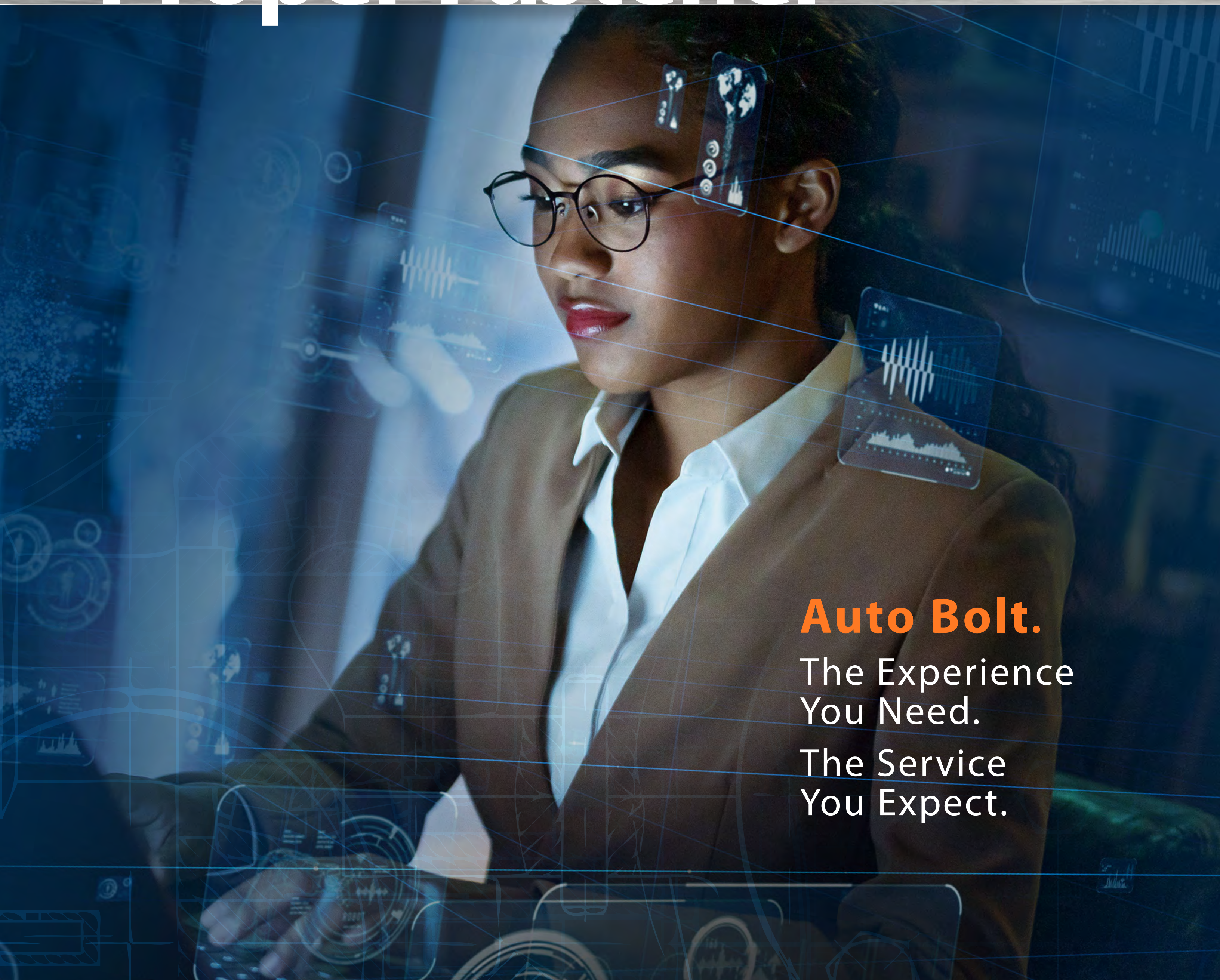
AUTO BOLT

10 Considerations for Selecting the Proper Fastener



Auto Bolt.

The Experience You Need.

The Service You Expect.

Design engineers often overlook the details required for selecting a proper fastener. Aggressive design schedules can lead to underestimating the complexity or the importance of proper fastening technology. While the primary engineering effort will go into designing the functionality of a product, the components, such as the fasteners that hold pieces together can be the weak link in the product if fastener design receives insufficient attention.

For example, if a machine designed for a production application has an improperly specified bolt, the result can be a delay in the product launch or a potential equipment failure. A common design error is selecting the wrong-sized fastener. Another error is specifying an inadequate material or grade for the fastener. Also use of an improper surface coating could result in a number of potential issues which can lead to the degradation of the fastener over time. Designers need to consider these factors and others to ensure reliable and safe operation of their product.

10 Considerations for Selecting the Proper Fastener

1 What is the application and the function for the fastener?

Will the fastener be used in a military, automotive, marine, or food service product? Will the fastener be used for a drilling machine, a metal cutting machine, or a robotic machine? Does the fastener secure the flanges of a valve? The application determines the environment that the fastener must withstand. Depending on the application, a fastener can be subject to extreme temperatures, high pressure, shock, and vibration. Understanding the purpose for the fastener will dictate many of its characteristics and properties.

2 What material should be used so the fastener can support the load?

The strength required for the bolt is the main determinant for selection of material. Most fasteners consist of carbon steel. The majority of fasteners are made from low to medium carbon and carbon alloy steel.

Grade 2 fasteners are a standard hardware grade. A Grade 2 fastener is the most common grade of steel and the least expensive. Select Grade 2 bolts where high strength Is not a concern. Handrails and pipe hangers are examples of applications in which Grade 2 fasteners provide sufficient strength. Grade 2 derives its strength from cold hardening of the fastener during forming.

Many applications will require a fastener that requires a strength greater than a Grade 2 steel. In order to achieve a greater strength, the fastener will require heat treatment consisting of neutral harden, quench, and temper operations. Typical higher-strength fastener grades are 5 and 8. Fasteners made to Grade 5 are typically made from medium carbon steel. For applications requiring greater strength than a Grade 5 fastener, a grade 8 fastener is recommended. Grade 8 fasteners are typically made from medium carbon alloy steel that has been heat treated for greater hardness than the Grade 5 steel. Be cautious when selecting a fastener with a high tensile strength. Fasteners with higher hardness and tensile strength tend to be more brittle.

Stainless steel has the typical tensile strength equivalent to grade 5 heat treated steel. It is not the strongest grade of steel, but it is corrosion resistant; and, as a result, stainless steel is a higher cost material. Stainless steel fasteners are necessary in food production, water treatment facilities, and in factories that use corrosive chemicals.

Two other materials that have excellent corrosion resistance are brass and bronze and are used primarily in the marine industry. Brass and bronze also have the benefit of being a visually-appealing fastener; but, their strength is generally equivalent to an un-hardened Grade 2 fastener.

The Society of Automotive Engineers (SAE) and the American Society for Standards and Materials (ASTM) have standards that define the specifications for fastener materials and offer approved uses for fasteners made of those materials. Example standards are:

SAE J429	ASTM A307	ASTM F593	ASTM A193/A193M
Specifies mechanical and material requirements for externally threaded fasteners	Specifies requirements for carbon steel bolts, studs, and threaded rod up to 60,000 PSI tensile strength	Specifies stainless steel bolts, hex cap screws and studs	Specifies alloy steel and stainless steel bolting for high pressure or high temperature service and other special applications

Referencing these standards can help in selecting an appropriate material for fasteners. Appendix A provides information on various grades of steel and their characteristics.

3 What size fastener is needed?

The fastener needs to clamp parts together; and the clamping force must be sufficient to prevent separation of movement between the clamped parts when forces are applied. Selecting the correct fastener diameter to support the required clamp force will provide a secure, high reliability joint.

A common problem is the selection of an under-sized fastener and using a higher strength material. The designer will specify a high torque for the fastener. The high torque causes the fastener to stretch by an excessive amount. Similarly, selecting an over-sized fastener does not necessarily lead to a tighter clamped joint. An over-sized fastener will stretch less under tension and result in the possibility of bolt loosening. **Table 1** offers guidance on bolt size and ranges of tightening torque for uncoated bolts and galvanized and waxed bolts.

Selecting the properly sized fastener and specifying an appropriate torque are challenges. Inexperienced designers should consider consulting with an expert.

ASTM A325

Bolt Size (in)	TPI	Tension (lbs)		Tightening Torque Range (ft lbs) (Min – Max)	
		Min	Max	Galv + Waxed	Plain
1/2	13	12,000	14,000	50 –58	100–117
5/8	11	19,000	23,000	99–120	198–240
3/4	10	28,000	34,000	175–213	350–425
7/8	9	39,000	47,000	284–343	569–685
1	8	51,000	61,000	425–508	850–1,017
1-1/8	7	56,000	67,000	525–625	1,050–1,256
1-1/4	7	71,000	85,000	740–885	1,479–1,771
1-3/8	6	85,000	102,000	974–1,169	1,948– 2,338
1-1/2	6	103,000	124,000	1,288–1,550	2,575–3,100

These torque calculations are estimates and are only offered as a guide. Because there are many variables that affect the torque-tension relationship, the only way to determine the correct torque is through experimentation under actual joint and assembly conditions.

Table 1. *Guidance for ranges of torque that can be applied to various-sized bolts*

4 Does the application require a screw or a bolt?

Often the terms, screw and bolt, are used interchangeably. There are differences between when these two fasteners types are used. Bolts are used when joining two or members together with a mating nut. Screws are used in applications where the one of the mating members has an internally tapped thread.

Bolts are more appropriate if the forces on the joint vary during use. Also, if the joint is subject to temperature changes or vibration, a bolt with a nut would be more capable of keeping the joint securely clamped. In high vibration environments, a locking feature, such a lock nut, lock washer, prevailing torque patch, or thread adhesive is recommended.

For joints in which the forces on it are relatively constant, low, and the joint is not subject to temperature swings, a screw can be a sufficient clamping solution. However, material selection, heat-treat, and other design considerations allow screws to be used with joints that have dynamic and cyclical loading. An example of such a screw would be a "head bolt" for an internal combustible engine.

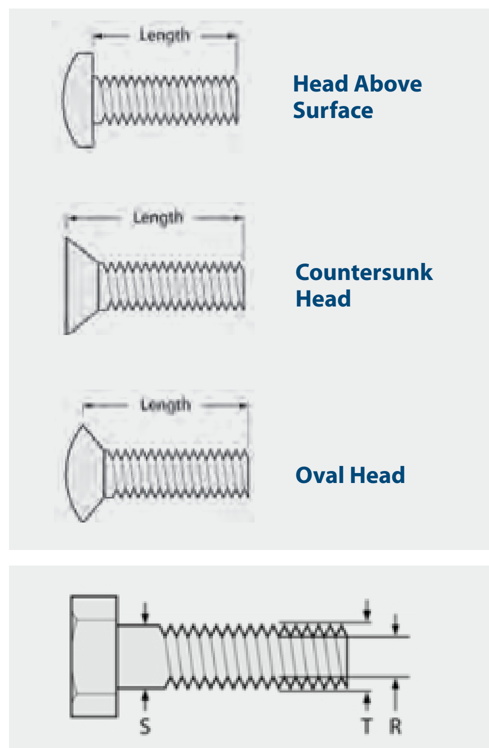
In many applications, the selection of a screw or bolt is already dictated by the various mating members of the joint.

5 How long should the fastener be?

The fastener needs to be long enough to completely engage the mating parts that need to be clamped together. Use of a long fastener does not compromise the joint as long as it secures the assembly together completely. If a designer selects a bolt, the bolt must be long enough to hold the assembly that needs clamping, any required gaskets or washers, and a nut. In addition, the bolt length should extend beyond the depth of the joint to allow for some excess threads. The extra length ensures that the nut is fully installed on the bolt.

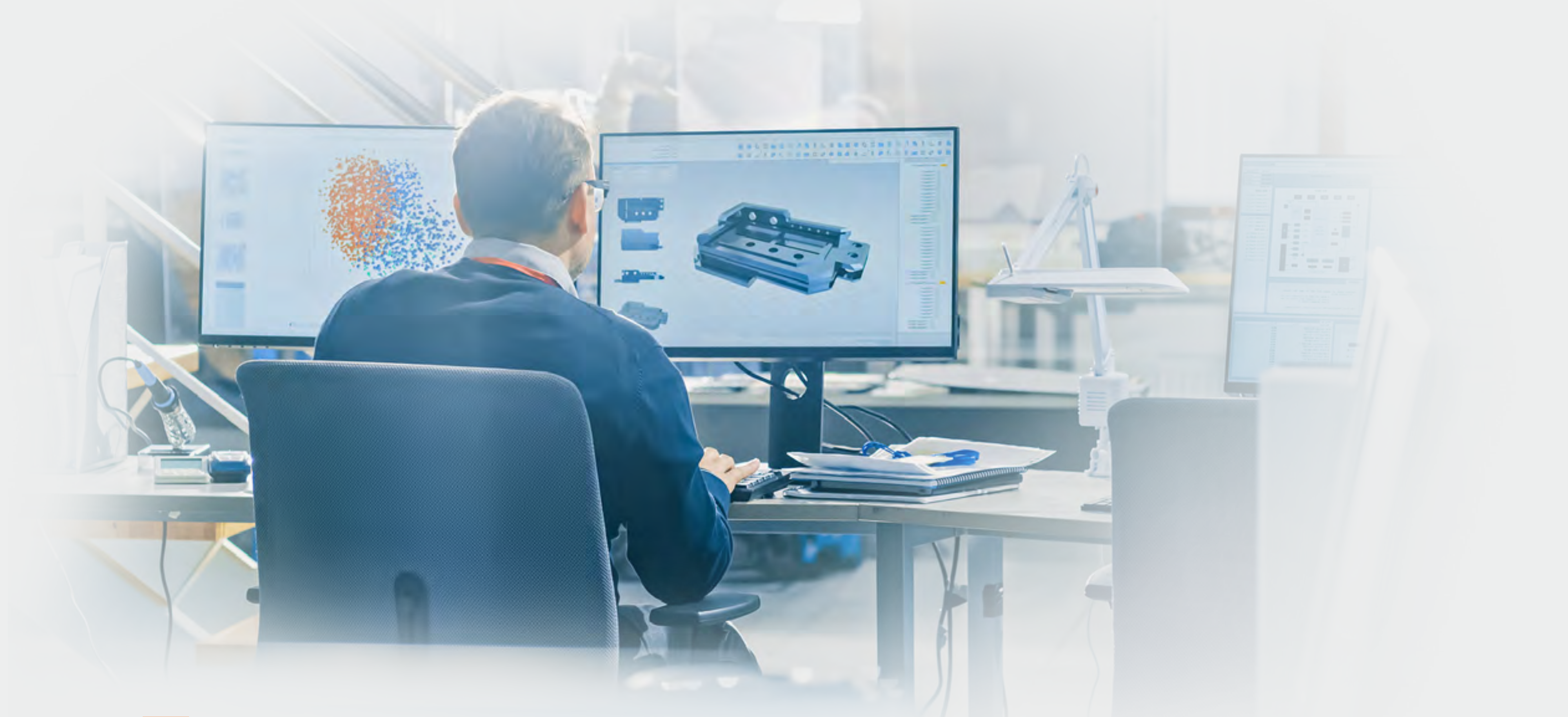
Also be aware of fastener dimension conventions. The length of a fastener is a function of the style of its head and how much of the fastener fits in the joint. If the head of the fastener mounts on the surface of the joint, then the fastener length only includes the dimension of the threaded portion of the fastener. For fasteners with heads that fit into the joint, the length includes the dimensions of the head and the dimension of the threaded portion. **See Figure 1**.

The thread diameter is the outer diameter of the threaded section of the fastener. It is the major diameter and is typically referred to as the diameter of the fastener. On the majority of fasteners, the shank or body diameter is roughly the same as the thread diameter. Again, defining the wrong dimension can cause an unstable connection between the materials that must be held together.



(T) Thread Diameter *Also called major diameter*
(S) Shank Diameter
(P) Thread Pitch
(R) Root Diameter *Also called minor diameter*

Figure 1. *Fastener dimension definitions*



6 What type of fastener head should be used?

A fastener can have a screw head, socket head, a hex head, or another style head. The design of the fastener head is important for supporting the amount of torque the fastener must withstand. If a joint is in an area with restricted access, the head may require a custom design to allow a tool to assemble and tighten the fastener. The need for a special fastener head should not deter the designer; many manufacturers can accommodate custom designs. Proper selection of the head will facilitate the assembly and tightening of the fastener to the appropriate torque. **Table 2** shows a wide range of head styles, primarily for bolts.

7 What thread style should be used?

The designer needs to select threads that will provide the best load handling characteristics for the application. The choice is between either coarse or fine threads. Unified coarse, UNC, and unified fine, UNF, are thread designations used in the United States. Metric threads, described as either ISO Metric or M, are the international standard thread. With coarse threads, assembly of the joint takes less time. Fine threads require a longer assembly time since they have more revolutions needed to traverse the equivalent distance that a coarse-threaded fastener would traverse. However, fine threads contribute to both a more secure joint and one that can permit a higher level of tension in the joint. Appendix B lists the thread designations and the thread dimensions for both unified and metric threads.

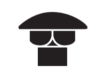
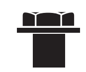
Fastener Head Style	Diagram
Square Neck, Carriage, Plow, Bumper Bolts	
Spring Center Suspension Bolts	
Hex Flange Bolts	
Hex Head Cap Screws and Hex Head Bolts	
Pan Head and Round Head Bolts	
Six Lobe Bolts	
12-Point Bolts	
Wheel Bolts and Studs	
Rivets and Pins	

Table 2. *Fastener head styles*

8 Is a coating needed for the application?

Coatings perform three functions for fasteners:

- **Coatings provide protection against corrosion of the fastener**
- **Coatings improve the appearance of a fastener and enable matching to a specific color**
- **Coatings add lubricity to prevent either a loose joint or excessive strain on the fastener**

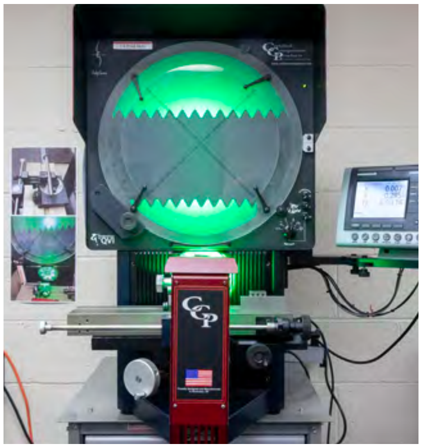
The two primary methods for coating fasteners are electroplating and organic processing.

Electroplating achieves high-quality, low-cost finishes. Zinc, zinc-alloy, copper, nickel, and tin are the metals most commonly used to plate fasteners. Electroplating offers good corrosion resistance, allows coatings as thin as 0.0001 in, and creates a long-lasting finish that can withstand a wide range of environments. In addition, a wide variety of topcoats, such as wax, sealers, and torque-tension modifiers are available for application over an electroplated coating. Designers should be aware that electroplating can be subject to uneven coating thickness, particularly on longer fasteners. Typically, the coating will be thicker on the ends of the fastener. Also higher strength steels can be subject to hydrogen embrittlement due to the introduction of acid in the electroplating process.

Zinc is the most common plating. It is the least expensive of the plating metals and has good corrosion resistance. Zinc offers a broad range of coating thickness; zinc coatings on fasteners can range from .0001 in to .00047 in. Chromate treatments enhance the appearance of the zinc-coated fastener and offer a variety of colors such as blue, yellow, and black. Chromates add a hard, non-porous film to the coating.

Organic coatings, carbon-based coatings, act as a protective barrier against both corrosion and oxidation due to their chemical inertness and impermeability. These coatings eliminate the risk of fastener embrittlement and have a more even build-up on the fastener. Organic coatings also provide a good base for rust preventive oils, zinc or aluminum flake coatings, thread adhesives, patches, and thread sealers. Organic coatings lack galvanic protection unless they have been heavily top coated with zinc or aluminum flakes; and, typically, they are a more expensive coating than a zinc-based electroplated coating.

9 What tolerance needs to be defined?



The tolerance in the joint will dictate the allowable tolerance for the fastener. Understanding tolerances in fastener manufacturing can avoid specifying tolerances that are not feasible. If a design specifies a fastener tolerance that fastener manufacturers cannot achieve, designers will need to re-think how they can re-design the joint. Extremely tight tolerances significantly increase part costs as manufacturers must perform additional machining, inspection and possibly sorting operations. Of most importance is obtaining fasteners with consistent tolerances.

ISO Standard 4759-1, *Tolerances for Fasteners*, can provide guidance on tolerance specifications for design engineers.

10 How can a fastener manufacturer help?

As with any product development, the designer has options and trade-offs; and designing a fastener for an application requires specialized experience and knowledge. If in-house expertise in this area is not available, consider relying on a fastener manufacturer. A good fastener manufacturer has the capability to design and manufacture a custom fastener to address unique requirements.

Select a manufacturer that meets recognized quality standards. The minimum general quality standard that a manufacturer should meet is ISO 9001 certification. Specific standards of quality include certification to automotive industry standards such as the International Automotive Task Force quality standard, IATF 16949. Another indicator of a high-quality manufacturer is one who is certified by the US Defense Logistics Agency and has obtained a listing on the Qualified Suppliers List for Manufacturers (QSLM). Selecting a manufacturing partner with these certifications will ensure that the manufacturer is supplying high quality material and holding required dimensional tolerances.

A good manufacturing partner can assist with more than just manufacturing a fastener. The manufacturer's engineers can help optimize fastener design, correct problems related to fasteners, improve productivity, and reduce manufacturing costs. Even if in-house expertise exists, partnering with a fastener manufacturer complements in-house engineering and ensures the design and manufacture of the optimum fastener for the designated requirements.

Auto Bolt is a proud American cold-heading bolt manufacturer with more than 70 years of experience in quality bolt-making. We specialize in low-to-high volume, high-performance and commercial fasteners for many industries including automotive, truck and trailer, heavy construction, agriculture, military, material handling and outdoor power equipment.

Auto Bolt offers extensive fastener knowledge at all levels of the organization. We provide a customized approach starting with quick, accurate quoting and carrying through to CAD drawings, die design and delivery. With products that are 100% domestically made in Cleveland, Ohio, Auto Bolt works directly with customers and distributor partners to customize a solution rather than one-size-fits-all products.

Appendix A

Fastener Grades and their Properties

Property Class Designation	Nominal Product Dia, mm	Material and Treatment	Mechanical Requirements								Property Class Identification Marking
			Proof Load Stress MPa Length Measure-ment	Yield Strength MPa	Tensile Strength MPa	Product Hardness					
						Surface Max Rockwell 30N	Core				
							Rockwell		Vickers		
							Min	Max	Min	Max	
4.6	M5 - M100	Low or medium carbon steel	225	240	400	–	B67	B95	120	220	4.6
4.8	M1.6 - M16	Low or medium carbon steel: partially or fully annealed as required	310	340	420	–	B71	B95	130	220	4.8
5.8	M5 - M24	Low or medium carbon steel: cold worked	380	420	520	–	B82	B95	160	220	5.8
8.8	M16 - M72	Medium carbon steel: product quenched and tempered	600	660	830	53	C23	C34	255	336	8.8 or 8S
8.8	M16 - M36	Low carbon martensite: product quenched and tempered	600	660	830	53	C23	C34	255	336	8.8
8.8.3	M16 - M36	Atmospheric corrosion resistant steel: product quenched and tempered	600	660	830	53	C23	C34	255	336	8S3
9.8	M1.6 - M16	Medium carbon steel: product quenched and tempered	650	720	900	56	C27	C36	280	360	9.8
9.8	M1.6 - M16	Low carbon martensite steel: product quenched and tempered	650	720	900	56	C27	C36	280	360	9.8
10.9	M5 - M20	Medium carbon steel: product quenched and tempered	830	940	1040	59	C33	C39	327	382	10.9
10.9	M5 - M100	Medium carbon alloy steel: product quenched and tempered	830	940	1040	59	C33	C39	327	382	10.9 or 10S
10.9	M5 - M36	Low carbon martensite steel: product quenched and tempered	830	940	1040	59	C33	C39	327	382	10.9
10.9.3	M16 - M36	Atmospheric corrosion resistant steel: product quenched and tempered	830	940	1040	59	C33	C39	327	382	10S3
12.9	M1.6 - M100	Alloy steel: product quenched and tempered	970	1100	1220	63	C38	C44	372	434	12.9
		See Notes 1 and 4									Notes 1, 2 and 3

***Table 2.** Designations, material and treatment, mechanical requirements and property class markings for carbon steel externally threaded metric fasteners*

Appendix B

English and Metric Thread Designations and Dimensions

Unified External Screw Threads (2A)

Thread	Major Dia.	Pitch Dia.	Minor Dia.
1/4-20 UNC	.2408/.2489	.2127/.2164	0.189
1/4-28 UNF	.2425/.2490	.2225/.2258	0.206
5/16-18 UNC	.3026/.3113	.2712/.2752	0.245
5/16-24 UNF	.3042/.3114	.2806/.2843	0.262
3/8-16 UNC	.3643/.3737	.3287/.3331	0.299
3/8-24 UNF	.3667/.3739	.3430/.3468	0.324
7/16-14 UNC	.4258/.4361	.3850/.3897	0.351
7/16-20 UNF	.4281/.4362	.3995/.4037	0.377
1/2-13 UNC	.4876/.4985	.4435/.4485	0.407
1/2-20 UNF	.4906/.4987	.4619/.4662	0.439
9/16-12 UNC	.5495/.5609	.5016/.5068	0.462
9/16-18 UNF	.5524/.5611	.5205/.5250	0.495
5/8-11 UNC	.6113/.6234	.5589/.5644	0.515
5/8-18 UNF	.6149/.6236	.5828/.5875	0.558
3/4-10 UNC	.7353/.7482	.6773/.6832	0.629
3/4-16 UNF	.7391/.7485	.7029/.7079	0.674
7/8-9 UNC	.8592/.8731	.7946/.8009	0.741
7/8-14 UNF	.8631/.8734	.8216/.8270	0.788
1-8 UNC	.9830/.9980	.9100/.9168	0.849
1-12 UNF	.9868/.9982	.9382/.9441	0.899
1-1/8-7 UNC	1.1064/1.1228	1.0228/1.0300	0.953
1-1/8-12 UNF	1.118/1.1232	1.0631/1.0691	1.024

All diameters are in inches.
Thread designation: thread diameter – threads/inch, example: ¼ -20 is a ¼ inch thread diameter with 20 threads/inch.
UNC: Unified National Coarse Thread / UNF: Unified National Fine Thread

Thread		Inches		
O.D.	Pitch	Major Dia.	Pitch Dia.	Minor Dia.
M6	1.0	.2282/.2351	.2052/.2096	0.186
M8	1.0	.3068/3139	.2839/.2883	0.258
M8	1.25	.3056/.3138	.2773/.2818	0.253
M9	1.25	.3449/.3532	.3167/.3212	0.292
M10	1.0	.3856/.3927	.3627/.3671	0.344
M10	1.25	.3843/.3925	.3560/.3606	0.332
M10	1.5	.3832/.3924	.3489/.3540	0.319
M11	1.5	.4225/4318	.3882/.3934	0.359
M12	1.25	.4630/.4713	.4342/.4393	0.410
M12	1.75	.4607/.4711	.4205/.4263	0.386
M12	1.5	.4618/.4711	.4273/.4328	0.399
M14	1.5	.5407/.5499	.5061/.5115	0.477
M14	2.0	.5387/.5496	.4923/.4985	0.453
M16	1.5	.6194/.6286	.5849/.5903	0.556
M16	2.0	.6175/.6284	.5710/.5772	0.531
M18	1.5	.6982/.7074	.6636/.6690	0.628
M20	2.5	.7726/.7857	.7152/.7218	0.665
M22	1.5	.8648/.8556	.8265/.8211	0.785
M22	2.5	.8513/.8644	.7939/.8005	0.730
M24	3.0	.9283/.9429	.8584/.8662	0.782

Metric Size dimensions are in millimeters.
O. D.: nominal outer diameter.
Pitch: Distance between threads.
Refer to Figure 1.

Appendix C

Glossary of Terms Describing Fastener Properties

Brittle Fracture – Fracture with little or no plastic deformation.

Clamping Force – The force that holds an assembly together by putting tension, or preload on the fastener. Tension in a bolt is equal to the clamp force on the joint.

Core Hardness – Hardness tested at mid-radius of a transverse section through the bolt at a one diameter distance from the end of the threaded section.

Ductility – The ability of a material to deform plastically without fracturing, being measured by elongation or reduction of area in a tensile test.

Heat Treatment – Heating and cooling a solid metal or alloy in such a way as to obtain desired conditions or properties.

Hydrogen Embrittlement – Embrittlement caused by the diffusion of hydrogen atoms into the atomic lattice of the metal, either during pickling or plating operations. When this occurs, the part is subjected to high internal stresses which result in premature and sudden failure.

Proof Load – A specific load below the yield strength which the product must withstand without a permanent elongation exceeding 0.0005 inches.

Rockwell Hardness Test – A test for determining the hardness of a material based upon the depth of penetration of a specified penetrator into the specimen.

Surface Hardness – Hardness of a part measured on the surface by properly preparing the area to be tested with a light grind to assure flat and parallel conditions.

Tensile Strength – The maximum load sustained in axial stress expressed in pounds per square inch (psi or kilograms per square millimeter).

Tension – A positive force exerted on the bolt when subjected to axial loading.

Torque – Force exerted multiplied by the distance through which the force acts expressed in inch-pounds, foot-pounds, or Newton-meters.

Yield Strength – The load at which the fastener exhibits a deviation from the straight-line proportionality of stress and strain in the plastic range of the stress-strain plot.

AUTO BOLT

To request a quote or learn more about the Auto Bolt Experience,
visit our website: https://www.autoboltusa.com/request-a-quote

The Auto Bolt Company
4740 Manufacturing Ave., Cleveland, OH 44135
Phone: 800.988.2658 | Fax: 216.881.3918