# A Peek Into Your Engine Through the Spark Plugs

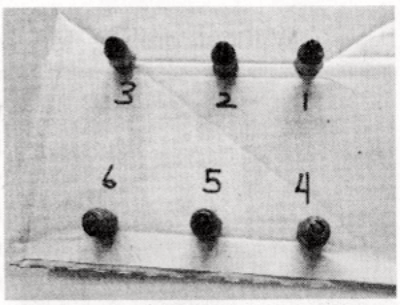
There is a very good chance that when you visit your doctor's office, he will refer to the results of the blood-draw that he had you do prior to your visit. That blood sample will tell him an awful lot about how your internal organs are working and whether the medications that you are taking are performing properly and effectively. Similarly, the spark plugs of your engine can reveal quite a bit about what's going on inside, and, like your doctor, you have to be skilled in reading the results.

Each spark plug tells its own story, and together they can give a pretty accurate indication of how the engine as a whole is performing.

Let the engine cool before you work on the plugs. It doesn't affect the results that you will find, but it's a lot more comfortable. Before you even reach for the spark plug wrench examine each cylinder. Are the wires securely attached to the spark plug? Even if the wire is not firmly attached, the plug may fire, but if the spark has to jump a gap from the wire to the plug (or within the distributor cap), it's losing power. Use a clean cotton swab, and wipe the area around the spark plug hole. Is the swab oily? Does it pick up black, sooty carbon? That's an indication that the plug is not fully seated. You are losing compression. Are the wires greasy or oil-covered? The problem is probably not a result of a bad plug but of a dirty engine compartment. The oil could be a conductor of the electricity and might be drawing off the current.

Use compressed air, and blow away any dirt or dust around each plug. This will prevent the crud from falling into the cylinder hole.

Find a small box and punch a number of holes, equal to the number of cylinders, in the box. As you remove a plug, you will immediately place it in a hole numbered to correspond with the cylinder number. You can go back later and examine each plug and know which cylinder that it was removed from. It will keep everything organized and keep the plugs from getting mixed up.




Grasp the wire at the plug terminal, and twist/pull it off the plug. Do not grasp the wire itself and pull; that can disconnect the wire from the terminal.

Remove the plugs, one by one, and place each in the correct hole in the box. Dampen the corner of a clean, lint-free rag with brake cleaner, and wipe out the threads in the head. If the rag shows black carbon or oil, make a note of the cylinder. It will require consideration as we go along.

Let's do this the correct way: take a pad of paper and a pencil, and number it to match the number of cylinders. Date the paper. Examine each plug, and write down your observations. Compare the plug to the illustrations on the following page, or go online and find colored photos of spark plug problems.

Look at the firing end of the plug. Are the threads clean or are they oily or covered with carbon? Nothing from the combustion chamber should ever reach the threads. If the threads show evidence of contamination, it probably means that the plug was leaking. Look at the center electrode, the insulator tip and the ground electrode. If the tips are clean and the ground electrode is an even yellow to light tan or gray, it is an indication that all is good with that cylinder. All that is needed is a cleaning and regaping.

***Forget the firing tip for now; look at the threads. They are covered with carbon indicating that the plug was not torqued down.***

If the firing end is oily-wet or covered with a dry, powdery carbon, it is an indication of a problem - maybe minor, possibly more serious. The dry, powdery plug indicates that

Normal Plug

Dry, Powdery Carbon

Wet, Oily Firing Tip

Oily Buildup of Sludge

the gas/air mixture is not being completely burned. The wet-oily tip indicates that oil is getting into the combustion chamber and is fouling the spark plug. A wet sludge on the tip is an indication of several problems: too much unburned gas plus oil.

Use a clean rag (moistened with brake cleaner if desired), and wash the insulator above the metal shell. Examine the ceramic for cracks, chips or other damage. If you find anything like that, throw the plug out, and replace it with a new one. While you are examining the firing end, look for broken or cracked insulators as well.

If you have found that the ceramic is broken or cracked and the firing tip is carbon-covered, you cannot judge the cylinder because chances are the spark has been leaking off through the crack, and the plug has not been firing properly. You will have to replace the damaged plug and drive the vehicle before you can evaluate the cylinder.

If there is no evident physical damage to the spark plug, and the firing tip is a black powdery carbon, it is an indication of one (or more) of several problems. The black powder indicates incomplete combustion. We now have to consider whether it is only the one cylinder (or a couple) or whether all of the plugs are so fouled.

**GAS-FOULED (Dry powdery carbon) PLUG**

If all of the plugs are gas-fouled, it is an indication of a bad spark getting to all cylinders, too rich a fuel mixture or the plugs not getting hot enough due to low speed or short-trip driving. A bad spark could be the timing, it could be bad or poorly adjusted points, it could be a weak coil, or it could be too much resistance in the electrical lines. Resistance could be caused by using resistor wires and resistor spark plugs in a car not designed for resistors. Most pre-war cars (and trucks as well) and cars and trucks through the 1950s were not designed for a resistor system. Replace the spark plug wires with metal-core spark plug wires, and replace the spark plugs with non-resistor plugs. That alone will probably be enough to increase the spark and will often solve the incomplete combustion problem. Retarded timing could throw the ignition cycle off. About 10° of retarded spark could lower the plug temperature about 158°F - 212°F [70°C - 100°C]. Conversely, advancing the spark could increase the spark plug tip temperature the same amount.

If the car is used at very low speeds or just for very short trips, the plugs are not getting hot enough to burn off the gas in the combustion chamber. Carbon fouling occurs when the spark plug firing end does not reach the self-cleaning temperature of approximately 842°F [450°C]. Carbon deposits will begin to burn off from the insulator nose when the self-cleaning temperature is reached. Or maybe there is too much gas in the gas/air mixture. The ideal gas/air mixture is 14 parts of air to 1 part gas, but chances are you will never hit that ratio. The carburetor will have to be adjusted to give the best possible mixture, but that is a topic for another time and another place. In some cases, the insulator nose can be cleaned by operating the engine at higher speeds in order to reach the self-cleaning temperature.

If everything checks out, timing is properly set, wires and ignition system are in good order, the carburetor is properly adjusted and still the plugs gas-foul, a hotter plug might be the answer. We will discuss hotter and colder plugs later in this article, but figure that for each temperature grade, up or down, the tip temperature of the plug is altered by about 158°F - 212°F [70°C - 100°C], or about the same as 10 degrees of change in timing.

If only one or two cylinders are affected by the black powdery ends, look for a bad wire to that cylinder (a shorted wire, a leaking wire, a poorly seated wire, etc.), and check the spark plug gap. Too small or too great a gap will reduce the effective spark in the combustion chamber. Make sure that the plug in that cylinder is the same temperature range as in the other cylinders. A compression test can tell you whether there is a bad valve; that too, could affect what is going on inside that cylinder.

**OIL-FOULED (Wet, oily) PLUG**

Oil-fouled plugs are more likely to affect only selected cylinders, unless the entire engine is so loose and sloppy that all of the rings, cylinder walls, valves, etc. are worn. If that is the case, an engine rebuild is called for. Fiddling with the spark plugs is not going to make much difference in performance.

One or two cylinders which have plugs that are oil-fouled could indicate leaky rings in that cylinder. Oil is being forced up past the rings and into the combustion chamber. Some oil - just a trace - is normal in the combustion chamber, and engine oils are designed to burn off. That little oil is necessary to lubricate the upper rings and cylinder walls. Leaky valves can allow oil to get into the combustion chamber as well. A compression test can confirm that the suspected cylinder(s) has mechanical problems. When too much oil gets into the combustion chamber, the spark plugs are not designed or intended to burn it all. The oil covers everything in the chamber, including the spark plug. The result will be a physically undamaged spark plug, with the firing tip covered in oil. It is possible that a hotter spark plug will burn the oil in the cylinder, but the problem will not be solved, just masked.

**GAS & OIL-FOULED (Wet, sludge coated) PLUG**

With both of the problems noted above, the excess gas and excess oil occur, and the spark plug will be fouled with a wet, gooey paste or sediment. Again, in a generally good engine, this problem will occur in only one or two cylinders, if at all. The wet oil mixes with the unburned gas/carbon and forms a paste. The heat in the chamber will bake this paste until it gets hard and cruddy. Little by little the sludge builds up and will fill the gap between the center electrode and the ground electrode and inside the plug between the insulator and the metal shell. Eventually the plug will not fire at all, and the sludge will continue to build up exacerbating the problem. The plug can be cleaned or replaced, but the problem is not solved, and the fouling will continue. A hotter spark plug might help by burning off some of the oil and unburned gas, but the cause has to be found and remedied.

Those are the three most common problems which will be indicated by the condition of the spark plugs. There are several other problems which can be identified by the condition of the plugs.

**OVERHEATED SPARK PLUGS**

If the nose of the ceramic insulator is blistered, white or shows signs of burning, it is an indication that there may be inadequate cooling. If all cylinders show this condition, coolant flow may be the problem. A stuck, or partially stuck thermostat, a worn water pump impellor providing inadequate water flow or even a low coolant level could cause this problem. Hard driving or unusually heavy demands on the engine could also cause an overheating problem. If it occurs only in one or two cylinders, there may be a partial blockage in the cooling system. A cooler plug might reduce the problem. The most serious result of selecting a heat range that is too hot is overheating. Overheating will cause the electrodes to wear quickly and can lead to pre-ignition. Pre-ignition occurs when the air-fuel mixture is ignited by a hot object/area in the combustion chamber before the timed spark occurs. If the spark plug tip exceeds 800°C, pre-ignition can occur. The overheated insulator ceramic will ignite the gasoline charge before the optimal moment. Pre-ignition will dramatically raise the cylinder temperature and pressure and can cause serious and expensive engine damage.

***The blistered insulator and white ground electrode indicate an overheated spark plug.***

## WORN SPARK PLUGS

Like everything else, spark plugs wear out. Actually, considering the amount of work that they do, they last a l-o-n-g time. Each time the cylinder fires, a hot, high voltage spark jumps the gap. The optimal firing end temperature is approximately between 932°F (500°C) and 1472°F (800°C). Slowly, but surely, the ground electrode begins to erode. It might initially show up as an increased gap, and then a visible erosion of the working end of the ground electrode. The cure? A new spark plug. If everything is working properly with the engine, all of the spark plugs should experience about an even amount of wear and will all require changing at about the same time.

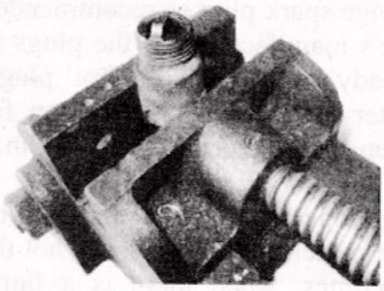
*The severly worn ground electrode is evidence of a long, hard life. Replace the plug.*

## CLEANING SPARK PLUGS

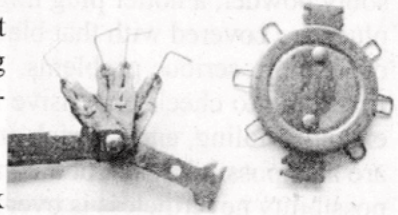
Spark plugs should be removed, cleaned and regaped. Clean the exterior of the plug with a rag dipped in brake cleaner. Remove all of the oil and dirt so that you can examine the plug for faults. As discussed earlier, any carbon or oil on the plug's threads indicate that the plug was leaking and allowing combustion to escape from the chamber. The most common and simplest reason for this was lack of torquing the plug properly. The plug hole represents a hole in the head. For the same reason that it is imperative to torque your head bolts, you must also seal those holes by torquing the plugs. Make sure the crush washers - spark plug gaskets - are in good condition. It is recommended that the crush washers be replaced whenever plugs are reinstalled, but we haven't found a source for replacement crush washers. Even the spark plug manufacturers admit that although recommended, it is not practical (due to the lack of replacement parts) to change the washers. Re-use them, they now say. Over-tightening a spark plug is just as bad as under-tightening it. The results vary, but an over-tightened plug can 'stretch' and distort the internal components, altering the firing and heat dissipation characteristics of the plug.

We strongly recommend against media-blasting spark plugs to clean them. There are two primary reasons for this recommendation. First, a very aggressive media - sand or aluminum oxide, for example - can abrade the glaze of the insulators making them susceptible to oil or gasoline fouling and causing possible shorts. The second reason is that often the blasting media will lodge between the metal outer shell and the insulator. When the plug heats up and expands, the media can drop out and get into the combustion chamber. Never a good thing.

We have found that the best tool for cleaning a spark plug is a steel finishing nail, hammered thin to fit between the shell and the insulator. Hold it in the end of a ViseGrip® and use it as a knife blade to remove any crud inside the plug. Follow with a brake cleaner wash and compressed air to remove any loose particles and any remaining liquid. Set the spark plug in a vise, gripping it between the vise jaws at the hex portion of the metal shell. Use a wire brush to clean the threads and both the center electrode and the ground electrode.



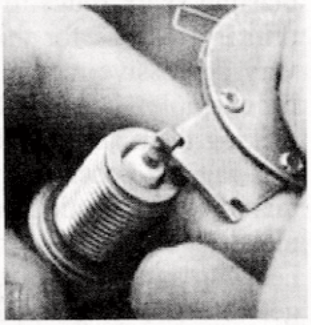
Next, using a wire (never a flat blade) spark plug gauge, measure the gap between the center electrode and the ground electrode. Your owner's manual, service manual or Motor's (or Chilton's) manual will give the correct spark plug gap. The wire gauge should fit between the two electrodes. It should just touch both surfaces at once, without any sloppiness and without having to force it through. Normally a difference of about 0.003" is not going to make any appreciable difference.



*Two types of spark plug gaping tools.*

The spark plug gauge generally has a built-in tool for opening the gap. Bend the ground electrode just a fraction to increase the gap. Tap the ground elec-

trode GENTLY against a solid surface to reduce the gap. Never increase the gap by filing the center electrode.



If the ground electrode is so badly abraded that it is no longer a flat surface, just replace the plug with a new one.

Occasionally the engine will run well once the plugs are cleaned and gaped, but very soon it begins to run roughly again. Pull the plugs again, and examine them. Identify problems within each cylinder. If the plugs deteriorate that quickly, it's time for some engine work. If you are sure that you set the gap properly, but after a short time running the gap is too small, well, read What Went Wrong on page 35 of this issue.

## TEMPERATURE RANGE OF SPARK PLUGS

We are going to assume that the starting point for determining the correct heat range is by the use of a mid-range spark plug as recommended by the car or truck's manufacturer. If the plugs in the engine are already 'cold' plugs or 'hot' plugs, you would do better to determine the reason for such a need and then fix the mechanical problem.

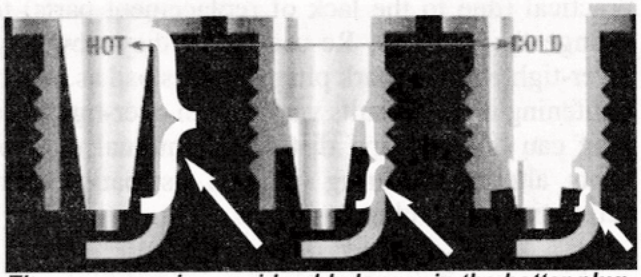
Altering the operation of the engine by going to a hotter or cooler plug is generally not the best answer. Sometimes, when there is a fairly minor problem with one or two cylinders, a hotter or cooler plug will alleviate the problem, or at least will mask the symptoms.

If the plugs are all covered with that black, sooty powder, a hotter plug might help, but if all the plugs are covered with that black soot, there may be other more serious problems. Timing would be the first thing to check. Extensive low speed operation, extended idling, and too rich an idle air/gas mixture are also possibilities. Not a common problem, but a possibility nevertheless is over-sized carburetor jets. How about engine operating temperature? If the engine is running considerably cooler than the manufacturer's recommendation, the block might not be getting hot enough for proper combustion. Does the car or truck have a thermostat or has it been removed? Replace the thermostat with a new one of the recommended temperature. That might be enough to raise the block temperature to a level where combustion is more complete. Are you using resistor wires and/or resistor spark plugs? Up until about 1960 cars were not designed to use resistor plugs or wires. And six volt cars should never use them. Resistor plugs and wires reduce the amperage to the spark plug and cause a 'cooler' spark. (See *Skinned Knuckles*, December 2012 - Resistor Spark Plugs and Spark Plug Wires.) If the timing is properly set, if the spark to all cylinders is good, and if the engine is operating at the proper (coolant) temperature, then you may want to try a plug one level hotter.

The same holds true of oil-fouled spark plugs. But in the case of oil-fouling we know that the problem is a mechanical one. Excessive oil is getting past the piston rings and into the combustion chamber, or possibly there may be leaking valves. Either way, hotter spark plugs are merely a Band-Aid; a mechanical repair is called for.

The term Heat Range refers to the speed with which a plug can transfer heat from the combustion chamber to the engine head. It has been found the optimum combustion chamber temperature for gasoline engines is between 500°C - 800°C [932° F - 1472° F]. Within that range it is cool enough to avoid pre-ignition and plug tip overheating (which can cause engine damage), while still hot enough to burn off combustion deposits that cause fouling.

The spark plug design determines its ability to remove heat from the combustion chamber. The primary method used to do this is by altering the internal length of the core nose. The alloy compositions in the electrodes can also be changed altering the rate of heat dissipation. This means you may not be able to visually tell a difference between heat




*The core nose is considerably longer in the hotter plug.*

ranges. If a spark plug is referred to as a 'cold plug', it is one that transfers heat rapidly from the firing tip into the engine head, keeping the firing tip cooler. A 'hot plug' retains more heat and has a much slower rate of heat transfer, which keeps the firing tip hotter. When making spark plug heat range changes, it is better to err on the side of too cold a plug. Running too cold a plug can only cause it to foul out, whereas running too hot a plug can cause severe engine damage.

The heat range numbering system used by spark plug manufacturers is neither consistant nor interchangeable. For example, a 10 heat range in Champion is not the same as a 10 heat range in NGK nor the same as in an Autolite plug.

Some manufacturers' numbering systems are opposite each other - for Champion, Autolite and Bosch, the higher the number, the hotter the plug. For NGK, Denso and Pulstar, the higher the number, the colder the plug.

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Basically, an engine requires two things to operate: fuel (mixed with oxygen) and a spark. Both components meet at one point: the firing tip of the spark plug. That simple little device can have a very meaningful impact on how well your engine runs. Don't ever take it for granted.

## HEAT RANGE CROSS REFERENCE CHART

| | NGK | PULSTAR | DENSO | CHAMPION | BOSCH |
|---|---|---|---|---|---|
| HOTTER | 2 | | 9 | 18, 19 | 10 |
| | 4 | 1 | 14 | 14, 16 | 9 |
| | 5 | 1 | 16 | 11, 12 | 8 |
| | 6 | 1 | 20 | 9, 10 | 6, 7 |
| | 7 | 1 | 22 | 7, 8 | 5 |
| | 8 | 2 | 24 | 6, 61, 63 | 4 |
| | 9 | 2 | 27 | 4, 59 | 3 |
| | 9.5 | | 29 | 57 | |
| | 10 | | 31 | 55 | 2 |
| | 10.5 | | 32 | 53 | |
| | 11 | | 34 | | |
| | 11.5 | | 35 | | |
| COLDER | 12 | | 37 | | |

***Note that the #10 range range for a Bosch or Denso plug is quite 'hot', while a #10 for an NGK is on the 'cool' side. A #10 Champion is a mid-range plug.***

**A CORRECTION** - in the July issue of *SK*, we gave the incorrect telephone number for the Sparkplug Collectors of America (SPCOA). The correct telephone number should be 860-651-9015, and their website is spcoa.net.