% carbon and cannot be strengthened by heat treatment. Strengthening may only be carried out through cold working. The low carbon material is relatively soft and weak, but has outstanding ductility and toughness; in addition, it is easily machinable, weldable and is relatively inexpensive to produce. Typically, low carbon material has a tensile strength between 60,000 and 80,000 psi (410 MPa to 550 MPa). The most commonly used chemical analyses include AISI 1006, 1008, 1016, 1018, 1021, and 1022. SAE J429 Grade 1 & Grade 2, ASTM A307 Grade A & Grade B and Metric Property Class 4.6, 4.8 & 5.8 fasteners are generally made from low carbon steel.

ASTM A307 Grade B is a special low carbon steel grade of bolt used in piping and flange work. Its properties are very similar to Grade A except that it has added the requirement of a specified maximum tensile strength. The reason for this is that to make sure that if a bolt is inadvertently overtightened during installation, it will fracture prior to breaking the cast iron flange, valve, pump, or expensive length of pipe.

Medium Carbon Steels

Medium carbon steels have carbon content between about 0.25% and 0.60%. These steels are heat treated to improve their mechanical properties. Medium carbon steels have a tensile strength between 90,000 psi and 120,000 psi. The plain medium carbon steels have low hardenabilities and can be successfully heat treated only in thin sections and with rapid quenching rates. As large diameters don’t get fully hardened in the center, smaller diameters do; large diameters have lower average tensile strengths. This means that the end properties of the fastener are subject to size effect. This is the reason for the strength properties to “step down” as the diameters increase. The most commonly used chemical analyses include AISI grades 1030, 1035, 1038, and 1541. SAE J429 Grade 5, ASTM A325, ASTM A449 and Metric Property Class 8.8 fasteners are generally made from medium carbon steel.

Alloy Steels

Carbon steel can be classified as an alloy steel when the manganese content exceeds 1.65%, when silicon or copper exceeds 0.60% or when chromium is less than 4%. Carbon steel can also be classified as an alloy steel if a specified minimum content of molybdenum, aluminum, titanium, vanadium, nickel or any other element has been added to achieve specific results. Additions of chromium, nickel and molybdenum improve the capacity of the alloys to be heat treated, giving rise to a wide variety of strength to ductility combinations. Alloy steels have tensile strength in excess of 120,000 psi (about 150,000 psi). The most commonly used chemical analyses include AISI grades 4137, 4140, 4340 and 5140. SAE J429 Grade 8, ASTM A354 Grade BD, ASTM A490, ASTM A193 B7, Metric Property Classes 10.9 & 12.9 are all common examples of alloy steel fasteners.

Elements such as manganese, phosphorus and sulphur are found in all grades of steel; manganese provides beneficial effects but phosphorus and sulphur are detrimental to steel's properties. However, sulphur is sometimes added to the steel to improve its machining performance.

Along with carbon and alloy steel, there are Carbon-Boron steels. Small amounts of boron allow steels to be heat treated to high strengths without the cost penalty of other alloying elements. The properties of carbon-boron steels are not as good as alloy steels but they give a reasonable compromise between cost and improved properties benefits.

Stainless Steel

Stainless steel is a family of iron-based alloys that must contain at least 10.5% chromium. The chromium reacts with the oxygen to form a complex chrome-oxide, an invisible surface layer/film that resists further oxidation and makes the material "passive" or corrosion resistant. If the surface layer is damaged, it rebuilds itself (self-repairs) in the presence of oxygen. Other elements, such as nickel or molybdenum are added to increase corrosion resistance, strength or heat resistance.

Stainless steels are logically divided into three classes/categories based on their microstructure: Austenitic, Martensitic and Ferritic.

Austenitic Stainless Steels

Austenitic stainless steels contain higher amounts of chromium and nickel than the other types. They are not hardenable by heat treatment and offer a high degree of corrosion resistance. Primarily, they are nonmagnetic. However, some parts may become slightly magnetic after cold working. The tensile strength of austenitic stainless steel varies from 75,000 to 105,000 psi. The B8 grade of alloys in the ASTM Specifications A193, A320 and alloy groups 1, 2 and 3 of ASTM Specification F593 are austenitic stainless steels.

18-8 stainless steel is a type of austenitic stainless steel that contains approximately 18% chromium and 8% nickel. 18-8 stainless steel include AISI types, but not limited to; 302, 303, 304 and 316.

Type 302, general purpose stainless retains untarnished surface finish under most atmospheric conditions and offers high strength at reasonably elevated temperatures. It is commonly used for flat washers.

Type 304 is a low carbon-higher chromium stainless steel with improved corrosion resistance when compared to type 302. Type 304 is the most popular stainless steel for hex head cap screws. It is used for cold heading and often for hot heading of large diameter or long bolts.

Type 304L is a lower carbon content version of 304, and therefore contains slightly lower strength characteristics. The low carbon content increases the corrosion resistance and welding capacity of 304L.

Type 316 has significantly improved corrosion resistance especially when exposed to seawater and many types of chemicals. It contains molybdenum, which gives the steel better resistance to surface pitting. Type 316 stainless steel has higher tensile and creep strengths at elevated temperatures than other austenitic alloys.

Austenitic stainless steels are suitable only for low concentrations of reducing acids. Very high levels of halide ions, especially the chloride ion can also break down the passive surface film.

Martensitic Stainless Steels

Martensitic stainless steels contain 11.5 to 18% chromium and up to 1.0% carbon. The carbon allows them to be hardened/strengthened by heat treatment. Martensitic stainless steels have poor welding characteristics and are considered magnetic. The tensile strength of martensitic stainless steel is approximately 70,000 to 145,000 psi. This type of stainless steel should only be used in mild corrosive environments. Martensitic stainless steels include AISI types 410, 416 and 431. Type 410 is commonly used for tapping screws.

Ferritic Stainless Steels

Ferritic stainless steels contain 12 to 18% chromium but have less than 0.2% carbon. This type of steel is magnetic, non-hardenable by heat treatment, only slightly strengthened by cold working and has very poor weld characteristics. They should not be used in situations of high corrosion resistance requirements. ASIS type 430 is typical of this group.

Precipitation Hardening Stainless Steels

Precipitation hardening stainless steels are hardenable by a combination of 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 17-4 PH. 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. 17-4 PH, is one of the most widely used precipitated hardened steels for fasteners. They have relatively high tensile strengths and good ductility. The relative service performance in both low and high temperatures is reasonably good.

Duplex Stainless Steels

Duplex stainless steels are characterized by their 50% austenitic and 50% ferritic structures which allow these materials to offer the corrosion resistance for the austenitic grades of material while providing higher design properties. Grade 2205, UNS Designation S32205 (ASTM A276 and ASTM A479) is typical of this group.

Stainless steels for handling corrosion resistance can be summarized as follows:

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

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.

Copper and Copper Alloys

Copper

Copper has a high degree of electrical & thermal conductivity and corrosion resistance. It is non-magnetic and can be hardened by cold working. The tensile strength of pure copper is about 30,000 psi and yield strength is about 10,000 psi.

Brass

Brass is composed of copper and zinc and is the most common copper-based alloy. Brass is approximately 65% Copper and 35% Zinc. Brass retain most of the favorable characteristics of pure copper, and generally cost less. The amount of copper content is important. Brass alloys with less copper are generally stronger and harder, but less ductile.

Naval Brass

Sometimes called **Naval Bronze**, Naval Brass is similar to brass but has additional qualities of resistance to saline elements. This is accomplished by changing the proportions of brass by adding a little tin (0.5% to 1.0%). This alloy has derived its name from its ability to survive the corroding action of salt water.

Silicon Bronze

Silicon bronze is the generic term for various types of copper-silicon alloys. Most are basically composed of high percentages of copper and a small amount of silicon. Manganese or aluminum is added for strength. Lead is also added for free machining qualities where required. In general silicon bronze is composed of approximately 94-96% Copper, 0.8-3.8% Silicon, 1.5% Zinc and 0.7-1.5% Manganese. Silicon bronze possesses high tensile strength (superior to mild steel). With its high corrosion resistance and non-magnetic properties, this alloy is ideally suited for naval construction.

Aluminum

Aluminum is a lightweight metal that has a high strength to weight ratio, good corrosion resistance in most environments, excellent electrical and thermal conductivity, is easily cold formed or hot forged and easily machinable. As aluminum's corrosion resistance is inherent to the material, scratching will not affect the corrosion resistance. Aluminum fasteners weigh about 1/3 those of steel. Pure aluminum has a tensile strength of about 13,000 psi. The strength properties of the more commonly used aluminum alloys are quite high and can actually approach that of mild steel. High strength aluminium fasteners are made from a variety of aluminium alloys like AISI grades 2024, 6061 and 7075. Aluminium fasteners are sometimes specified in automobile applications where light component construction is required.

Titanium

As compared to aluminum, titanium has superior strength to weight ratios, excellent corrosion resistance, good high temperature performance, and is therefore extensively used in the aerospace industry. Due to corrosion resistance, they are also used in marine, saltwater applications and in the chemical industry. However, the extremely high cost of this material prevents its wider use.

Nickel and Nickel Alloys

Nickel and nickel alloys offer some remarkable combinations of performance capabilities. Mechanically they have good strength properties, exceptional toughness and ductility, and are generally immune to stress corrosion. Their corrosion resistance properties and performance characteristics in both elevated and subzero temperatures is superior. Unfortunately, nickel based alloys are relatively expensive. Following are the most popular nickel alloys. These alloys are often referred to as super alloys because of their ability to perform in extremes of temperature or possess extremely high strength qualities as compared to standard fastener materials.

Monel® 400 (UNS N04400)

Monel® is the trademark of Special Metals Corporation. Monel 400 is the most commonly used nickel-copper alloy (Ni 65.1, Cu 32.0, Fe 1.6, Mn 1.1). This alloy is hardened by cold working only. It is an alloy with high strength and toughness over a wide temperature range and excellent resistance to a range of media including seawater, hydrofluoric & sulfuric acids and alkalies. The tensile strength is 80,000 psi (550 Mpa) and yield strength is 35,000 psi (240 Mpa). Monel 400 is used in marine and offshore engineering, and chemical and hydrocarbon processing. Typical applications are valves, pumps, propeller shafts marine fixtures and fasteners, springs, chemical processing equipment, etc.

Monel® K-500 (UNS N05500)

Monel® K-500 (Ni 64.7, Cu 30.2, Al 2.7, Fe 1.0, Ti 0.6) is Similar to Monel 400 but age-hardenable for improved strength and hardness as a result of added aluminum and titanium. The tensile strength is 160,000 psi (1100 Mpa) and yield strength is 115,000 psi (790 Mpa). Typical applications are pump shafts, oil well tools, doctor blades, springs, fasteners and marine propeller shafts.

Inconel®

Inconel®, Incoloy® and Nimonic® are registered trademark of Special Metals Corporation. Inconel® is a family of austenitic nickel-chromium based super alloys; for example, Inconel 600, Inconel 625, Inconel 718, etc.; are used for corrosion resistance and high temperatures. The nickel content may vary from 44 to 72 percent. Inconel® Alloy 625 (UNS N06625) is resistance to severely corrosive environments, particularly to pitting, crevice corrosion and high-temperature oxidation, and with high strength from cryogenic temperatures up to 1500°F (815°C). Alloy 625 is used in aerospace engineering, gas turbines, chemical processing, oil and gas extraction, pollution control, and marine and nuclear engineering.

For more information on Monel and Inconel, please visit website of Special Metals, A PCC (Precision Castparts Corporation) Company: www.specialmetals.com/tech-center/alloys

Hastelloy®

HASTELLOY® is a registered trademark (brand) of Haynes International. It represents a group of super alloys with many designation numbers; for examples, HASTELLOY® B-3® alloy UNS N10675, HASTELLOY® C-276 alloy UNS N10276, HASTELLOY® G-30® alloy UNS N06030, etc.; to identify different physical characteristics. They are used for high stress and elevated temperature applications. They have excellent corrosion resistance, especially to acids, and is used in many chemical plants. Their high-temperature family of alloys are generally distinguished by the HAYNES® brand. For more information on HASTELLOY® and HAYNES® alloys, please visit website of Haynes International: www.haynesintl.com.

Waspaloy Alloy

HAYNES® Waspaloy alloy (UNS N07001) is an age-hardenable, nickel-based super alloy with very good strength at temperatures up to about 1800°F (980°C). It is widely used as a wrought material for forged and fabricated gas turbine and aerospace components. Waspaloy alloy is now being replaced in many applications by HAYNES® 282® alloy, due to the superior fabricability and creep-strength of 282® alloy.

Note:

Industries often specify alloys by a UNS designation, unaware that such alloy specifications only address issues of chemical composition, not corrosion or heat resistance. Branded alloys protect the alloys' quality and assure their performance by focusing on precise control of chemical composition and thermo-mechanical processing, in addition to systematic testing.

Plastic

Plastics Fasteners are manufactured from various plastic compounds the most popular nylon 6/6 have low strength characteristics but are quite suitable for applications where lightness or electrical non-conductivity is important. Various plastic materials are used to give a wide variety of properties. The more commonly used grades are nylon, polycarbonate and high-density polyethylene. Nylon is also used as an insert into nylon insert nuts and other internally threaded fasteners to give a locking feature.

Selection of Fasteners for High and Low Temperatures.

Selection of fasteners require careful consideration of temperature. Some material become brittle at lower temperatures. Whereas material perform satisfactory up to certain temperature above room temperature. Following table shows the recommended temperature range of various fastener materials. It may be noted that the bolt plating material is usually the limiting factor on maximum service temperature.

Material	Surface Treatment	Design Temperature Limit, °F (°C)
Carbon steel	Zinc plated	−65 to 250 (−54 to 121)
Alloy steels	Cadmium plated, nickel plated, zinc plated, or chromium plated	−65 to limiting temperature of plating
A193 Grade B6	None	−65 to 932 (−54 to 500)
A193 Gr. B7, A320 Gr. L7	None	−148 to 752 (−100 to 400)
A193 Grade B8	None	−423 to 1067 (−253 to 575)
A193 Grade B16	None	−65 to 968 (−54 to 520)
17-4 PH stainless	None	−300 to 600 (−184 to 316)
17-4 PH stainless	Passivated	−200 to 600 (−129 to 316)
300 series stainless	Furnace oxidized (oxidizing reduces galling)	−423 to 800 (−253 to 427)
410, 416, and 430 stainless	Passivated	−250 to 1200 (−157 to 649)
Inconel 718	Passivated or cadmium plated	−423 to 900 or cadmium plate limit
Inconel X-750	None	−320 to 1200 (−196 to 649)
Waspaloy	None	−423 to 1800 (−253 to 982)

It may be noted that a material may be suitable for high temperature application but its strength gets reduced with increase in service temperature. For example, following table shows HAYNES® Waspaloy alloy's ultimate tensile strength and yield strength at various temperatures.

Typical Tensile Properties of HAYNES® Waspaloy alloy					
Test Temperature		**0.2% Yield Strength**		**Ultimate Tensile Strength**	
°F	**°C**	**ksi**	**MPa**	**ksi**	**MPa**
RT	RT	130.4	899	189.2	1304
400	204	118.9*	820*	183.2*	1263*
800	427	120.4*	830*	171.6*	1183*
1000	538	117.8	812	170.4	1175
1200	649	113.8	784	164.9	1137
1400	760	102.4	706	119.2	822
1500	816	75.0	517	91.9	633
1600	871	51.8	357	66.2	456
1700	927	30.5	210	43.1	297
1800	982	19.2	132	25.2	174

* Limited data

Mechanical Properties and Grade Marking as per ASTM and SAE Specifications

In this chapter, as a ready reference, mechanical properties and grade marking requirements for externally threaded fasteners is presented in a tabular form for common fasteners as per ASTM and SAE specifications. Information about compatible/suitable nuts to be used with the fasteners is also given the table.

Grade Marking	Specification	Material and Treatment	Nominal Size (in.)	Proof Load Min. (ksi)	Yield Strength Min. (ksi)	Tensile Strength Min. (ksi)	Hardness Rockwell Min.	Hardness Rockwell Max.	Compatible Nut
Marking Not Required	SAE J429 Grade 1	Low or Medium Carbon Steel	¼ to 1½	33	36	60	B70	B100	SAE J995 Gr. 2 or ASTM A563 Grade A Hex
Marking Not Required	SAE J429 Grade 2	Low or Medium Carbon Steel	¼ to ¾	55	57	74	B80	B100	SAE J995 Gr. 2 or ASTM A563 Grade A Hex
			over ¾ thru 1½	33	36	60	B70	B100	
	SAE J429 Grade 5	Medium Carbon Steel	¼ to 1	85	92	120	C25	C34	SAE J995 Grade 5 Hex
			over 1 thru 1½	74	81	105	C19	C30	
	SAE J429 Grade 8	Medium Carbon Alloy Steel	¼ to 1½	120	130	150	C33	C39	SAE J995 Grade 8 Hex
307A	ASTM A307 Grade A	Low or Medium Carbon Steel	¼ to 4	-	-	60	B69	B100	ASTM A563 Grade A Hex up to 1½, over Heavy Hex
307B	ASTM A307 Grade B	Low or Medium Carbon Steel	¼ to 4	-	-	60 min. 100 max.	B69	B95	ASTM A563 Grade A Heavy Hex
A325	ASTM F3125 Grade A325 Type 1	Carbon Steel or Alloy Steel	½ to 1½	85	92	120	C25	C34	ASTM A563 Grade DH
A325	ASTM F3125 Grade A325 Type 3	Weathering Steel	½ to 1½	85	92	120	C25	C34	ASTM A563 Grade DH3
A490	ASTM F3125 Grade A490 Type 1	Alloy Steel	½ to 1½	120	130	150 min. 173 max.	C33	C38	ASTM A563 Grade DH
A490	ASTM F3125 Grade A490 Type 3	Weathering Steel	½ to 1½	120	130	150 min. 173 max.	C33	C38	ASTM A563 Grade DH3
A449	ASTM A449 Type 1	Carbon Steel or Alloy Steel	over ¼ to 1, incl.	85	92	120	C25	C34	ASTM A563 **For Plain:** ¼ to 1½ - B Hex 1½ to 3 - A Heavy Hex. **For zinc-coated.:** DH Heavy Hex
			over 1 to 1½, incl.	74	81	105	C19	C30	
			over 1½ to 3, incl.	55	58	90	Bri-nell 183	Bri-nell 235	
A449	ASTM A449 Type 3	Weathering Steel	over ¼ to 1, incl.	85	92	120	C25	C34	ASTM A563 C3, DH3 Heavy Hex
			over 1 to 1½, incl.	74	81	105	C19	C30	
			over 1½ to 3, incl.	55	58	90	Bri-nell 183	Bri-nell 235	
BC	ASTM A354 Grade BC	Alloy Steel	¼ to 2½	105	109	125	C26	C36	ASTM A563 **For Plain:** C Heavy Hex **For zinc-coated:** DH Heavy Hex
			over 2½ to 4, incl.	95	99	115	C22	C33	
BD or Six Radial Lines	ASTM A354 Grade BD	Alloy Steel	¼ to 2½	120	130	150	C33	C39	ASTM A563 **For all finishes:** DH Heavy Hex
			over 2½ to 4, incl.	105	115	140	C31	C39	
B5	ASTM A193 Grade B5	Ferritic Steel, 5% Chromium	up to 4, incl	-	80	100	-	-	ASTM A194 Grade 3

B6	ASTM A193 Grade B6	Ferritic Steel, 12% Chromium	up to 4, incl	-	85	110	-	-	ASTM A194 Grade 6
B7	ASTM A193 Grade B7	Ferritic Steel, Chromium-Molybdenum	2½ and under	-	105	125	-	C35	ASTM A194 Grade 2H, 7
			over 2½ to 4	-	95	115			
			over 4 to 7	-	75	100			
B7M	ASTM A193 Grade B7M	Ferritic Steel, Chrom-Moly	4 and under	-	80	100	-	B99	ASTM A194 Grade 2HM
			over 4 to 7	-	75	100			
B16	ASTM A193 Grade B16	Ferritic Steel, Chrom-Moly-Vanadium	2½ and under	-	105	125	-	C35	ASTM A194 Grade 7
			over 2½ to 4	-	95	110			
			over 4 to 8	-	85	100			
B8	ASTM A193/320 Grade B8 Class 1	Stainless Steel AISI 304	All Sizes	-	30	75	-	B96	ASTM A194 Grade 8
<u>B8SH</u> for A193 and <u>B8</u> for A320	ASTM A193/A320 Grade B8 Class 2	Stainless Steel AISI 304 Strain Hardened	¾ and under	-	100	125	-	C35	ASTM A194 Grade 8, Strain Hardened
			over ¾ to 1, incl.	-	80	115			
			over 1 to 1¼, incl.	-	65	105			
			over 1¼ to 1½, incl.	-	50	100			
B8M	ASTM A193/320 Grade B8M Class 1	Stainless Steel AISI 316	All Sizes	-	30	75	-	B96	ASTM A194 Grade 8M
<u>B8MSH</u> for A193 and <u>B8M</u> for A320	ASTM A193/A320 Grade B8M Class 2	Stainless Steel AISI 316 Strain Hardened	¾ and under	-	95	110	-	C35	ASTM A194 Grade 8M, Strain Hardened
			over ¾ to 1, incl.	-	80	100			
			over 1 to 1¼, incl.	-	65	95			
			over 1¼ to 1½, incl.	-	50	90			
L7	ASTM A320 Grade L7	AISI 4140, 4142, or 4145	¼ to 2½	-	105	125	-	-	ASTM A194 Grade 7

Note:
It may be noted that fasteners as per ASTM A193 B8 class 1 and ASTM A193 B8M class 1 have lower yield strength than the ASTM A193 B8 class 2 and ASTM A193 B8M class 2 respectively (strength of B8 class 1 and B8 class 2 are not same). This difference is frequently not recognized and has been the cause of failures. In view of this, while ordering/replacing fasteners, take care to specify/replace class 2 fastener if required.

Approximate Metric - Imperial Equivalency Chart

Metric Bolt Class	SAE J429 Grades	ASTM Grades
4.6	1	A307, Grade A
5.6	2	-
5.8	2	-
8.8	5	A449; F3125, Grade 325,
10.9	8	A354, Grade BD; F3125, Grade 490
12.9	-	A574

References

Fastener Design Manual by Richard T. Barrett, NASA Reference Publication 1228, 1990

Fastenal Technical Reference Guide (S7028) by Fastenal Company (www.fastenal.com)

Technical information by Portland Bolt & Mfg. Co. (www.portlandbolt.com)

Technical information by FABORY (www.fabory.com)

Internet: www.fastenerdata.co.uk