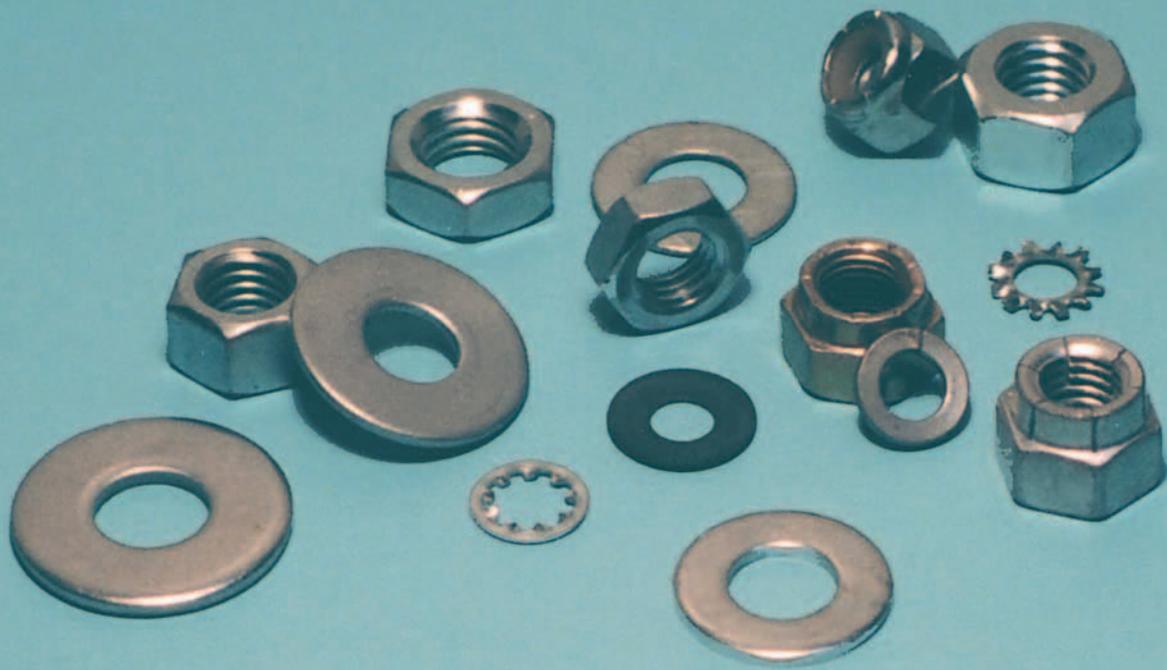


# The Nuts & Bolts



## of Fasteners —Part 2

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**Bolts alone can't do the job without nuts and washers.**

Last issue, I talked about the importance of using the right hardware for the job in your electric vehicle conversion. We looked at bolts and machine screws—sizes, head styles, grades, and finishes. But bolts aren't much good by themselves. Let's look at the rest of the hardware.

### *Nuts—The Second Part of the Team*

Unless it is being threaded into a tapped hole, a bolt cannot do its job without a nut. The first and most obvious requirement for the correct nut is that the thread has the same diameter and thread form as the bolt. In U.S. hardware, correct means coarse threaded nuts with coarse bolts and fine nuts with fine bolts.

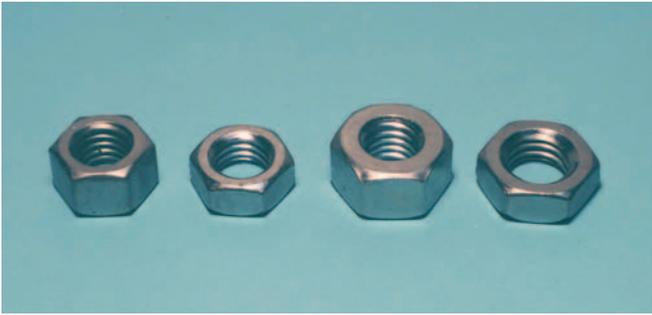
With metric fasteners, this is a little more difficult, particularly if you are trying to replace lost or broken nuts or bolts. There are two conflicting thread types. In European vehicles, and some U.S. cars and trucks built since 1975, the ISO (formerly the Deutsche Industry Normal or DIN) metric thread system is used. This system falls between the USS (coarse) and SAE (fine) pitches (the distances between the thread peaks).

Fasteners in Japanese vehicles conform to the Japanese Industry Standard. The JIS system has two pitches: one between the ISO and SAE pitches, and a second pitch that is finer than SAE. This means that not all 10 mm bolts will fit all 10 mm nuts. This is why you should save all the fasteners you take off the vehicle you are converting.

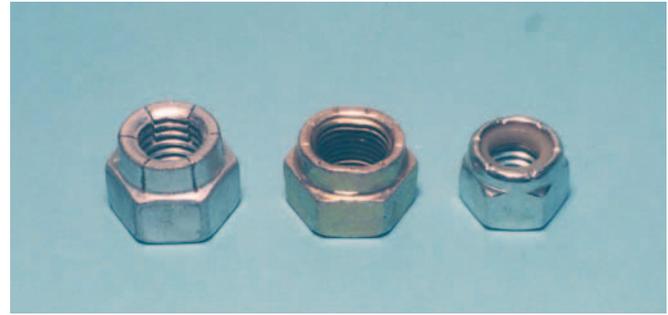
Since the hex nut is the type most commonly used in the automotive world, it is the type we will be referring to in this article. Square nuts are available, but they are generally used on farm implements and decorative ironwork.

Although nearly all automotive nuts are made of the same low carbon steel, they are hardened to Grade 5 or Grade 8. As for finishes, nuts are offered either plain or zinc plated to match the grade color code. Stainless steel nuts should only be used with stainless steel bolts. As we discussed last time, due to the expense and brittle nature of stainless steel, it should only be used where needed to avoid corrosion.

Wrench size is determined by the width of the nut, measured across the top, from the center of one flat side to the opposite flat side. To make things easy, there is a



Left to right: nut, jam nut, heavy nut, heavy jam nut.  
All of these nuts fit the same size bolt.



Left to right: slotted thread locknut, deformed thread locknut  
(also called a "stover"), and nylon insert locknut.

standard that dictates the nut width and height for common bolt sizes. For example, the nut for a  $\frac{1}{4}$  inch bolt is  $\frac{7}{16}$  inch wide and  $\frac{7}{32}$  inch high.

The dimensions described above are for a standard  $\frac{1}{4}$  inch hex nut. There is also the jam, or half-height, nut. This nut has the same width as the standard hex nut, but is a little more than half as high. The jam nut is used where clearance between moving parts is an issue. Since the strength of a nut is determined by its thickness (the thicker the nut, the more threads gripping the bolt), jam nuts should only be used when absolutely necessary. A jam nut can also be used to lock another nut in place, which is probably where its name came from.

The only other size variation involves "heavy" nuts. These are wider than the standard nuts, for a bigger contact area, and thicker for greater strength. The heavy jam nut has the same width as the heavy nut and is a little more than one-half the heavy nut's height.

### Nuts Come in Different Flavors

So far, we have identified nuts by their material, hardness, thread diameter, thread pitch, width, and height. Nuts are also identified as plain or self-locking. A plain nut is the type we have been discussing up to now. It threads on the bolt and turns easily until it contacts one of the parts that it and the bolt are holding together. Then the head of the bolt is held with a wrench and the nut is turned with another wrench until your elbow or a torque wrench tells you it is tight enough (more on "tight enough" later). Once tightened, the plain nut is held in place by the friction between the threads of the nut and bolt. If the assembled parts are subjected to vibration, it is only a matter of time before the nut loosens and the assembly fails.

Since the effects of a fastener failing on an automobile can range from inconvenient to deadly, keeping the fasteners tight is desirable. This leads us to the second type of nut—the locknut. We will look at the two most common versions of locknut—the nylon-lined or Nylock nut and the all-metal, self-locking nut.

The Nylock nut is a plain nut with a nylon ring built into its top. When the Nylock nut is threaded onto a bolt, the nylon ring deforms to match the threads of the bolt. This produces an interference fit between the bolt and the nylon insert, which locks the nut in place.

This does not harm the threads on the bolt, which allows easy assembly and disassembly. However, the Nylock nut should be discarded after six applications. Its features make the Nylock nut the most widely used type of locknut. A word of caution: Nylock nuts should not be used where they are subjected to more than 250°F (121°C), which will melt the nylon.

There are two types of all-metal, self-locking nuts. The first type has the top half of the nut slotted multiple times around the diameter of the threaded hole. The threads in the slotted part of the nut have a slightly smaller inside diameter than the standard threads in the bottom half of the nut. When the bolt hits the slotted portion of the nut, it forces the metal parts of the nut to spread between the slots. This creates an interference fit, which locks the nut in place. This locknut does not distort the threads of the bolt and is reusable.

The second type of all-metal locknut is the deformed thread locknut. These nuts have part of their threads deformed, which forces the bolt to act like a thread-cutting tap to reform the threads of the nut. This causes a very heavy interference fit and can damage the bolt. These nuts should be used where the assembly is considered to be permanent. If disassembly becomes necessary, both the nuts and bolts should be discarded.

### Washers—The Third Part of the Team

There are many different kinds of washers. We are going to discuss two types—lock washers and flat washers.

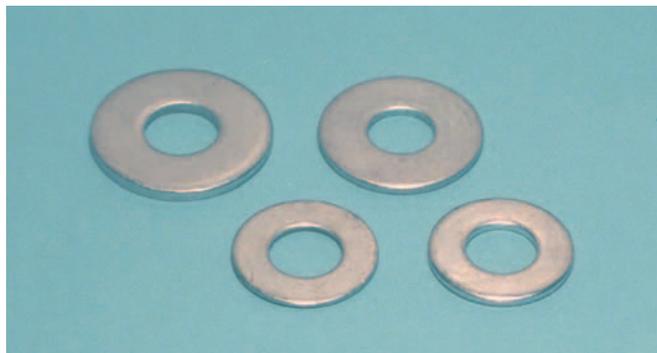
**Lock washers—springs and teeth.** A lock washer is installed on a bolt between the nut and the part. Its purpose is to keep the nut from vibrating loose. A pure spring lock washer, like the slightly dished Belleville washer, works by increasing the friction between the threads of the nut and bolt. It does not damage the nut or the part, but costs five times as much as the common split spring washer.

The split spring lock washer is what most people think of as a lock washer. It has a split across it, and one edge of the split bends up while the other edge bends down. It is widely used, does its job pretty well, and best of all, it's cheap. Its main disadvantage is that it gets part of its locking ability from the ends of the spring digging into the nut and into the part, which permanently damages both of them.

You can put a flat washer between the lock washer and the part to protect it, but then all you accomplish is locking



Lock washers, left to right: Belleville concave spring, split spring, internal toothed, and external toothed.



These are all 1/2 inch flat washers. The lower right one is SAE standard. The other three are from different batches of USS standard. Note the wide disparity among the USS washers.

the nut to the flat washer, leaving only the spring force to prevent loosening. A plain nut and a split spring lock washer should not be considered the equivalent of a Nylock nut.

Toothed lock washers are steel stampings that can have either internal or external teeth. They do their job by digging their teeth into the nut and into the part. Since they are low strength, their use is usually limited to machine screws under 1/4 inch in diameter.

**Flat washers—no nut and bolt should go without.** The basic flat washer has two jobs to do. The first is to spread the clamping force of the nut and bolt over a larger area. The second is to prevent damage to the parts during tightening.

Like everything else in this article, flat washers come in many different types. We are going to look at the difference between two types—USS and SAE. Both are identified by the size of bolt they fit, but that and being round is all they have in common.

The USS washer is kind of a free spirit. The inside and outside diameters and thickness vary among manufacturers, and among countries of origin. This lack of consistency makes the USS flat washer useable for distribution of force and part protection only.

The SAE flat washer, however, is a precision part. Its inside and outside diameters as well as thickness (all of which are smaller than the USS washer) meet an established standard. Knowing these dimensions is important when you are designing parts for your conversion. If a part has a limited amount of space between the bolt hole and the edge, it is nice to know that the washer you are planning to use will fit.

The SAE washer's uniformity has many technical advantages, such as the ability to use it as a precision spacer. It also gives the finished product a more professional appearance. Use SAE washers. You may pay a few pennies more, but you will be going first class.

### No Loose Nuts

Determining how much force to use with nuts and bolts can be tricky. If a plain nut is not tightened sufficiently, there won't be enough friction between the threads to hold it in place. Vibration will work on the loose nut until it falls off, usually at the worst possible time.

Although a Nylock nut is not affected by vibration, if it is not tightened enough, the parts being held together will move against each other. This movement can result in bolt hole distortion as well as damage to the mating surfaces. Either of these conditions, left uncorrected, can result in a big oops.

**A little too tight.** The obvious solution is to get the longest wrench you have that will fit the nut, apply some real muscle to it, and get that nut tight. The problem with this technique becomes apparent when the bolt snaps and comes off in your hand. This usually occurs with small bolts (1/4 to 5/16 inch diameter), when the force exceeds the tensile strength of the bolt.

With larger bolts (3/8 inch and up), what usually happens is, just as you're really pulling on the wrench, suddenly the nut starts to turn easily but it isn't getting any tighter. When you try to back the nut off the bolt, it spins but doesn't move in that direction either. What we have here is a case of stripped threads. This happens when the force being applied to an already tight nut and bolt exceeds the tensile strength of the threads of the nut or bolt or both.

**Just tight enough.** The way to avoid the two failures above is to know exactly how much force (called "torque") to apply. There are two ways to determine the tightening torque for the fasteners used in your conversion. If the parts being assembled were originally part of the vehicle, your factory service manual will have torque tables. These are usually at the end of each section relating to a specific group of components such as brakes or steering.

If the fasteners are for parts being added as part of the conversion, you must refer to a torque chart (see the table). The torque chart tells the torque limit for a bolt of a specific size and grade. As you choose fasteners and look up their torque ratings, note these in your project notebook. After the conversion is done, use those notes to create a torque table for the conversion parts of your EV.

**Use the right tool.** To determine how much torque you are applying, use a torque wrench. The simplest form of this tool has a drive for a socket wrench on one end of a long arm with a handle on the other end. It has a pointer attached to the socket drive end that runs along the arm until it ends at a calibrated scale just below the handle.

## Torque Chart (Foot-Pounds)

Type	Bolt Size (In.)						
	1/4	5/16	3/8	7/16	1/2	9/16	5/8
Grade 5	10	19	33	54	78	114	154
Grade 8	14	29	47	78	119	169	230

When force is applied to the fastener, the arm bends. The pointer does not bend, and its free end points to a graduation on the calibrated scale that shows how many foot-pounds of torque are being applied. While this tool sounds primitive, it is quite accurate. I rebuilt an awful lot of VW Bug engines using this kind of torque wrench.

With the more modern torque wrenches, the desired number of foot-pounds of torque is preset against a calibrated spring. When that amount of torque is reached, the handle gives a bit and a loud click is heard. This type is easier to use because you don't have to watch the pointer. An experienced mechanic will develop a calibrated elbow over the years, and only use the torque wrench when a more precise amount of torque is required.

If you don't have much mechanical experience, it might be best if you tighten all the fasteners until they are snug, and then go over them again with a torque wrench. After using this procedure enough times, you may develop a calibrated elbow of your own.

Another good habit involves tightening a number of fasteners that are in a pattern around the edge of an assembly. Instead of tightening one nut and bolt and then moving to the next set in line, use the criss-cross method. Start with one fastener and tighten it a few turns. Then move to another one across the assembly and give it a few turns. Keep moving this way from fastener to fastener until they are all tight.

This method pulls the two parts of the assembly together evenly and avoids distortion. Examples of places to use this technique are fastening the battery rack to the vehicle's frame or body, and bolting the flywheel to the adaptor hub.

**Two versions of the torque wrench for precision tightening, the older style on top and the newer style on bottom.**



You might not feel like putting a torque wrench on every fastener you put on your conversion. Few people do. However, as a minimum, you must torque any fastener that is helping to support a lot of weight or is part of a rotating mechanism. These are the areas where failure is likely and will cause the most damage.

### Attention to Detail Counts

Fasteners are such small things, so people rarely give them much thought. But as you can see from what we've discussed in this article and the previous one, there are a lot of differences among them. These little differences can make a big difference in the success of your electric vehicle conversion project, or any other project.

### Access

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