PREVENTING CYLINDER HEAD GASKET AND COOLING SYSTEM FAILURES

One of the most important parts of the cooling system is also the most invisible

A cylinder head gasket is required to affect a seal between the cylinder head and block of a gasoline or diesel engine. It is an integral component of the engine and is requires to perform many functions at the same time during engine operation.

The head gasket must maintain the seal around the combustion chamber at peak operating temperature and pressure. The gasket must seal against air, coolants, combustion and engine oil at their respective peak operating temperature and pressure. The materials used and design employed must be thermally and chemically resistant to the products of combustion and the various chemicals, coolants and oils used in the engine.

When assembled, the head gasket becomes an important part of the total structure of the engine. It supports the cylinder head along with its operating components. It must be able to withstand the dynamic and thermal forces that are transmitted from the head and block. The type of engine application will be the determining factor in cylinder head gasket design. With engines ranging in size from one cylinder gasoline fired engines up to twelve cylinder, turbocharged or supercharged high-compression diesels, the material and design of the gasket is paramount to its functional life span.

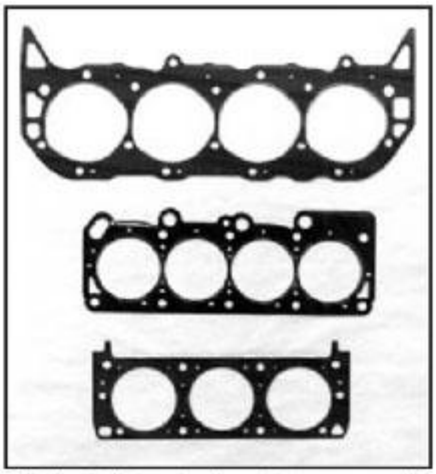

FIG. 1. Cylinder head gaskets are usually sold one to a package. On 6 and 8 cylinder engines, if one has failed it is good practice to recommend that both be replaced.

Every application requires a unique cylinder head gasket design to meet the specific performance needs of the engine. The materials and designs used are a result of testing and engineering various metals, composites and chemicals into a gasket that is intended to maintain the necessary sealing capabilities for the life of the engine. (See Fig. 1).

The most widely used materials are as follows:

- Steel and stainless steel of various grades and forms.
- Fibre based composite materials.
- Graphite in various densities.
- Chemical formulations containing polytetrafluorothylene, silicone, nitriles, neoprene, polymeric resins and others.

HOW TO PREVENT HEAD GASKET FAILURES CAUSED BY ENGINE OVERHEATING

WHEN AN ENGINE OVERHEATS

Engines are designed to operate within a “normal” temperature range of about 190 to 220 degrees F. A relatively consistent operating temperature is absolutely essential for proper emissions control, good fuel economy and performance.

If the engine overheats and exceeds its normal operating range, the elevated temperatures can cause extreme stress in the cylinder head, which may result in a head gasket failure. This is especially true with aluminium cylinder heads because aluminium expands about two to three times as much as cast iron when it gets hot. The difference in thermal expansion rates between an aluminium head and cast iron block combined with the added stress caused by overheating can cause the head to warp. This, in turn, may lead to a loss of clamping force in critical areas and allow the head gasket to leak.

What else can happen when an engine overheats? Coolant can boil out of the radiator and be lost. Pistons swell inside their cylinders and can scuff or seize. Valve stems can swell in their guides and also scuff or seize. This, in turn, may damage valve train components (broken rocker arms, bent pushrods, etc.) or possibly result in damaging contact between the valve head and piston if the valve sticks open. Valve lifters can also stick, possibly causing a valve to remain open a little too long. Bearings can seize. Cylinder heads can crack (especially if someone dumps cold water into the radiator in an attempt to “cool off” the engine). Combustion chambers can become so hot that a spark is no longer needed to ignite the fuel, leading to a condition known as “pre ignition” where the engine misfires and runs erratically. Air/fuel mixtures are upset, and gasoline becomes less able to resist detonation. Oil thins out and is less able to protect the engine’s internal components against friction and wear.

HOT SPOTS

When a localized hot spot forms, it causes the surrounding metal to swell excessively. This, in turn, can crush the head gasket causing the gasket to leak, erode and/or eventually burn through. Hot spots also create added stress in the head itself, which may cause the head to warp (go out-of-flat) and/or crack.

Aluminium cylinder heads with Siamese exhaust valves (such as the Chrysler 2.2L and Honda 1.3L and 1.5L) seem to be especially vulnerable to localized overheating in the area between adjacent exhaust valves. This is typical of head designs that restrict or limit coolant flow and circulation in critical areas. Some engine blocks with Siamese cylinders also provide minimal cooling between the cylinder bores. Even engines like small block Chevy V8s that have adjacent exhaust valves in the two centre cylinders can experience hot spots if other factors are present, such as overheating, detonation and/or pre-ignition.

As long as the coolant level is okay and the cooling system is functioning normally, there should be no problems. But if there’s a loss of coolant due to a leak, an air pocket in the cooling system, a cooling problem that causes the engine to overheat or some other type of engine problem that causes normal combustion temperatures to soar (such as loss of EGR, incorrect ignition timing, vacuum leak, lean air/fuel mixture, exhaust restriction, etc.), the result can be the formation of localized hot spots and head gasket failure.

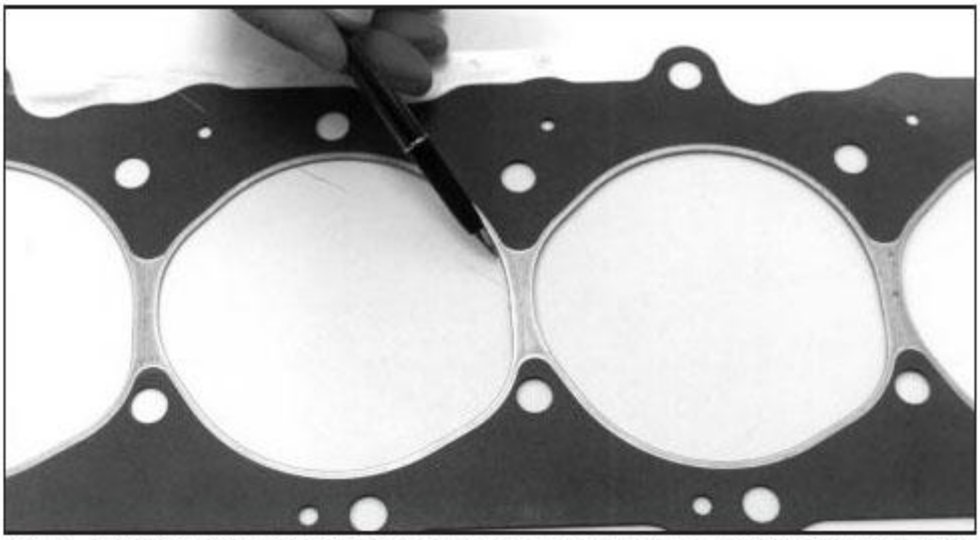

Fig. 2. The "fire ring" is the first place a head gasket usually fails. Once this area is burned through, the gasket is junk and complete failure is only a moment away...

PIN POINTING HOT SPOTS
A head gasket that has failed because of excessive crush created by a localized hot spot will be measurably thinner in the damaged area when checked with a micrometre. By comparison, a gasket that has failed due to detonation or pre-ignition will usually have cracked armour around the combustion chamber, which leads to burn through. (See Fig. 2).

The corresponding surface areas on both the head and engine deck where the gasket failed should be inspected for damage (erosion, pitting or cracks) as well as flatness. If either surface is damaged or is not flat, the head and/or engine block must be resurfaced otherwise the new head gasket may not seal properly. What's more, the same conditions that caused the original hot spot to develop may still be present, which will only make matters worse.

AIR POCKET DAMAGE
One of the most common causes of localized hot spots is air in the cooling system. Air pockets can form when the cooling system is being refilled after a coolant change or when other engine repairs are being made (valve job, replacing a water pump, thermostat, etc.). As coolant is being poured into the radiator, the thermostat often blocks the venting of air from the engine leaving air trapped in the upper portion of the block and/or heads. Some thermostats have a small bleed hole or jiggle pin to prevent this from happening, but many do not. Some engines also have special bleeder valves on the thermostat housing or elsewhere to help vent trapped air from the system.

If the trapped air isn't removed, it may cause localized hot spots to form when the engine is started. The trapped air may also prevent the thermostat from opening and cause the engine to overheat. That, in turn, may lead to additional damage such as head cracking or warping. Another symptom of air trapped in the cooling system would be little or no heat output from the heater when the engine is warm.

IF AN ENGINE HAS OVERHEATED...
If a head gasket has failed as a result of severe engine overheating, both the face of the cylinder head and block deck should be checked for warpage — and resurfaced if

needed to restore flatness prior to replacing the head gasket. If the face of the head and/or block deck are not flat and are not resurfaced when the head gasket is replaced, the new head gasket will be unevenly loaded and will likely leak or fail.

Flatness can be checked by placing a straight edge on the face of the cylinder head or block, and then using a feeler gauge to check any gaps between the straight edge and head or block. If the amount of warpage exceeds the following maximum limits, the head or block is not flat enough to hold a good seal against the head gasket and should be resurfaced:

Maximum out of flat (Total of head and block combined)

◆3 cylinder and V6 engines
◆4 cylinder and V8 engines
◆Straight 6 cylinder engines
◆Length=.003 in. / Width=.002 in.
◆Length=.004 in. / Width=.002 in.
◆Length=.006 in. / Width=.002 in.

The surface finish on the face of the head and block is also important. The surface finish should be 54 to 113 RA micro inches (60 to 125 RMS), with a recommended range of 80 to 100 RA (90 to 110 RMS).

If the surface is too rough (more than 113 RA), it may be too rough to seal properly and the head gasket will leak. If the surface is too smooth (less than 54 RA), it may not provide enough "grip" to prevent the gasket from flowing or scrubbing.

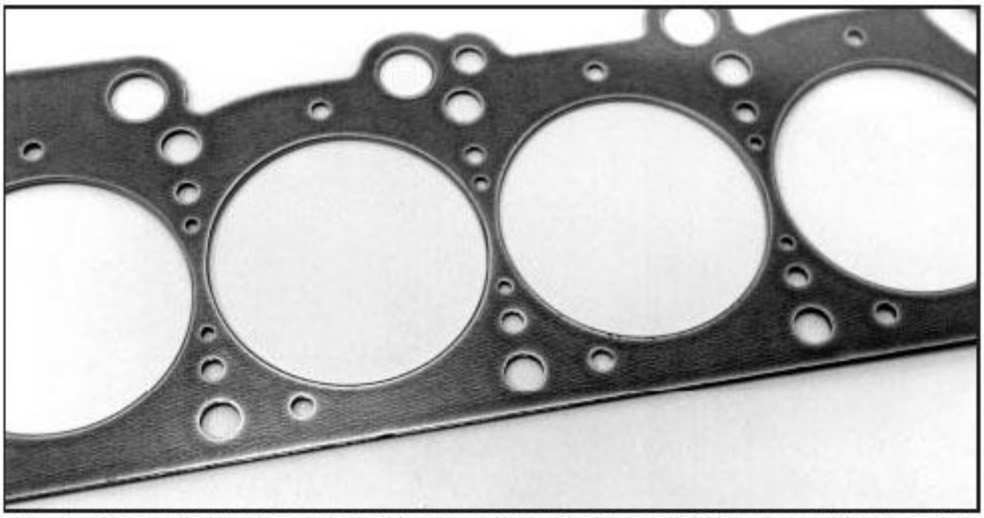

Fig. 3. This gasket is pre-coated with a pressure sensitive sealer. Use of additional sealers will interfere with the gaskets ability to provide a secure seal.

All cylinder head gaskets and gasket sets come with detailed installation instructions or at least installation tips from the manufacturer. Follow these carefully; not matter how many head gaskets you have replaced. Many modern gaskets come pre-coated with either a sealer or a hi-tack coating to assist with correct gasket placement and sealing. (See Fig 3).

If you were to apply an additional gasket sealer or gasket maker, you could actually inhibit the ability of the gasket to seal correctly. In addition, many gaskets have different torqueing or pre-torqueing specifications that must be followed to ensure a good seal. Failure to follow these instructions will most likely result in a comeback.

A frequently overlooked component when replacing cylinder head gaskets are the cylinder head bolts. The best rule to follow is if in doubt, replace them. (See fig 4). Cylinder head bolts can stretch during their working life. The constant temperature cycling causes them to expand and contract, changing their dimensions. All it takes is an extra few thousands of an inch to provide an incorrect torque reading. Unless you happen to be working on a brand new or near new engine (less than 10,000 miles) replace the head bolts. Most head bolt sets can be purchased for under $25.00. A small price to pay to insure a quality repair.

Fig. 4. A new set of cylinder head bolts is cheap insurance against a comeback. The set above is for a Quad 4 and was obtained at a local jobber for under 20 bucks.

WHAT CAUSES OVERHEATING?

Overheating can be caused by anything that decreases the cooling system’s ability to absorb, transport and dissipate heat. A low coolant level, loss of coolant (through internal or external leaks), poor heat conductivity inside the engine because of accumulated deposits in the water jackets, a defective thermostat that doesn’t open, poor airflow through the radiator, a slipping fan clutch, an inoperative electric cooling fan, a collapsed lower radiator hose, an eroded or loose water pump impeller, or even a defective radiator cap.

One of nature’s basic laws says that heat always flows from an area of higher temperature to an area of lesser temperature, never the other way around. The only way to cool hot metal, therefore, is to keep it in constant contact with a cooler liquid. And the only way to do that is to keep the coolant in constant circulation. As soon as the circulation stops, either because of a problem with the water pump, thermostat or loss of coolant, temperatures begin to rise and the engine starts to overheat.

The coolant also has to get rid of the heat it soaks up while passing through the block and head(s). So the radiator must be capable of doing its job, which requires the help of an efficient cooling fan at slow speeds. Finally, the thermostat must be doing its job to keep the engine’s average temperature within the normal range. If the thermostat fails to open, it will effectively block the flow of coolant and the engine will overheat.


Even the newest vehicle is not exempt from cylinder head gasket failure. Incorrect installation from the factory or disregard for manufacturers guidelines on operation and maintenance can produe the pictured result.

WHAT TO CHECK
If your engine overheated and the cause hasn't been determined, all of the following should be checked to make sure the engine doesn't overheat again:

THERMOSTAT

Severe overheating can often damage a good thermostat. Therefore, if the engine has overheated because of another problem, the thermostat should be tested or replaced before the engine is returned to service.

One way to check the thermostat is to start the engine and feel the upper radiator hose. The hose should not feel uncomfortably hot until the engine has warmed-up and the thermostat opens. If the hose does not get hot, it means the thermostat is not opening.

Another way to test the thermostat is to remove it and dip it into a pan of boiling water (it should open). The exact opening temperature can be checked by using a thermometer.

If the thermostat needs to be replaced, install one with the same temperature rating as the original. Most cars and light trucks since 1971 require thermostats with 192 or 195-degree ratings. Using a cooler thermostat (160 or 180 degree) can increase fuel and oil consumption, ring wear and emissions. On newer vehicles with computerized engine controls, the wrong thermostat can cause major performance and emission problems if the engine fails to reach the proper operating temperature. Cooling system leaks Loss of coolant because of a leak is probably the most common cause of overheating. Possible leak points include hoses, the radiator, heater core, water pump, thermostat housing, head gasket, freeze plugs, automatic transmission oil cooler, cylinder head(s) and block.

VISUAL INSPECTION
Make a careful visual inspection of the entire cooling system, and then pressure test the cooling system and radiator cap. A pressure test will reveal internal leaks such as seepage past the head gasket (usually due to warpage in the head or block, too rough a surface finish on the head or block, or improperly torqued head bolts) as well as cracks in the head(s) or engine block. If there are no leaks, the system should hold pressure for at least a minute or more.

PRESSURE TESTING

It's important to pressure test the radiator cap too, because a weak cap (or one with a pressure rating too low for the application) can allow coolant to escape from the radiator. Fan With mechanical fans, most overheating problems are caused by a faulty fan clutch — though a missing fan shroud can reduce the fan's cooling effectiveness by as much as 50% (depending on the fan's distance from the radiator) which may be enough to cause the engine to overheat in hot weather or when working hard.

FAN AND FAN CLUTCH

The fan clutch disengages the fan when less cooling is needed to reduce the parasitic horsepower drain on the engine as well as fan noise. Inside the clutch is a special silicone fluid that acts like a fluid coupling to turn the fan. Above a certain r.p.m., the resistance created by the fan exceeds the shear characteristics of the fluid and the fan ceases to spin any faster. "Thermal" fan clutches also have a bimetal thermostat spring on the front that increases or decreases the amount of slippage depending on the temperature of the air flowing through the radiator. This allows more or less cooling as needed.

Defective fan clutches are a common and often overlooked cause of overheating. The shear characteristics of the clutch fluid gradually deteriorate over time, with an average loss in drive efficiency of about 200 r.p.m. per year. Eventually, slippage reaches the point where effective cooling is no longer possible and overheating results. (On average, the life of a fan clutch is about the same as a water pump. If one needs to be replaced, the other usually does too.)

If the fan clutch shows signs of fluid leakage (oily streaks radiating outward from the hub of the clutch), spins freely with little or no resistance when the engine is off, or wobbles when the fan is pushed in or out, it needs to be replaced.

With an electric cooling fan, check to see that the fan cycles on when the engine gets hot and when the air conditioner is on. If the fan fails to come on, check the fan motor wiring connections, relay and temperature sensor.

Try jumping the fan directly to the battery. It runs the problem is in the wiring, relay or sensor. If it fails to run, the fan motor is bad and needs to be replaced.

WATER PUMP
Any wobble in the pump shaft or seepage would call for replacement. In some instances, a pump can cause an engine to overheat if the impeller vanes are badly eroded due to corrosion or if the impeller has come loose from the shaft. The wrong pump may also cause an engine to overheat. Some engines with serpentine drive belts require a special water pump that turns in the opposite direction of those used on the same engine with ordinary V-belts.

BELTS AND HOSES

Check belt tension and condition. A loose belt that slips may prevent the water pump from circulating coolant fast enough and/or the fan from turning fast for proper cooling.

The condition of the hoses should also be checked. Though not leaking now, internal corrosion or old age may make them vulnerable to sudden failure. Radiator and heater hoses should be replaced if leaking, cracked, brittle, mushy feeling or otherwise damaged. Make sure the clamps are tight, too.

Sometimes a lower radiator hose will collapse under vacuum at high speed and restrict the flow of coolant from the radiator into the engine. This can happen if the reinforcing spring inside the hose is missing or damaged.

RADIATOR
The most common problems radiators fall prey to are clogging (both internal and external) and leaks. Dirt, bugs and debris can block airflow through the core and reduce the radiator's ability to dissipate heat.

Internal corrosion and an accumulation of deposits can likewise inhibit coolant circulation and reduce cooling. "Back flushing" the radiator and cooling system when changing coolant is highly recommended to dislodge accumulated deposits and to flush the remaining coolant from the engine block. Back flushing is running water back through the radiator and engine in the opposite direction to which it normally flows. After the coolant has been drained from the radiator, a T-fitting is installed in the heater inlet hose.

The fitting is then connected to a pressurized water hose or power flusher. The water is turned on and the system is reverse flushed. The flushing should be continued until only clean water emerges from the radiator. Cleaning chemicals may also be used to remove accumulated deposits from the system.

When the cooling system is refilled, use a 50/50 mixture of ethylene glycol antifreeze and water. This will give freezing protection down to -34 degrees Fahrenheit, and boiling protection to 265 degrees F. in a pressurized system with a 14-psi radiator cap. A 70/30 mixture will protect against freezing down to -84 degrees F. and boil over up to 276 degrees F. Do not use more than 70% antifreeze because antifreeze carries heat less efficiently than water. Straight water should never be used in the cooling system because it offers no boil over or freezing protection and no corrosion protection (which is extremely important in today's bimetal and aluminium engines).

When refilling the cooling system, be sure you get it completely full. Air pockets in the head(s), heater core and below the thermostat can interfere with proper coolant circulation and cooling. Some cars (mostly front-wheel drive) may have one or more "bleeder valves" for venting trapped air from the cooling system. On some vehicles, it may be necessary to temporarily loosen a heater hose to get all the air out of the system.

Other factors that can contribute to overheating include retarded ignition timing, detonation/pre-ignition, a lean air/fuel mixture, exhaust restrictions (partially plugged converter or muffler), a radiator that's too small for the engine, and overworking the engine (towing, mountain driving, etc. in unusually hot weather)

Produced by the National Automotive Radiator Association (NARSA)