

## OVERHEATING

Most modern engines operate within a temperature range of approximately 88° to 105° Celsius (190° to 220° Fahrenheit). If an engine exceeds its normal operating range and overheats the elevated temperatures can cause extreme stress in the cylinder head. This particularly true of bi-metal engines where the difference in the thermal expansion rate of the aluminium cylinder head is two to three times that of the cast iron block. It is important to note at this time that a water temperature gauge only records the average temperature of the engines coolant it does not indicate the temperature of the engine block or cylinder heat castings.

Overheating is caused by the inability of the engines cooling system to absorb and dissipate the heat generated by the combustion process. Low or loss of coolant, accumulated deposits in the water jackets, defective thermostat or radiator cap, slipping fan clutch or inoperative electric fan, eroded or loose water pump impeller, poor air flow through the radiator can all contribute to an engine overheating. Other factors such as retarded ignition timing, lean air/fuel mixture, detonation/pre-ignition, exhaust restrictions and overworking the engine will also contribute to overheating.

## HOT SPOTS

Hot spots in a cylinder block or head are caused by a localised overheating. When a hot spot forms the surrounding metal expands greatly creating added stress which may cause the head to warp or even crack. The extreme temperature of a hot spot can also cause a localised soft spot in the cylinder head.

A cooling system that is not operating efficiently, loss or lack of coolant, an air pocket in the cooling system, or an abnormal combustion problem that causes combustion temperatures to increase dramatically can result in the formation of a localised hot spot. Aluminium cylinder heads where the exhaust valves for the two centre cylinders are positioned back to back are also prone to localised overheating between the adjacent sets of valves.

Localised hot spots are one of the more easily identifiable causes of a head gasket failure. A hot spot causes the surrounding metal in the cylinder block and head to expand which in turn can crush and damage the head gasket, creating a leak where the exhaust gases will erode the gaskets facing material. Eventually the escaping exhaust gases will burn through the gaskets fire rings and steel core.

## HARDNESS

Checking for hardness requires a hardness tester. While this in itself is not overly expensive or complicate it is often difficult to obtain a specification as to what the allowable hardness figure should be. Each engine manufacturers has their own "blend" of aluminium alloys with the mix trace elements used differing slightly from manufacturer to the next. Some further complicate this by using a number of different alloys within their range of engines i.e. the specific alloy used for a Nissan CA20 engine may differ to the alloy used for a Nissan RB30 engine.

**Cylinder heads that  
have softened  
should not be put  
back into service**

Most aluminium cylinder heads will have begun to soften when exposed to temperatures between 200° to 250° Celsius (392° to 482° Fahrenheit). At 250° to 300° Celsius (482° to 572° Fahrenheit) the softening will have become quite severe making the cylinder head not suitable for service. For this reason, even with the difficulties mentioned above, it is very important to hardness test any aluminium cylinder head when the engine is known to have overheated or when repair work such as welding has been carried out on the head. Localised hot spots within the cylinder head can result in localised soft spots so it is essential that the testing is carried out over a number of positions on the head. In addition to the sealing surface of the cylinder head particular attention should also be paid to the mating surfaces for the cylinder head bolts. Indentations on the head bolt mating surface resulting from where the bolt head has sunk into the cylinder head is a sure sign of softness.



# BEFORE YOUR HEAD GOES ON THE BLOCK...

## CLEANLINESS

Prior to assembly a final check of all components should be made paying particular attention to the cleanliness of all items. Assembling of the engine should be carried out on a clean work surface free from foreign objects and debris.

The presence of foreign debris such as abrasive residue, dirt, carbon, old gasket material, etc. on either of the gasket sealing surfaces can greatly reduce the ability of the gasket to create an effective seal. Foreign material can prevent the gasket from establishing good contact with the sealing surfaces creating a path through which leakage can occur and debris that becomes embedded in the surfaces of the gasket can cause damage to the gasket or in extreme cases to the sealing surfaces.



A build up of carbon deposits in the combustion chamber and on the crown of the pistons is a common cause of detonation. A thick layer of carbon can also have an insulating effect that inhibits the transfer of heat from the combustion chamber to the cylinder head and into the cooling system causing combustion temperatures to rise. This rise in the combustion temperature can lead to the condition known as pre-ignition.

## DISTORTION

A gasket's ability to create and maintain a seal is directly related to the condition of the surfaces upon which it is required to perform. Distortion on either surface, damage such as corrosion, deep scratches, gouges, pitting, excessive surface roughness and or waviness will all reduce the gasket's performance. In short, a poor surface will produce a poor seal. It is therefore very important when replacing a gasket to inspect the condition of both surfaces to ensure both are within acceptable limits. Of equal importance is to check that the cylinder head has not developed any cracks or has not softened particularly on the sealing

surface and the head bolt mating surfaces. While the following refers to cylinder blocks and cylinder heads the basic principles should be applied to all surfaces where a gasket is required to create a seal.

Distortion relates to the total values of the cylinder head and the cylinder block. To measure just the cylinder head or just the block in isolation produces an incomplete result that may be outside the recommended specification. Total maximum distortion values for cylinder heads and blocks combined are shown below:

### 3 cylinder & V6 engines

Length: 0.076mm (0.003")  
Width: 0.051mm (0.002")

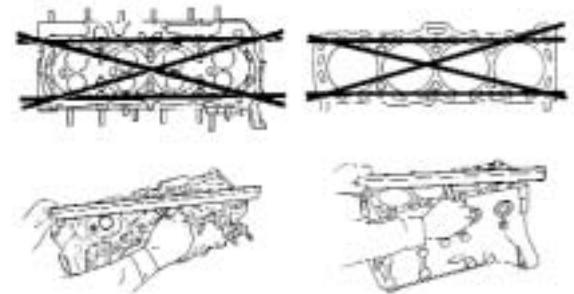
### 4 cylinder & V8 engines

Length: 0.102mm (0.004")  
Width: 0.051mm (0.002")

### Straight 6 cylinder engines

Length: 0.152mm (0.006")  
Width: 0.051mm (0.002")

Using a good straight edge and feeler gauge check both the cylinder head and block for warpage and flatness as shown:



Both the cylinder head and block surfaces should also be checked for waviness. Undulations or waves across the sealing surface should not exceed a maximum height of 0.01mm (0.0005") for wave peaks between 0.76mm (0.030") and 2.54mm (0.100") apart. Wave peaks with a spacing greater than 2.54mm (0.100") the wave height should exceed a maximum of 0.02mm (0.0008"). There should be no wave peaks with a spacing of less than 0.76mm (0.030") and there should be no sudden irregularities on the sealing surface that exceeds 0.025mm (0.001") or any out of flat of plus or minus 0.025mm (0.001") across a 76.2mm (3.000") section in any direction.

## FINISH

If a surface finish is too rough or coarse the gasket can not fully conform to the irregularities. Combustion gases and engine fluids can not be properly sealed. In the past the prevailing theory was if the surface finish was too smooth, friction between the surface and the gasket is reduced allowing the gasket to move and prone to blow out. Due to the improvement to composite materials in recent years current thinking is now that the smoother the finish that can be achieved the better.

Surface finish or perhaps more correctly surface roughness values are normally expressed as roughness average or Ra, either in micrometers or microinches. Ra is the calculated value of the average roughness deviation from the mean roughness height. Another expression commonly used for surface finish is average peak to valley height or Rz, again either in micrometers or microinches. Rz is the average value of individual peak to valley heights in five continuous individual measurement sections. Unfortunately Ra and Rz are not comparable and therefore the value of one cannot be converted to that of the other.

There are two ways to check surface finish. One is to use a comparator gauge which is a flat piece of metal upon which a number of specimens of standard surface finishes have been reproduced. By comparing the appearance and the feel of the machined surface to those of the specimens on the comparator an approximate surface finish can be estimated. The other method is to actually measure the surface finish using a surface roughness tester called a profilometer which drags a diamond tipped stylus across the surface to measure and calculate the surface finish.

The material from which the gasket and the components to be sealed are manufactured have a bearing on the level of required surface finish however the following general specifications are suitable for most petrol and diesel engines whether of aluminium or cast iron construction however due to the rapid changes in technology always check the manufacturers specification.

### Conventional Fibre type gaskets

2.00 to 2.50 micrometers Ra  
(80 to 100 microinches Ra)

### Graphite (Carbon Fibre) type gaskets

0.75 to 1.50 micrometers Ra  
(30 to 60 microinches Ra)

### Laminated (Multi Layer) Steel type gaskets

- without rubberised coating  
less than 0.75 micrometers Ra  
(less than 30 microinches Ra)
- with rubberised coating  
less than 0.50 micrometers Ra  
(less than 20 microinches Ra)

## COOLING SYSTEMS

More than half of head gaskets received by AA Gaskets Pty Ltd for evaluation that have failed in service clearly show signs that can be directly attributed to engine overheating. As we have mentioned earlier in this section (page viii) the reasons for overheating are many and varied. Quite often however the condition and proper functioning of an engines cooling system is ignored.

It is the job of an engines cooling system to absorb, transport and dissipate the heat generated by the combustion process. In today's modern vehicles the cooling systems are smaller and are designed to operate a near maximum capacity. It is therefore essential that the cooling system is properly maintained to the manufacturers' specifications. Following a major engine repair or rebuild it is essential that the vehicles cooling system is thoroughly checked. Radiator tanks and cores, thermostats and thermo switches, fan belts and water pumps should all be inspected and if necessary replaced. The cooling system should be drained, thoroughly flushed and refilled with fresh coolant.



One of heats basic principles is that it will always flow from an area of higher temperature to an area of lower temperature. Corrosion and or contamination can severely reduce a cooling systems ability to operate efficiently and effectively. In basic terms corrosion is the deterioration of a solid by a chemical or an electrochemical process. Corrosion is assisted by moisture and oxidation. When we apply this to an automotive environment the solids are the engines metal components which are immersed in a chemical, the engines coolant. These metals are subjected to a number of different forms of corrosion; cavitation, chemical, crevice, galvanic, general and pitting corrosion are all common in automotive cooling systems. In the case of the more modern engine of the 90's we must add to these stray current corrosion.

Cavitation corrosion is due to the sudden collapse of air bubbles against the walls of the casting. This exploding action of the air bubbles erodes the protective film formed by the coolant and eventually the oxide layer of the metal exposing the casting to corrosive action. Preventative maintenance can greatly reduce the occurrence of cavitation corrosion by maintaining the layer of protective film over the casting as well as suppressing the occurrence of foaming and the formation of air bubbles.

# BEFORE YOUR HEAD GOES ON THE BLOCK...

Chemical corrosion can be caused by mixing different types of coolant or having an incorrect amount of ethylene glycol in the cooling system. Chemical corrosion can also occur when the coolant has exceeded its service life and the protective properties of the corrosion inhibitors have been severely depleted. Again the best cure is prevention through proper maintenance of the cooling system.

Crevice corrosion can occur in areas where coolant flow is poor and small amounts of coolant can stagnate. Typically this type of corrosion can occur where radiator and heater hoses join clamping areas such as thermostat housings and water outlets. Hose clamps should be positioned as close as possible to the lip of the outlet or housing to prevent coolant from penetrating between the ID of the hose and the OD of the outlet.

Galvanic corrosion or electrolysis occurs when two or more dissimilar metals are in contact with each other or immersed in a fluid capable of conducting a charge. For example if copper particles from the radiator, carried by the coolant, coat an aluminum housing a galvanic cell is formed as the two metals react chemically producing an electric charge. The aluminum becomes the sacrificial metal the housing begins to corrode. Eventually the corrosion will completely perforate the aluminum housing.

General corrosion will occur where metal is in contact with both water and oxygen. A common result of general corrosion is rust and scale which can block radiator tanks and cores. Even a relatively thin layer of rust / scale on an engines metal components can greatly reduce the transfer of heat from the components and into the coolant.

Pitting corrosion is a very localised form of general corrosion which penetrates deeply into the metal component eventually establishing a stress point in the component. Pitting corrosion usually on components such as cylinder sleeves.

Stray current corrosion generally occurs in modern vehicles where for vibration and noise control reasons the radiator is insulated from the vehicle on rubber mountings. Introduce a bad electrical connection in a component such as a cooling fan or headlight and a condition exists for very aggressive electrolysis as the electrical current endeavours to find an earth path through the engine coolant. Older vehicles may also suffer from stray current corrosion however the radiator in these vehicles is usually fixed directly to the bodywork providing an earth path for stray current that may get into the cooling system. Corrosion damage to

components in and around the radiator of a vehicle operating a clean cooling system is usually a good indication of stray current.



## COOLANT

The function of an engines coolant is to absorb, transport and dissipate the heat generated by the combustion process from the engine to the radiator. For many years ethylene glycol has been the main ingredient in almost all automotive coolants. Mixed with water ethylene glycol will lower the freezing point and raise the boiling point of the coolant. Too high a concentration of ethylene glycol however, reduces the coolants primary function of absorbing and transporting heat away from and out of the engines components and can also promote corrosion in the cooling system. Ethylene glycol also has a tracking property which can cause leak problems with hose connections, gaskets and welsh plugs on rebuilt engines. As a caution you should also be aware that ethylene glycol is a toxic substance which if ingested can be lethal.

As the coolant is in constant contact with metal antifreeze also contains inhibitors that form a protective coating on the surfaces of the engines coolant system against rust and corrosion. These inhibitors create an alkaline coolant mixture that needs to neutralise the acids that are formed over time from degradation of the glycol. As the chemicals in coolant deteriorate their protection against corrosion becomes greatly reduced. Once depleted the level of acidity within the coolant increases and corrosion within the cooling system accelerates.

More recently we have seen the emergence of Long Life Coolants using corrosion inhibitors called Organic Acid Technology (OAT). The main advantage of OAT coolants over more traditional coolants is an extended service life; up to five years. To distinguish OAT coolants from other coolants an orange dye is added. OAT coolants should not be mixed with any other type of coolant.

When adding antifreeze to a cooling system a key point to consider is what is the coldest temperature that the vehicle is going to be exposed to when parked overnight or when in operation? Based on this information how much antifreeze is actually required for the protection of the vehicle?

## WATER PUMP PERFORMANCE

An engines water pump is the heart of its cooling system. Its primary function is to circulate coolant through the engine in sufficient volumes to maintain the correct operating temperature. In order for the cooling system to function correctly it is essential that the water pump is performing at optimum levels. Corrosion of a water pumps impellers or incorrect impellor clearance will greatly reduce the water pumps performance. Water pumps should be tested for efficiency, pressure and cavitation.

## PREVENTATIVE MAINTENANCE

As we can see from above prevention is the best cure for a number of the problems that can occur within the cooling system. Following are some preventative maintenance measures that can be taken to extend the life of an engine:

- Use a good quality coolant. For newer vehicles use the coolant specified by the vehicles manufacturer. On older vehicles use a coolant meets or exceeds the manufacturer's specifications.
- The entire cooling system should be flushed and the coolant replaced at the specified intervals even if the coolant looks to have maintained its colour and is clean. The chemicals in coolant deteriorate over time and their protection against corrosion becomes greatly reduced.
- Never mix different makes or brands of coolant additives. The chemicals in one brand may not be compatible with those of another brand resulting in a chemical reaction which could damage your cooling system. If the coolant in the system is unknown drain, flush thoroughly and refill with fresh coolant.
- When adding new coolant to a system or topping up the existing coolant always use a solution that is premixed to the correct concentration as specified by the coolant manufacturer. Do not exceed the recommended concentration as this may change the coolants properties. Premixing the coolant will eliminate the guess work in estimating the cooling systems capacity and ensures that the correct concentration level is maintained.
- When premixing coolant, rain water or distilled water is best. Ordinary tap water contains trace elements that can accelerate corrosion. Do not top up coolant level with plain water as this will dilute the coolant and reduce its protection level.
- When refilling a cooling system ensure that all air is purged from the system and that there are no air pockets trapped within the vehicles cooling system.

## OIL SEALS

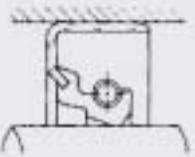
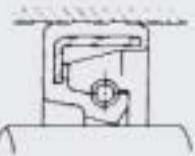
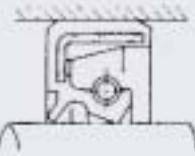
Oil seals in an automotive environment perform two main functions; retain the engines lubricant within the engine and exclude outside contaminants such as dirt and dust from entering the engine. In order to perform these functions there are four key components that make up the Oil Seal Concept. The shaft, on which the oil seal must run; the bore, in which the oil seal is housed; the conditions, in which the oil seal must operate and the oil seal itself.

When a radial lip oil seal is operating correctly the sealing lip does not actually come in contact with the surface of the shaft. The difference in internal and external engine pressures allows a very thin film of oil to seep between the seal lip and the shaft. It is on this film of oil that the sealing lip runs. If the load provided by the oil seals garter spring and the internal pressure of the seals elastomer (rubber) are correct then the film of oil is maintained and oil is prevented from leaking past the sealing lip. An incorrect balance of engine pressures and seal load will allow either too much oil through causing the seal to leak or too little oil through resulting in excessive lip wear and eventual leakage.



## STANDARD DESIGN TYPES

In the majority of automotive applications radial lip oil seals fall into one of two main design categories. The table below illustrates the differences between 'S Lip' and 'T Lip' design oil seals.

Lip Type		S	T
Body Type	B – Metal Case		
	C – Rubber Case		
Features		Single sealing lip with garter spring to provide a consistent radial load against the shaft.	Single sealing lip with sealing applications and severe grease sealing conditions.
Main Applications		General non-pressure garter spring combined with an auxiliary dust lip to provide effective light duty dust exclusion.	General non-pressure sealing applications and severe grease sealing conditions with light duty exclusion of dust or foreign materials.

# BEFORE YOUR HEAD GOES ON THE BLOCK...

Variations on standard seal design types include the addition of hydrodynamic sealing lips which have helical ribs or helix lines which help pump oil back under the sealing lip. Hydrodynamic sealing lips can be mono-directional or bi-directional. Other variations include flange style casings and special synthetic fabric dust lips. These variations are identified by the use letter which prefix and or suffix the standard design code i.e.: TC is a rubber cased, single lip oil seal, with an auxiliary dust lip. HTCKL is a rubber cased, single lip oil seal with mono directional helix lines for a left hand rotation with a special synthetic fabric dust seal.

## MATERIALS

One of the most important components of the radial lip oil seal is the elastomer material used in the seals construction. There are many different classes of elastomer blends specially developed to meet a wide variety of sealing requirements each with an individual formula to satisfy various sealing conditions. The majority of these blends use a base polymer from one of the four main groups listed below:

### Nitrile

Commonly known as Buna-N, nitrile is the most common base polymer used in fluid sealing. Nitrile has very good resistance to the swelling effects of petroleum based products. Generally when a nitrile seal fails in service it is because it has been subjected to temperatures outside of its recommended limits or to chemicals that have a degrading effect on nitrile. The result is hardening and eventual embrittlement.

### Polyacrylate

Used in applications where a higher temperature resistance is required. Polyacrylate has very good resistance to the swelling effects of petroleum based products and it's resistance to the decomposition products of extreme pressure gear oil additives.

### Silicone

Functions satisfactorily over a very wide temperature range and at extreme temperatures silicone is superior. With excellent resistance to compression set the main application for silicone is crankshaft seals. In comparison to other elastomers used in the manufacturing of oil seals silicone has a very poor resistance to abrasion.

### Fluoroelastomer

Common trade names include Viton, Technoflon and Fluorel. Has very good heat resistance and swelling in highly aromatic fuels is low. Certain

oil additives can cause embrittlement at relatively low temperatures. Fluoroelastomers have a very good resistance to abrasion.

A Special Caution on Fluoroelastomers – Fluoroelastomer is a synthetic material containing fluorine used for gaskets, o-rings and seals. When used within design specifications it is completely safe however if exposed to high temperatures the material decomposes and one of the by products formed is hydrofluoric acid. This acid is extremely corrosive and is almost impossible to remove especially from human tissue. When inspecting equipment which has been exposed to high temperatures check if any gaskets, o rings or seals have suffered from decomposition which will appear as charred or black and sticky. DO NOT under any circumstances touch either the seal or the area containing the seal until a substantial cooling period has been allowed. The affected area should be decontaminated before undertaking any further work.

**Note:** Viton is the registered trade mark of Du Pont Inc., Technoflon is the registered trade mark of Montecatini Spa., Fluorel is the registered trade mark of Minnesota Mining & Manufacturing Ltd.

## SHAFT FINISH, HARDNESS & TOLERANCE

If a radial lip oil seal is to perform correctly the condition of the shaft surface where the seal is to operate is as important as the condition of the seal itself. Shafts having too rough or too smooth a finish will greatly affect the performance and service life of the seal. Research by oil seal manufacturers recommend that the shaft surface at the point of seal lip contact be machine lead free with a finish between 0.25 micrometers to 0.50 micrometers Ra (10 microinches to 20 microinches).

The preferred method of achieving this finish is by plunge grinding to spark out with short to medium marks which are at 90 degrees to the shaft axis. These machine marks retain oil which improves seal life. A grinding wheel of 80 grits is recommended. The ratio grinding wheel rpm to the shaft rpm must not be a whole number ratio or lead will result (i.e. 10.5:1 not 10:1). To assist in installation of the oil seal the leading edge of the shaft should be chamfered 15/30° with the corners blended and burr free.



15/30° with corners blended and burr free

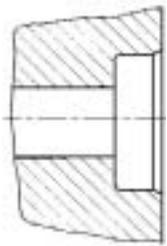


Another shaft condition relevant to oil seal performance is hardness. Oil seal manufacturers recommend a minimum shaft hardness of 45 Rockwell C to prevent excessive wear. Oil seals are designed and manufactured to operate on a specific shaft diameter. For shafts up to 100mm (4.0") in diameter the tolerance is  $\pm 0.08\text{mm}$  (0.003"). Shafts 100 to 150mm (4.0 to 6.0") in diameter the tolerance is  $\pm 0.10\text{mm}$  (0.004").

## HOUSING

A bore chamfer is necessary to assist in the installation of the oil seal. A proper chamfer angle  $15/30^\circ$  and depth of 1.5~2.5mm minimises cocking or lack of squareness of the seal to the shaft, distortion of the seal case and reduces force required in assembly.

For metal case seals a bore surface finish of 0.25 micrometers Ra (100 microinches) is recommended. A slightly rougher surface finish of 0.375 micrometers Ra (150 microinches) is acceptable for rubber case seals. Excessively rough bore finishes may allow paths for fluid to leak between the seal OD and the bore. Too smooth a finish may allow the seal to back out of the bore.



15/30° with corner burr free

## INSTALLATION

Before the installation of any oil seal it should be checked that no foreign matter is adhering to the seal, that the sealing lip is not damaged, cut or distorted and the garter spring has not been displaced. The sealing lip of the oil seal should be pre-lubricated to reduce friction on the contact surfaces and help protect the seal lip during initial run-in. The case of the oil seal should be dry and free of dirt. Do not lubricate or apply any retaining agent to the seal case.

An installation tool should always be used when installing an oil seal. The use of a tool improves ease of installation and reduces the possibility of seal cocking (non-perpendicular to shaft). A hydraulic or pneumatic press is advised to supply the necessary, uniform force to install the seal.

The advisable sequence for oil seal installation is to install the seal over the shaft and then in the housing bore. Care should be taken not to damage or deform the seal lip. When installing over a keyway or spline a sleeve or bullet should be used to protect the seal lip from cuts or tears. Where the shaft must be installed through the seal centering guides for the shaft will prevent lip deformation and dislodging of the spring. When possible the shaft should be rotated as it passes through the seal to reduce sliding friction.

## TORQUE-TO-YIELD HEAD BOLTS

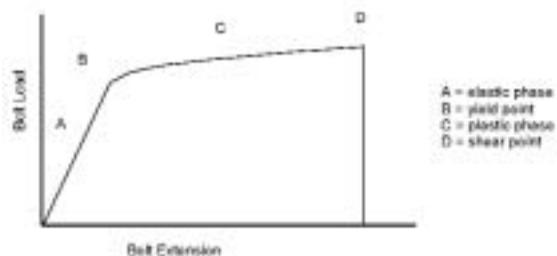
Torque to yield bolts, also commonly referred to as angle torque or stretch bolts, are used in many of today's modern engines predominantly for cylinder head bolts but also main bearing caps. Compared to conventional type bolts torque to yield bolts offer the engine manufacturer a number of advantages; including greater flexibility of design, reductions in component costs, more accurate assembly and reliability of seal. Engines designed utilising torque to yield (TTY) head bolts require fewer head bolts to achieve the desired clamping loads than those using conventional bolts. With fewer bolts the engine manufacturer has more flexibility in cylinder head and block design as well as reducing the cost of the engine.

While torque to yield bolts are attractive to the engine manufacturer there are disadvantages to the engine repairer, which we all need to be aware of. For most of us it would be unthinkable to replace a conventional head bolt unless the bolt was damaged; i.e. stripped threads, the bolt head was rounded off, the shank was severely corroded or pitted. Conventional head bolts simply just did not wear out. Torque to yield head bolts however by the very nature of their design do wear out and should never be reused.



## BOLT PERFORMANCE

Under the application of load all bolts exhibit four main phases the elastic phase, the plastic phase, the yield point and the shear point. In the elastic phase a bolt will stretch under tension but return to its original length when the load is removed. As we continue to apply load the bolt reaches the plastic phase from which it can no longer recover to its original length and is now permanently stretched. The point that separates the elastic phase from the plastic phase is called the yield point of the bolt. Finally if we continue to apply load, the shear point is reached and the bolt material waists and breaks. The chart below demonstrates these four phases:

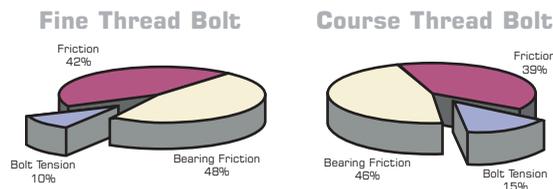


# BEFORE YOUR HEAD GOES ON THE BLOCK...

## CONVENTIONAL BOLTS

Conventional head bolts are tightened in a series of stages and in sequence to a predetermined torque setting. Given any set of bolts each will be tightened to a slightly different loading as the torque wrench simply clicks off when the set resistance level is reached. The applied tension is well within the elastic phase of the bolt; i.e. the bolt stretches under load and then returns to its original length when loosened. No allowances are made for variances, such as higher resistance due to friction or thread damage, in the applied load of individual bolts within the engine set.

These variances and inaccuracies are well known by engine designers. The following two graphs show that when tightening a conventional bolt using a torque wrench only 10 or 15% of the tightening force produces tension in the bolt. The remaining 85 to 90% of the tightening force is lost to friction.



Torque to yield head bolts are also tightened in a series of stages and in sequence however they are not tightened to a predetermined torque they are tightened through a series of specified angles. This data is provided by the engine manufacturer and should always be adhered to. While the first step in the tightening process is normally stated has a torque figure it is done only to provide a uniform baseline from which the true load is then applied. This is commonly referred to as a pre-load or snug torque. A typical tightening specification would look as follows:

- i. uniformly tighten in sequence in several passes to 78Nm
- ii. tighten in sequence 90°
- iii. tighten in sequence a further 90°

This procedure ensures that friction does not cause an uneven bolt loading and that the correct high tension is achieved every time during assembly. It is essential that a quality wrench with an accurate angle gauge be used to achieve the correct angles of turn of the tightening process.

Unlike a conventional bolt, torque to yield bolts are tightened beyond their elastic range, past their yield point; i.e. past the point from which the bolt material can recover to its original length; and into the plastic phase of the bolt material. The bolt is permanently stretched and it is for this reason should not be reused. The reliability of these bolts once stretched is greatly reduced. If they are reused, they are permanently stretched further a second or third time. It is for this reason you should never re-torque a torque to yield bolt.

Some engine manufacturers provide a measurement within which a bolt may be reused however the age and history of the bolt is not taken into account. The bolt may well be within specification to pass a simple measurement test but the bolt could be very close to its shear point. Only one failed bolt can result in serious combustion leakage. The cost of a new set of torque to yield bolts is well justified when compared to the costs of having to repair an engine for the second time because of insufficient clamping load due to bolt fatigue.

Engine manufacturers that are using torque to yield head bolts include:

Chrysler	Mazda
Daewoo	Mitsubishi
Ford	Nissan
Holden	Opel
Hyundai	Rover
Isuzu	Subaru
Lexus	Toyota

There are a variety of factors that will shorten the service life of a head gasket but lack of proper clamping load is certainly one of the leading contributors. Always ensure that the bolt hole threads are clean prior to fitting. It is recommended that you do not use a standard engineering thread tap for this purpose as torque to yield head bolts are manufactured to finer tolerances. Standard engineering taps, in these applications, can remove material from the threads resulting in minimal thread contact reducing the amount of clamping load that is applied to the cylinder head. This can cause premature engine failure. An alternative is to use an old bolt, with a machined groove the length of the thread, can achieve a satisfactory cleaning result. Always apply a light coating of oil to the threads and bearing surfaces of the bolt and have your torque wrench checked and calibrated every 12 months. Remember that if the tightening sequence is specified in degrees then you are dealing with a torque to yield bolt.

**Don't Re-use; Replace!**