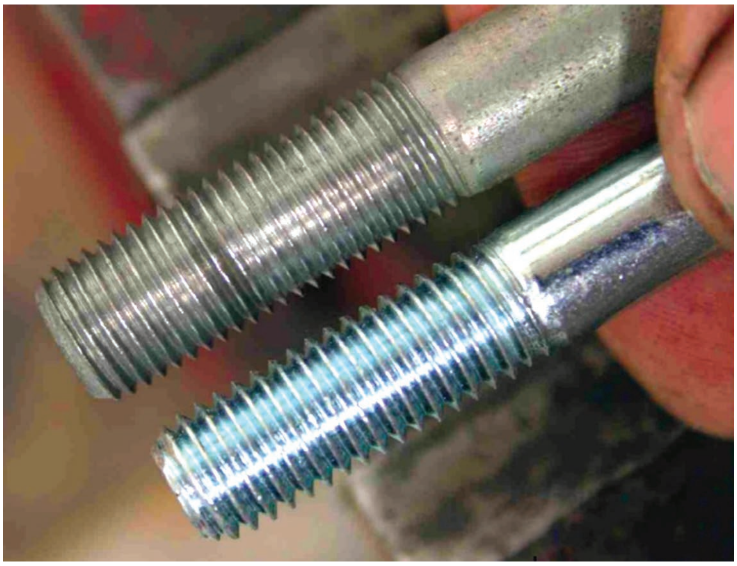
Technical - Getting Down To The Nuts And Bolts



One is metric, the other imperial, but how do you tell the difference?

If you're a little confused between metric and imperial threads, and which version your Jaguar uses, the following guide should help explain the differences between both.

Screw threads are in many ways like the English language; yes, there are rules and conventions, but there are also many exceptions, usually adopted for a reason lost in the midst of time.

In broad terms, Jaguar started building cars with British Standard Whitworth threads back in the late 1920s, then moved on to UNF/UNC threads just after the war and then, since the mid- 1970s, gradually adopted the metric system.

Try stripping down a mid '80s XJ-S, however, and the chances are that you will find threads from all three standards, not to mention the BA screws holding the instruments together and the BSP threads found in parts of the fuel system.

Things really got complicated with the later versions of the V12 engine, which retained UNC threads in the block but switched over to metric coarse for some of the threads in the cylinder heads.

Another carryover from the days of old was the need of a ¼ inch Whitworth spanner to loosen the battery terminals.

We now look into the standards that define each thread and, crucially, learn how to recognise each of them before a metric bolt is mistakenly wound into a UNC thread.

Glossary

Bolt size:

The outer diameter of the thread in millimetres or fractions of an inch; the internal diameter of the nut will be smaller by the corresponding thread depth.

Thread pitch:

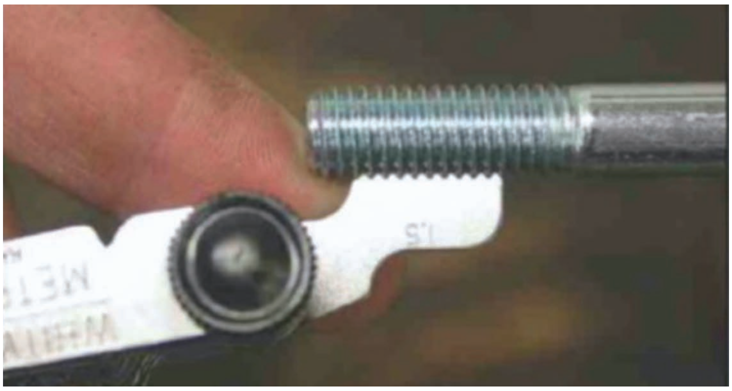
The spacing between each thread in millimetres per 360-degree revolution or the number of threads per inch.

Thread angle:

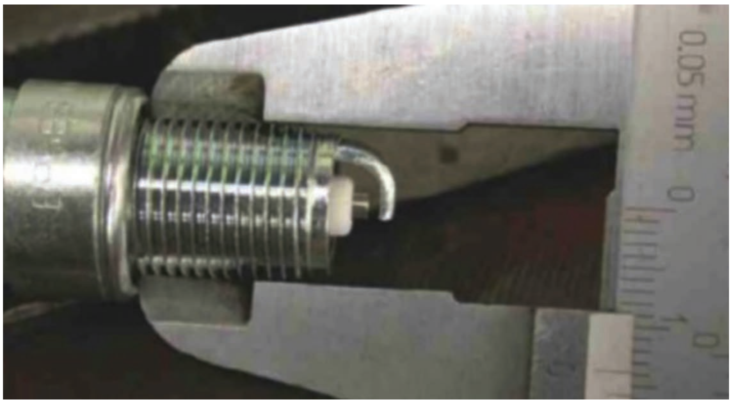
The included angle between the two thread faces, 60 degrees for metric and UNC/UNF and 55 degrees for Whitworth.

1 Most metric bolts have a flat head with a maker's mark and the strength rating.

2 This standard M10 bolt has 1.5mm gap (or pitch) between threads.



3 To identify a thread, first measure the overall diameter. In this case 14mm.



4 Then use a thread gauge to identify the pitch, here 1.25mm = M14 x 1.25.

Common metric bolt dimensions

Bolt size	Coarse pitch (mm)	Fine pitch (mm)	Across flats (A/F, mm)*
M5	0.8	n/a	8
M6	1	0.75	10
M8	1.25	1	13
M10	1.5	1.25 or 1	17
M12	1.75	1, 1.25 or 1.5	19
M16	2	1.5	24

**It is quite common for Jaguar to use bolts with a hexagon one size smaller than the standard on engines with metric threads*

Common imperial bolt dimensions

Bolt size (in)	UNF pitch	UNC pitch	Across flats (A/F, in)
0.112	48	40	3/8
0.25 (1/4)	28	20	7/16
0.3125 (5/16)	24	18	1/2
0.375 (3/8)	24	16	9/16
0.4375 (7/16)	20	14	5/8 (bolt) or 11/16 (some nuts)
0.5 (1/2)	20	13	3/4

Metric

The metric bolt designation system is based on the relationship between the bolt diameter, the head size (A/F - the distance 'across flats') and the thread pitch, that is the distance the thread travels in millimetres for each 360-degree rotation of the bolt Standard metric sizes assume a coarse pitch, i.e. for M6 it is 1; that is a 6mm bolt, where the thread advances 1 mm each time it completes one revolution.

Other standard sizes commonly found are M8 with a 1.25mm pitch and M10 with a 1.5mm pitch.

Where a finer pitch is used the pitch, itself is incorporated into the bolt size, the most common being M14 x 1.25 as used on most spark plugs — a standard 14mm bolt by contrast would have a pitch of 2mm.

Most bolts will have their strength rating marked in raised letters on the bolt head in a standardised format. There will normally be two numbers divided by a dot, where the first number denotes the tensile strength in MPa divided by 100, and the second number denotes its elastic limit as a percentage (divided by 10) of the tensile strength.

For example, the number 8.8 means that the bolt will break at a tensile load of 800MPa, but will go beyond its elastic range, that is deform permanently, at a tensile load of 640MPa.

One of the first uses of metric threads and bolts came with the introduction of four piston calipers on the front brakes of the Series 2 XJ in late 1973. The rear brakes by comparison remained imperial until the inboard brake design was finally abandoned in 1993.

The AJ6 became Jaguar's first 'metric' engine when it was fitted to the XJ-S in 1983, with the V12 adopting metric cylinder heads 10 years later.

The Borg Warner model 65 of 1973/4 adopted some metric threads, but with the switch to ZF as the transmission supplier in 1986 it became an all-metric assembly.

As for the rest, the process continued slowly with the S-Type of 1999, all but eliminating imperial threads.

BA, or British Association thread (commonly OBA to 6BA) as found in many instruments is actually metric in design, the largest size, OBA, having a 1 mm pitch; developed in metric units, the dimensions were then rounded to the nearest thousandth of an inch.

Imperial

The most commonly found imperial threads, UNF and UNC are, in fact, largely an American import agreed upon between the US, UK and Canada, just after the 2nd World War.

UNF stands for Unified National fine, and UNC Unified National Coarse, both define a bolt by its diameter and the number of threads per inch, along with a set relationship between the thread diameter and the size of the hexagon.

A 5/16 UNF bolt will therefore have a thread diameter of five-sixteenths of an inch, 24 threads per inch and a half inch AF (Across Flats) hexagonal head. An exception to this rule can be found on many suspension assemblies as here the nut, although using the same thread, will be one size larger in the hex (both to increase its surface area and eliminate the need for two spanners the same size).

Since the early '70s, when metric threads became more prevalent it has become common practice to identify imperial bolt heads with a raised circle. They can also have a strength rating indicated by the number of straight lines radiating out from the centre of the head (the more lines the stronger the bolt).

In Jaguar applications UNF threads gradually replaced Whitworth (see below) in the years following the 2nd World War. Though their use declined substantially during the '80s, they were used for items such as wheel studs until relatively recently. UNC is most commonly found in aluminium components, most notably the V12 engine, but also some gearboxes and the external attachment points on an IRS differential.

British Standard Whitworth (BSW), commonly used in the first half of the 20th centum uses the same pitch as UNC but with a slightly different thread angle and the use of curved rather than flattened thread outer faces. Except the half inch size which has a slightly different pitch, the two threads are to all intents interchangeable, though BSW bolts generally have much larger heads than the equivalent UNC bolt.

Where BSW does differ substantially is in the way that the spanner sizes are identified. Metric and most imperial spanners are sized by the gap between the jaws and therefore the 'across flats' dimension of the bolt head. BSW spanners on the other hand are dimensioned according to the diameter of the bolt itself rather than the A/F of the head, accordingly a 5/16 BSW spanner will be much larger than a 5/16 UNF/UNC (A/F) spanner.

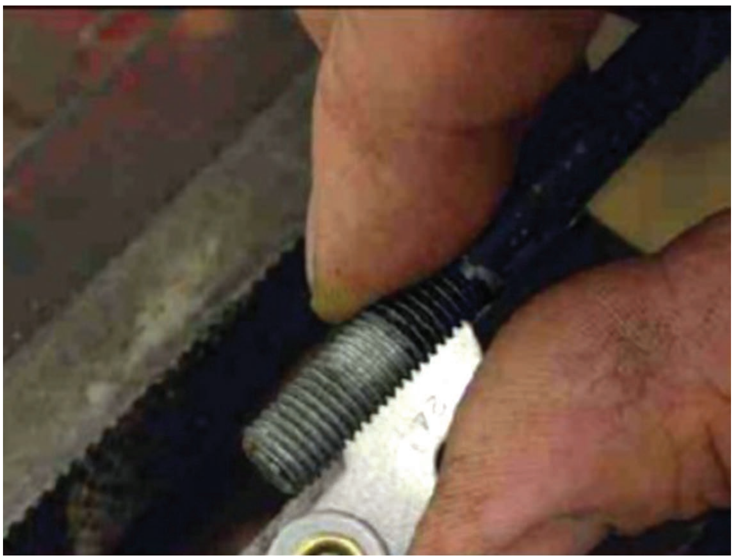
Related to BSW but with a finer thread and a one size smaller hexagon, is British Standard fine (BSF) — this is why BSW spanners are often marked with a second, smaller BSF size. BSW bolts eventually adopted BSF hexagon sizes and so spanners for these are simply marked with BS indicating they fit both.

The Whitworth legacy continued to influence Jaguar production long after the thread itself became obsolete, electrical connections on starter motors for instance, although having a 5/16 UNC thread for some reason persisted with a 1/4 BSW hexagon size on the nut. The upper chain tensioner on the XK engine retained a 3/8 BSW hex right through to the late '70s when it was replaced by 11/16 AF.

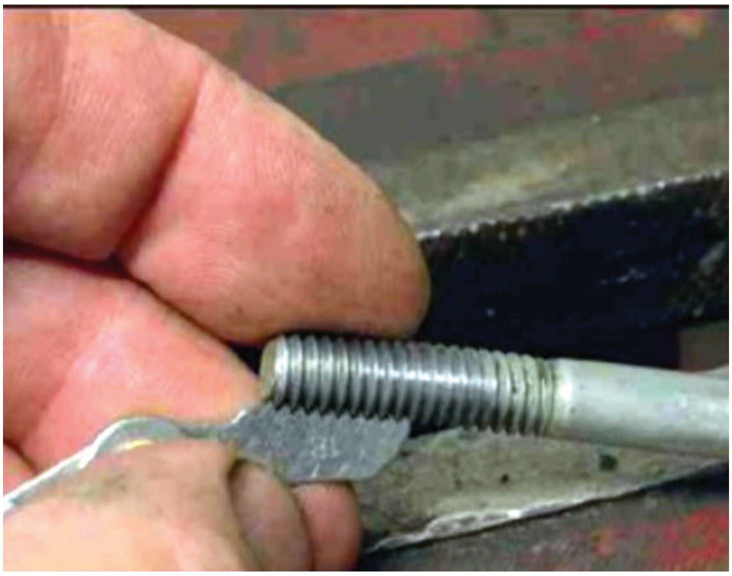
1 The imperial bolt has a raised circle, and three lines indicating medium strength.

2 Again, measure the thread diameter - which in this case is $^{5}/_{16}$ of an inch.

3 Next the pitch, here measuring 24 threads per inch and indicating UNF.



4 Another $^{5}/_{16}$ bolt, but with 18 threads per inch indicating UNC.



5 A much earlier BSW bolt, $^{7}/_{16}$ diameter, with 14 threads per inch.

6 This Chain adjuster has a $^{5}/_{16}$ UNC/BSW thread, but a $^{3}/_{8}$ BSW nut hex.

Types of Fasteners

All bolts are not created equal; strip down the average car and very few will be identical in every respect.

Each bolt will be carefully specified in terms of strength, length, diameter, head type, and even the length of the thread in relation to the overall length of the bolt.

This is not just for reliability but also economy — using the smallest bolt capable of doing the job saves both weight and, when factored over a year's production, money as well.

In most applications the actual thread on a bolt will only be slightly longer than is necessary to fully tighten it, this is because the threaded part is also the weakest, even though the threads themselves are normally rolled with tiny radiuses where the threads meet the central core.

In a similar fashion, nut thickness is usually restricted to one-and-a-half times the diameter of the bolt as this gives maximum strength.

Often a nut or bolt is adapted to suit a particular purpose; the bolts securing the radius arm safety straps on Jaguars, for example, have slots machined into their threads to collect any grit that may have accumulated, while some hub nuts incorporate a hardened steel thread insert for added durability.

Where a component has to be located accurately, the bolt shank (not the thread) will be slightly oversize to fit the hole exactly.

Pipe nuts, as used in the braking system, deserve a special mention here as it is very easy to mix metric and imperial threads, especially between 10mm and 3/8 nuts found on most 1970-80 Jaguars which feature metric front calipers and imperial rear calipers; the 3/8 pipe union can screw into a metric thread but will be a loose fit and may strip.

On cars where both systems are present (Series 2 to the end of XJS), metric and imperial unions will often be marked, either with notches or interlocking Ms for the former, or interlocking circles and a tapered pipe end in the case of an imperial female nut.

There is no positive way to identify an imperial male union other than by feel and the inferred lack of notches.

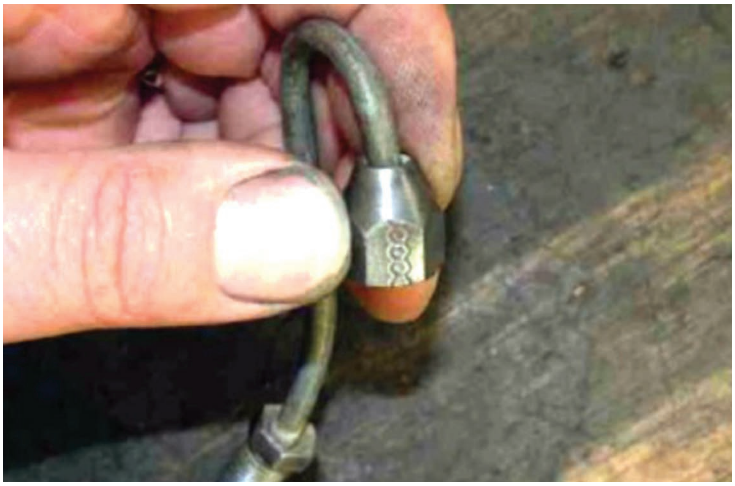
Thread length will usually be kept as short as possible to maintain strength.

Some nuts come with a Heli-coil already installed for added durability.

This suspension bolt is slotted as a self cleaning aid.

A male pipe union with notches indicating metric thread.

The metric female union can have identifying notches or a band of Ms - or nothing.



The imperial female union is normally tapered where the pipe exits, a fact that aids identification.

Care of Threads

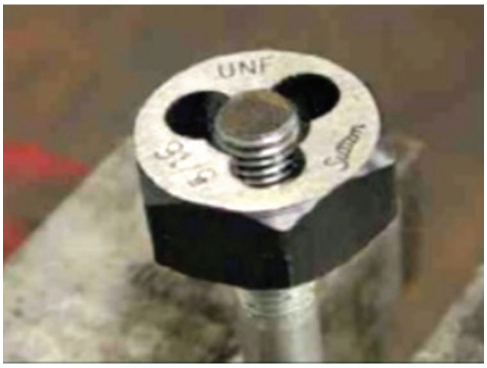
While over tightening is one sure way to damage a thread, leaving it loose is just as harmful as it may then chafe and eventually wear away.

All bolt tensions as specified in a workshop manual are carefully calculated for maximum clamping without damage.

Where a specified tension is not given let the spanner guide you, as most are sized to correctly tension the bolt or nut with moderate hand pressure at the outer end, hence a 7/16 will be considerably shorter than a 3/4; hooking another spanner onto the end for extra leverage just defeats the purpose.

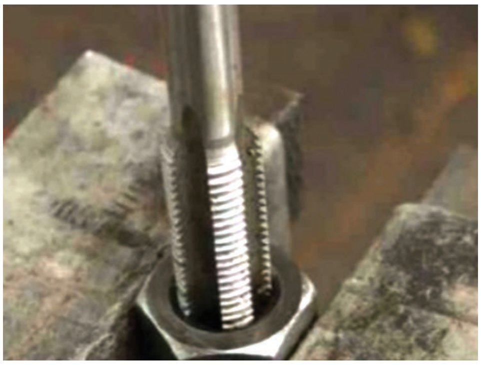
Where possible, always use undamaged bolts, cleaning the thread with a wire brush if necessary. Die nuts can dean up a damaged bolt but will also weaken it by cutting away the radius at the bottom of the thread; a better option is to use a thread file to tackle individual burrs.

Cleaning up an internal thread with a tap is not as dangerous and, in the case of domed head nuts for example, is important to prevent any tendency to bind which would then cause an incorrect tension setting when the nut was torqued down.



Using die nuts to clean threads should be avoided if possible as they weaken the bolt.

A thread file is a much better option if you need to remove individual burrs.



Domed head nuts should always be cleaned out before reuse - Here they are using a tap.

Tensioning

Depending on the age of a car, the tensions given in the workshop manual will be Foot Pounds (1b ft) or Newton Metres (Nm).

Both denote a specific rotational force to be applied perpendicular to and a set distance from the nut or bolt head; therefore 60 1b ft would indicate a force of 60 pounds at the end of a foot long 'bar' while its equivalent, 81.35Nm would indicate 81.35 Newtons at the end of a metre long 'bar'.

Most torque wrenches are calibrated with both metric and imperial scales, but for accuracy it is vital that the thread be lubricated and the final tensioning done in one constant pull as the force needed to get the nut/bolt moving will be greater than that needed to keep it going.

Spring type wrenches should always be slackened off at the adjustment immediately following use to preserve the calibration.

With the AJ6 engine of 1983, Jaguar introduced torque-to-yield cylinder head bolts for even tension; these work by engineering into the bolts a range where they cease to tighten anymore, but do not relax their grip either.

If all the bolts are exactly the same it is simply a matter of tightening until they are at the brink of the 'stretch zone' and then tightening a further number of degrees to position them in the middle of that zone so all apply exactly the same force on the cylinder head. For this reason, Torque-To-Yield bolts should only ever be used once.

Thread Locking

Where once it was common practice to wire bolts together in order to stop them coming undone, today a bottle of thread-locking fluid, usually referred to as Loctite after the most common brand, has taken the place of most mechanical locking devices.

Locking washers come in several types, the most common being a square section coil with offset ends that then dig into both the surface below and the nut. A second type can have internal and external 'fingers', twisted at a slight angle to perform the same purpose many times around the nut.

Often found on the later XK and V12 engines, is a slightly concave washer with raised ridges radiating out, which locks effectively without damaging the soft aluminium surfaces. Some more recent nuts incorporate this type of washer into a single unit.

Locking washers can be reused as long as they have not flattened out or lost their raised edges.

Locking nuts fall into two types, the more common Nylock, which has a ring of nylon above the thread to grip tightly onto the bolt or stud, and the Metalock or Clevelock type which have the top face deliberately distorted and which are used where heat would melt the nylon.

Falling into the same category are the bolts used to secure V12 cam covers, which have three raised areas on each thread (in a triangular formation) to grip into the thread in the cam boxes — care must be taken with these as it is easy to damage the soft aluminium cam box thread.

Nylocks should always be replaced whenever possible, as should a metal nut that fails to grip when refitted.

Thread-locking fluids are anaerobic, that is they remain liquid in the presence of oxygen, but harden once it is removed, as is the case where a nut fits snugly around a bolt — an almost identical compound is injected into gas mains to plug leaks.

Thread locker comes in various strengths covering every application from the temporary locking of adjustment screws to the permanent fixing of bearings in damaged housings, with some variants also suitable for high temperature applications.

Always use the correct grade and clean off all traces of old thread-lock prior to reassembly, and if a (temporarily) locked bolt won't budge, try warming it up first. ■

Editor: Information for this story sourced from various sources and Jaguar World (Garreth Coomber).

Three common types of lock washers

Some bolts come with the thread-lock already applied.

Clevelock and Nylock (bottom) self-locking nuts.
The former uses a distorted face to grip, the latter Nylon.

Modern nuts & bolts often have an inbuilt locking mechanism --this is concave with raised edges.