How to Read Spark Plugs

SPARK PLUG TECH
By: WBH

Cold? Hot? Fouled? Confused?

No matter what kind of bike, truck, buggy, ATV, watercraft or snowmobile you operate, chances are just about 100% that you have one or more spark plugs firing the fuel and creating the power required for forward motion.

If the plug(s) quits working, your engine stops. Or maybe things start sputtering. Could be the plug is beginning to foul.

So you yank it out and take a look at it. But what are you really looking for? What kind clues can a visual check tell you about what's going on inside that engine?

Let's walk through it.

A spark plug is inserted into the engine, the engine is operated for a while, and then the spark plug is removed for examination. It shows how hot the plug has been while the engine was running and also tells you about a variety of other symptoms. This procedure is called "reading" the plugs, and it's probably the single most important guide to tuning an engine.

Plugs do a simple task: they make sparks to ignite the fuel-air mixture in the combustion chamber. They have to cope with heat, pressure, vibration, noxious fumes, liquids and chemicals. When you remove the plug, it can tell you how bad (or good) things were in the combustion chamber, just by its appearance.

WHAT'S IN A PLUG?

The bottom part of a plug is metal, threaded to screw into a hole in the cylinder head, and is often called the **shell.** The diameter of the threaded section, or the diameter of the hole it fits, is specified in millimeters (mm). Common plug diameters are 10mm, 12mm and 14mm. There are many stories around about boneheads trying to stuff a 14 mm plug into a 12 mm hole.

The length of the threaded portion of the shell is called **reach,** and it's usually measured in inches. Common reach lengths are 1/2-inch and 3/4-inch, although there are many other reaches. You **can** install a plug with incorrect reach, but you can also really screw up an engine by doing so. So always put a plug in with the correct reach. Period.

Inside the metal shell is an **insulator,** usually white, which is tapered at the working end of the plug. The tapered part of the insulator is called the **nose.**

Right in the center of the insulator, is an electrical conductor, which connects the electrical terminal at the top of the plug to a round wire that sticks out of the insulator nose at the firing end of the plug.

This round wire is called the **center electrode.** The main purpose of the insulator is to prevent the electrical spark current from going anywhere except down to the center electrode.

Welded to the bottom of the shell is a small piece of metal called the **side electrode,** which sticks over toward the center electrode and forms an air gap between the two electrodes. The ignition current is supposed to jump across the air gap between electrodes and make a spark. The name of the air gap is **spark gap.**

HOT PLUGS VS COLD PLUGS?

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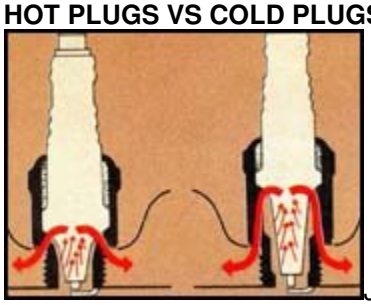

Just about everyone has heard that plugs have heat ratings, and are called "hot" or "cold" types. Some people think that means the plug either makes the engine run hot or cold, which is completely wrong.

The amount of heat a plug brings into an engine due to the electrical sparks is so small it's insignificant. The amount of heat a plug removes from an engine is also small.
Those ratings - "hot" and "cold" - mean simply this: a plug becomes very hot in an engine, so we say it's a hot-running plug — or just hot. Another plug doesn't reach such a high temperature, so we say it's a cold-running plug — or just cold.
The firing end of a hot plug reaches a higher temperature than a cold plug, in the same engine, under identical operating conditions. The metal shell of each plug will operate at very nearly the same temperature as the metal of the head itself, because the plugs are screwed into the head and there is a good path for heat flow between shell and head.
Heat gathered by the insulator nose tends to accumulate there, because the insulator material is not a very good conductor of heat. The path for heat flow is away from the insulator nose. Heat has to flow upwards along the nose until it reaches the place where the insulator is in mechanical contact with the shell.
From there, heat can flow into the shell, then to the metal of the engine.
If the path for heat flow is short and relatively easy, more heat will escape and the nose of the plug will tend to run cooler.
If the path for the heat flow is long and difficult, more heat will remain at the tip of the insulator and the plug will run hotter. **The main difference between hot-running and cold-running plugs is the length of the insulator nose.**
Those two electrodes also get hot. The center electrode gets hotter than the side electrode, because the center one loses heat to an insulator, whereas the side electrode loses heat directly to the metal shell of the plug.
Spark plugs are manufactured with different heat ratings, from very cold to very hot, so a suitable plug can be found for your engine, depending on what you need, based on your riding or driving conditions. Plugs with the same diameter and reach will have different lengths of the insulator nose section and different type numbers to indicate which runs hot and which runs colder.
These plugs are mechanically interchangeable, but will run at different operating temperatures in the same engine. Part of the tuning problem is to find a plug that survives in an engine.

WHAT HAPPENS WHEN THE PLUG IS TOO HOT?

It's easy to overheat a plug in an engine. A mixture that's too lean will do it, because the gasoline drawn into the firing chamber has a cooling effect. If there is not enough gasoline, there is not enough cooling.
Working the engine hard at slow speeds — such as running uphill in a deep sand wash — will do it, because the engine is generating a lot of heat but airflow for cooling is reduced by the slow speed of travel.
Using the wrong spark plug will also do it also. If you are not using the plug specified in your owner's - manual, you might have problems.
When a spark plug gets too hot, the insulator may boil and bubble on examination, it will be plain that it has been too hot. Also, the metal electrodes may melt away and disappear. If any of these bad things happen, that's good.
The worst result of too-hot plugs that fails-to destroy its self is when it destroys the engine instead; this is called pre-ignition. If the tip of the plug becomes hot enough to ignite the fresh mixture being drawn into the cylinder, then the incoming mixture will start to burn without waiting for the spark to happen.
Ignition due to any hot spot in the cylinder begins before the proper time for ignition, so it is called pre-ignition. Anything in the combustion chamber that gets hot enough can cause pre-ignition, but typically the end of the spark plug is the cause. When the mixture is firing sooner than it should, that's like advancing the spark too much, and no matter what causes it, early ignition makes engines heat up, causing pre-ignition. Eventually, something melts, which comes under the heading of a bad thing.

WHAT HAPPENS WHEN THE PLUG IS TOO COLD?

You can install a plug that is too cold running for the engine. Or you can have an engine that's running way too cool, such as riding ten miles downhill on a frosty morning in the mountains.
Whatever the cause, if the nose of the plug is not hot enough, it will gradually accumulate deposits, known as fouling. During normal engine operation, residue from the combustion process

hits the insulator nose. This may include carbon, unburned fuel and oil, and chemical additives present in both fuel and oil.
If the insulator nose and electrodes are hot enough, the heat of the plug will continuously burn off the combustion deposits. The ideal situation is to have the deposits burned off as fast as they accumulate, so the insulator nose stays fairly clean and free of deposits.
If the deposits accumulate on the plug because it is not reaching a high enough temperature to burn them off, the gradual accumulation will eventually short out, or foul, the plug. The fouling is electrically conductive and forms a path along the insulator, which connects the center electrode to the metal shell of the plug.
The spark current will flow along the fouling path and **will not jump across the spark gap.** The engine stops running, but all you have lost is a spark plug. Fouling due to a too-cold plug is much better than pre-ignition due to a too-hot plug.

PICKING THE RIGHT PLUG

If the tip of the plug gets hotter than about 1500 degrees Fahrenheit, electrode burning and pre-ignition will result. Below 600 or 700 degrees, fouling will occur. A normal spark plug gets hot enough just above idle to burn away fouling deposits, and when running at full throttle, the plug is still not hot enough to cause problems. The reason a plug gets hotter at full throttle is simply because more fuel is burning in there.
A plug that is too hot will run hotter than normal over the entire range, and at full throttle, will be into the pre-ignition zone. Similarly, a plug that is too cold tends to foul more easily when the engine isn't working hard.
Reading the plug from your engine gives you some clues about whether it is too hot or too cold.

Jetting Principles

READING THOSE SPARK PLUGS!

To read a plug, you must first prepare it properly for reading, so it will give you the real story. That means you can't just go over to an engine and yank the plug. You have to know how the machine was operated in the period just before you look at the plug, and the machine must be run in some steady condition for a while before taking the reading.
You can't just make a fast pass down a dirt road, then pull into the pits and let the engine idle for a while before shutting it off. This kind of a reading from a spark plug will be totally worthless. A plug can tell you only about a recent, sustained, single operating condition.
First off, the engine should be in reasonably good tune and mechanical condition, and the plug should also be in reasonable condition and the plug proper for the engine.
Then you can begin by making a flat-out, **full- throttle** run up a slight incline for about a mile. If you try that with a worn engine, or in bad tuning condition, it may not last the flat-out mile.

But if it does, at the end of your run, pull in the clutch and kill the ignition. Coast to a stop and don't run the engine anymore until you yank the plug. That is called cutting clean. What the plug will now tell you is how lean or rich your engine performed at Wide Open Throttle.
The best way to read the plug after removing it from the engine is to use an **illuminated magnifier**. With that, you can see smaller details allowing you to make better judgments than the average person just eyeballing it. So use a magnifying glass.

The main indicator is the general appearance of the insulators. If it looks like it has been too hot — it has. If deposits a visible, chances are it's too cold.
Now you're ready for a second plug reading, and this one should be taken at mid-throttle. The full-throttle test tells you about the condition in the combustion chamber while it was on the main jet, because that's what controls mixture strength at full throttle.
The half-throttle reading tells you about the needle and needle jet (or mid-range jets) performance, because they control that part of the engine performance. Most average tuners won't even perform this part of plug reading and tuning, and will be happy with full throttle runs and readings.

READING SPARK PLUGS AND MAKING CHANGES

When you pull the spark plug, inspect the electrode/insulator for a nice slightly mi9lky tan or gray color paying attention to the electrode shape and condition. Once your spark plug achieves this color consistency your finished and ready ride. Follow this reading for Wide Open Throttle and Mid Range Throttle for jetting your carburetor.
To Rich of a condition: The plug electrode/insulator will look blackened and possibly wet you must lower your main jet until achieving a milky tan brown residue on the electrode/insulator. Dropping the size of the main jet depends on your ability to read the degree of richness indicated on the spark plug. Normally one full size (i.e. 240 to 230) is appropriate. Repeat steps until you achieve a slightly milky tan or gray color on the electrode/insulator.
To Lean of a condition: The plug electrode/insulator will look burned white, clear or no color you must increase your main jet until achieving a milky tan brown residue on the electrode/insulator. Continue to raise your main jet until you achieve a slightly milky tan or gray color on the electrode/insulator.
Plug Type Changes:
After trying to achieve the appropriate color residue on the spark plug and you continue to find black fouling to suggest a too-cold plug or running rich, or the plug is burned white and clean looking, you better do something to correct the situation. You can certainly change plugs, provided you have the recommended normal plug in the engine. Most manufacturers select the normal plug for normal riding conditions. You can go colder or hotter, or you may even have to make carburetion or timing changes. We can't get into all that here, but you get the drift.
If your wife or girlfriend just putts around all day, they aren't making enough heat to keep the plug clean. This is the perfect condition for you to use the next hotter heat rating to see if it helps. You find the type number of the next hotter plug by checking a spark plug selection chart, or by asking at the parts counter.
If the plug looks burned and you have been riding all day flat-out, tucked-in and too fast, you should more than likely to go one step colder in plug heat rating. If you don't have the correct plug installed, or its next-door neighbor on the heat rating chart, your best bet is to try the correct plug first and then go from there.
If you can't solve the problem by a one-step heat rating change of spark plugs, you may need to re-jet the carb, or do mechanical work on the engine.

PLUG VARIATIONS

You'll find all kinds of plugs, plug materials, designs and variations. And you'll also find wild claims and promises to match. Most plugs have what is called the conventional gap style, and it doesn't have any letter identification. It is the common plug used in cars and motorcycles. There are zillions of these around, giving good service.
In the I-gap, the side electrode is cut back partially so it only covers about half of the center electrode. This design is less subject to fouling due to something getting between the electrodes. This is often considered to be a special design for two-stroke engines.
A Y-gap, or extended-nose plug, has a wider heat range than a conventional plug, which means it operates well over a greater range of temperatures. The insulator nose and gap will stick out pretty far into the combustion chamber when this plug is installed. Because of the extended nose, the tip of the plug is farther out into the combustion area and receives more heat at low engine speeds. This tends to prevent fouling at low operating temperatures.
At open throttle where you might expect this plug to heat up more than a conventional design, the extended nose gets a good blast of cool, fresh mixture during each intake and therefore it gets

less hot than a conventional plug. This _ extends the operating range to higher engine temperatures. This is normally considered to be a four-stroke plug.
An extended-nose plug cannot be casually substituted for a conventional plug type, because the piston, or a valve may hit the extended nose. If it is specified as original equipment, you know there's enough clearance for the long nose.
A G-gap plug is also called a fine-wire plug, because the electrodes are made of smaller wire. A spark will jump at lower voltage across a gap formed of sharp edges or smaller electrodes. Both the I-gap and G-gap benefit from this. The J-gap "shows" the center electrode the sharp edge of the side electrode and that gives a lower firing voltage requirement.
The Gold Palladium fine-wire design has the same advantage, because the electrodes are smaller. When the electrodes are made smaller, precious metals such as gold and platinum are better able to withstand heat and erosion. G-gap plugs cost more, but when properly used, they are worth it.
A surface-gap plug uses a completely different construction, with no side electrode at all. An insulator fills the space between center electrode and shell. The spark jumps from center electrode directly to the shell, taking any path it chooses. These plugs are for motorcycles with super-high-voltage electronic ignition and should only be used where the manufacturer originally specified them.