# When Spark Plugs Cry Foul

BY HOWARD ECKSTEIN

The lowly spark plug leads a long and difficult life. Generally it does its work without complaint and we motorists take it for granted. That is until one or more of them start to balk. What's up with those things, anyway? Why are they misfiring?

All a spark plug needs to do is ignite a compressed mixture of gasoline and air so that the charge burns completely. The rest is up to the members of the ignition system, carburetor performance and the integrity of the engine components.

**Mind the Gap**

To get a spark to jump a gap is not that hard. All that is needed is for electrons to get from one electrode to the other. We accomplish this by forcing them across an open gap with high voltage. The amount of voltage required depends upon the dielectric of the medium between the electrodes.

A dielectric is not quite an insulator; but is a very poor conductor of electricity such as a gas. In the case of our spark plugs, it's the high resistance of the air/fuel mixture in the cylinders. The distance of the gap is also a factor in how much voltage is needed. A smaller plug gap requires less voltage to make the jump than a larger one. Under normal operating conditions our plugs can require 20,000 volts or more.

A spark plug operates on the same principles as lightning. In both cases, Opposite charges are built up on the electrodes which get strong enough to ionize the air between them; thus creating a path for the spark which then discharges through the gap. This little spark is very hot and is more than adequate to ignite the compressed fuel in the cylinder.

If we look at the construction of a spark plug, we can see that great effort is made to insulate the two electrodes from each other. We want the full voltage of the spark to be directed through the gap. See **Fig 1**.

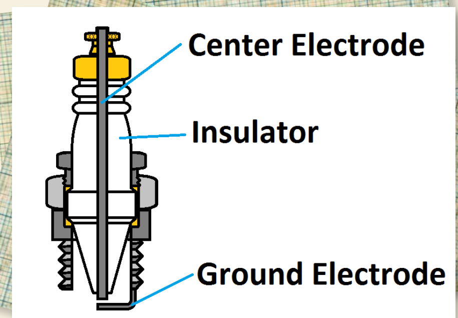



**Fig. 1**

Most Model A manuals published today advocate a plug gap of .035". In Victor Page's book published in 1931, he said the gap should be about 1/32" (.031") or the thickness of a worn dime. In September 1928, a service bulletin announced the discontinuation of the double venturi carburetor for a single venturi design with a change in all the jet orifice sizes. In connection with this supersession, the bulletin said to adjust plug gaps to .027". In April 1930, another bulletin specified the gap to be between .032" and .035"; so .035" it is.

When accelerating or climbing a hill, the driver opens the throttle and more of the air/fuel mixture is suddenly packed in the cylinders before engine speed can catch up. Under this condition, greater voltage is needed to ionize the extra air in the gap sufficiently to create an arc between the electrodes of the spark plug. If there is not a sound electrical delivery system to the plug, a misfire occurs.

**Ignition Health**

The primary ignition runs through the 6 volt side of the coil and includes the ignition switch, points and condenser. Wire terminals need to be clean and tight with the distributer and engine block well grounded.

Ignition points need to be clean and properly aligned to reduce resistance that can rob high voltage output from the coil. In addition, the point arm spring pressure needs to be strong to prevent "point float" at high speeds. In **Fig 2** you can see how the points are

Fig. 2

mounted in the distributor. Over time the spring gets a new memory as it is held in its installed position. Notice that the spring of the old points arm in the foreground is curled half way around. This spring has lost much of its original tension, thus its strength is compromised. The one in the back is new with its straighter thus stronger spring which is able to resist point float.

Starting with the ignition coil's big terminal and ending with the tips of the center electrodes of the spark plugs, the secondary ignition circuit conducts high voltage for the spark at the gap. Any break down along the way can cause what is called a "voltage leak" which robs power from where it is needed. Not all the high voltage escapes through these leak areas, but enough can to be diverted from the plug gaps to cause misfiring. Here are some of the secondary ignition failures this writer has seen:

1. *Carbon tracking in the big terminal of the coil.* This is usually a crack in the tower which over time has been leaking some of the high voltage to the case. After a while, the repeated weak electric arc causes carbon from the air to deposit in the crack and form a lower resistance path for some of the voltage. This is easily diagnosed at night while the engine is being accelerated. Little arcs can be seen where the carbon track is located. A water leak from the radiator or water pump can be picked up by the fan and sprayed onto the coil exacerbating this problem.
2. *Moisture under the distributor cap and in the body.* These parts are not sealed very well due to the advance arm knockout in the body. Sometimes condensation can accumulate here. Car washes are a great source for water droplets in the distributor, thus shorting out the spark.
3. *Defects in the distributor body.* The internal conductors that are cast into the body can arc across internally. This leads to internal carbon tracking which will eventually burn through the case.
4. *The spark control rod can vibrate around to become too close to the distributor-to-plug connector for cylinder #3.* Simply rotate the rod until it is away from the brass strip.
5. *The "stinger" wire from the coil to the cap may have a bad spot in the insulation.* If too long a wire is used and allowed to drape on the hot engine or to chafe against the #3 or #4 plug connectors or other metal parts, the insulation becomes compromised and carbon tracking begins. Usually the wound has a white and dried appearance. An arc here can also be seen after dark.
6. *The rotor can be damaged by a loose-fitting body.* With a snug fitting body on the distributor, there should be about a .025" gap between the end of the rotor and the terminals in the body. If the body fits loosely, it can slip off center. A rotor that has smacked the body terminals can have a crack which soon becomes carbon tracked. It generally shorts to the distributor shaft through the center of the rotor.

7. *A worn carbon button in the cap does not transfer voltage well to the rotor.* In addition, excessive wear of the rotor brush indicates time to replace it. See **Fig 3.** Here the rotor brush (the stainless steel part) has sustained continual arcing which has eaten part of it away. The spark has grounded out through the Bakelite to the distributor shaft. Notice the large white burn mark on the top of the rotor.

**Fig. 3**

8. *Dirty distributor parts cause trouble as the dirt can create a pathway to ground.* This won't cause a direct short, but enough voltage will leak off to cause a misfire under load. Clean the cap, body and rotor with carburetor cleaner or replace them if they are too hard to get clean.

**Air/Fuel Ratio is Important**

Way back in the days of ancient Greece, there was a philosophical school of thought called the Stoics. Part of their belief was that everything should be in balance with as little extravagance as possible. Today, we talk of air/fuel mixtures as stoichiometric when they are in ratios that produce the best performance.

An example of this is familiar to anyone who has started a fire. If you set a lit match against a log, there's just too much fuel and not enough air to get the log to ignite. Tinder, on the other hand, is made up of smaller pieces of fuel where air is present between them. By lighting the tinder, the fire will grow to eventually heat up and involve the log. In this example there are three elements needed to ignite the log. First, air/fuel ratio must be correct. Second, sufficient heat has to be present. And third, getting the log to burn takes time.

For most engines, a stoichiometric air/fuel ratio of about 14.7 to 1 produces the best performance. This is 14.7 parts of air to 1 part of gasoline. It's possible to burn different ratios, but the results will be categorized as too rich or too lean; meaning there is either too much fuel in the mix for rich and excessive air when running lean.

Even with a correct air/fuel ratio, plugs can become gas fouled if the fuel is not vaporized effectively. The carburetor atomizes the gas into small droplets and the heat of the manifold causes the droplets to vaporize. Like the tinder in the log example, the more the fuel is vaporized, the better it will burn.

One rare condition that can gas foul the plugs is carburetor icing. Due to the small opening of the throttle at idle, the air that passes through that area is suddenly depressurized above the throttle plate. This drop in pressure dramatically lowers the temperature of the air passing through. Water ice can condense inside and outside the carburetor around the throttle area when ambient temperatures are below freezing. See **Fig 4.** This photo was taken at a time when the engine had been sitting at idle for a while in humid sub-freezing weather. To ameliorate this icing problem, the intake and exhaust manifolds are bolted together so that heat is transferred to the air passing through the carburetor. Under these conditions, the fuel is poorly vaporized and although the air/fuel ratio is correct, some of the gasoline is not burned completely, leading to gas fouling of the plugs.

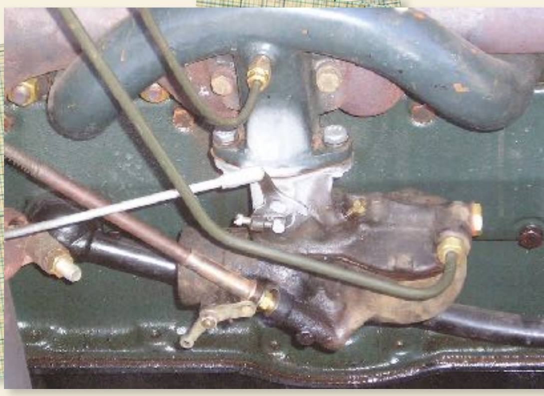


Fig. 4

## Cleanliness is Paramount

Any condition with the plug that creates a lower resistance than that found in the gap will provide an alternate path for the electrical discharge. The electricity finds its way to ground but not through the gap; so no spark is created, thus resulting in a misfire. If this condition persists, carbon, gasoline and oil eventually build up on the insulator and electrodes until the plug is no longer able to sustain a spark even under good conditions. **Fig 5** illustrates deposits on the insulator and electrodes creating a short circuit which is a cause for a misfiring plug.

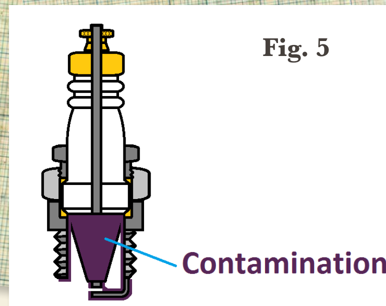



Fig. 5

When a plug gets a little fouled, it will begin to misfire occasionally. Depending on the conditions, the plug can clean itself. Spark plugs are designed to be self-cleaning where an engine is in good operating condition.

Did we read that right: self-cleaning? If plugs couldn't clean themselves, you wouldn't be able to make it much past the end of your driveway after having just started the engine with the choke. To demonstrate how the heat of combustion can clean the plugs, **Fig 6** shows a badly carbon fouled plug being cleaned with the flame of a propane torch.

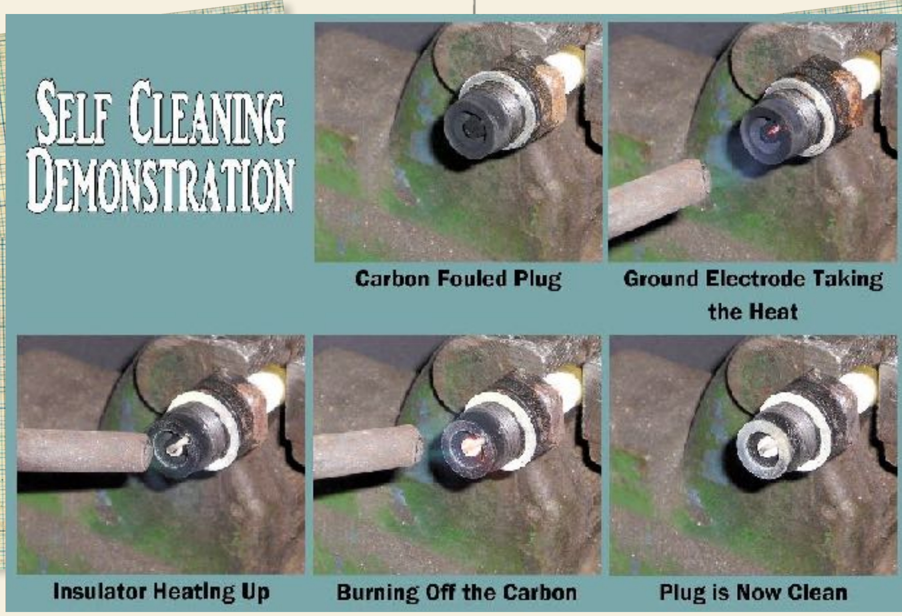



Fig. 6

Of course it will be understood that if the plug is so badly fouled that no spark is present, flame from combustion in the cylinder will not exist; thus the plug can't clean itself.

### Heat Range

To accommodate variations in engine demand, the spark plug is built so that the tip of the insulator retains the proper amount of heat to keep it clean. In order to keep the insulator of the spark plug at the optimum temperature for the engine, plugs are designed to have a hot or cold heat range. In any given engine, too cold of a plug can foul easily and too hot of a plug can cause pre-ignition which is harmful to the engine.

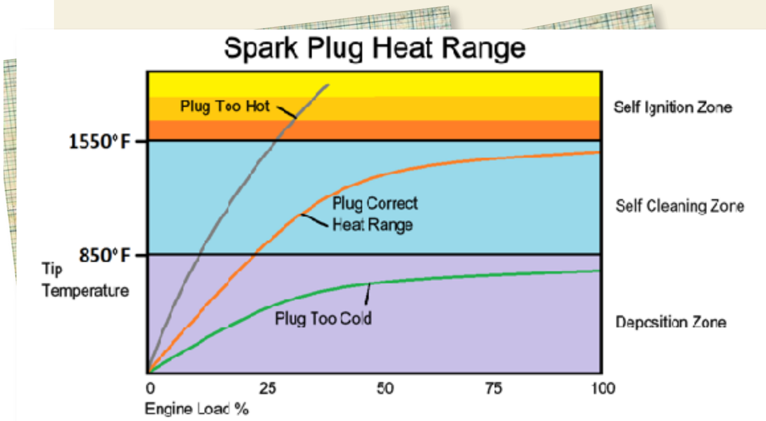
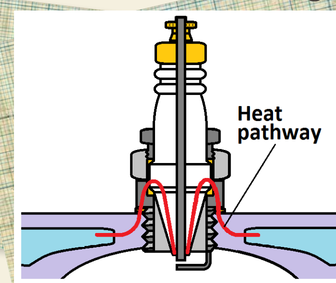



**Fig. 7**

In **Fig 7** the blue zone above 850 F is the temperature range where carbon and deposits will be burned off; as shown in the demonstration in Fig 6. The ideal is to have a plug that operates in this temperature range under all driving conditions. The orange line shows that even with a correct heat range plug, operating at slow speeds below 25% of engine load does not elevate the temperature of the insulator into the sweet zone.

This leads us into a discussion of what constitutes a "cold" or "hot" plug. **Fig 8** shows how the heat of combustion travels from the tip of the insulator to the metal base of the plug. Here the heat is absorbed by the cylinder head which in turn is cooled with recirculating water. The difference between a hot or cold plug has to do with the distance the heat travels to get to the base of the plug.

**Fig. 8**




Spark plug engineers design insulators with different length tips to achieve the heat ranges recommended by engine manufacturers. **Fig 9** shows various insulator lengths.

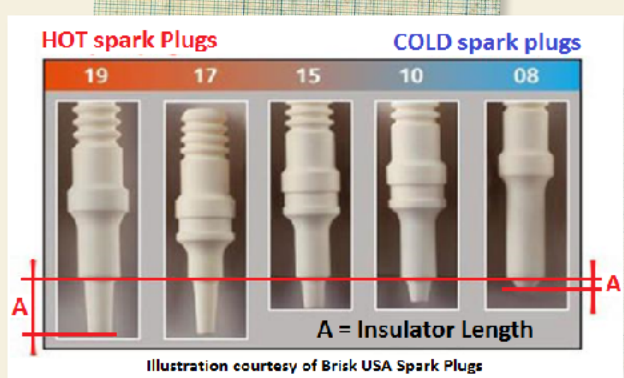



Illustration courtesy of Brisk USA Spark Plugs

**Fig. 9**

The longer length insulator retains heat more easily since the distance to the base of the plug is greater. This is referred to as a "hot" plug. Heat travels quickly to the base with the short insulator and consequently operates at a lower temperature, thus it's called a "cold" plug.

**Fig 10** shows two plugs from the same manufacturer. The plug labeled W-18 is hotter than the W-14. This is evidenced by the height of the base to accommodate a taller insulator.

Fig. 10

Even with the right heat range, an improper air/fuel ratio can lead to fouling or pre-ignition. **Fig 11** shows that for a given plug, a change in air/fuel mixture can adversely affect it. As the air/fuel mixture gets richer, incomplete combustion occurs, which results in carbon fouling of the plugs. A leaner mixture runs hotter and will cause the deposits

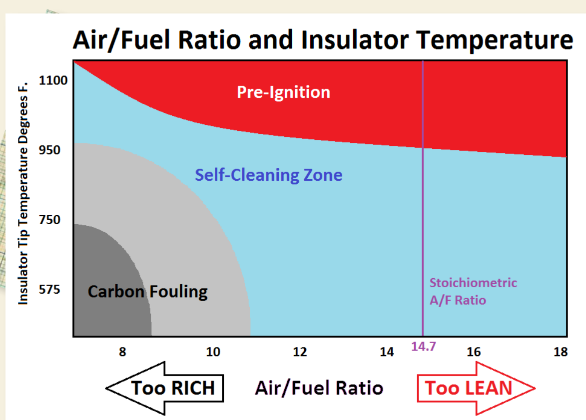
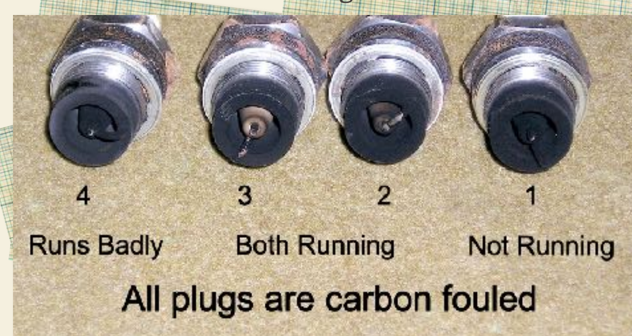



Fig. 11

to glow bright red. This is hot enough to set off the charge of gasoline in the cylinder before the spark is supplied by the ignition system. Pre-ignition is a spontaneous combustion of the fuel before the properly timed spark. By occurring too early, it can put shock loads on the bearings and crankshaft. This "glow plug" effect is visible in the top right photo in Fig 6 where the ground electrode is glowing red in the torch flame.

**Fig 12** shows four Model A plugs of the correct heat range (Champion 3X) which were quickly carbon fouled due to oversize jets in the carburetor. Although the newly rebuilt engine ran, it was never able to develop much power on a road test and idled badly. Cylinders 2 and 3 were doing all the work, and even they were struggling.

Fig. 12




Cylinders 1 and 4 were not contributing much to the power of the engine nor the smoothness of the idle. Once the carburetor was rebuilt using properly-sized jets and the plugs cleaned, this engine ran like it should. No more black smoke was belching out of the tailpipe.

It should be remembered that carbon build up on the plugs is an indicator of the deposits that will be found in the combustion chambers, on the valves and on the tops of the pistons. If poor running conditions are left unattended for many miles, these deposits will build up and harden on those surfaces and can lead to pre-ignition even though new plugs have been installed. When that happens, it is necessary to pull the cylinder head and scrape the carbon off of these areas.

One word about worn engines that blow blue smoke: there are no spark plugs on Earth that will perform well in an oil burner; the plugs will oil foul in short order. Loose valve guides or worn piston rings that allow too much oil to get into the combustion chambers need to be corrected. This usually means an engine rebuild is in order

**What is the best plug for my car?**

As a rule of thumb, slow parade driving and puttering around the block with the grandkids does not generate a lot of plug insulator heat, thus making that car an easy candidate for plug fouling. A hot plug would be good in that case. On the other hand, a car that is driven on long tours with the club and is otherwise a daily driver, a colder plug would be OK. For the average Model A driver who parades this week and tours the next, a mid-range plug is just fine. In fact, that's the plug the Ford factory recommended for the Model A; the Champion 3X, of which reproductions are now available.

There are other plugs on the market today that work well and it is up to you to try them out to decide which works best for your driving conditions. A conversation with the technical staff at any of the catalog houses can help you decide which plugs to order. In reality, there is not a big difference in the heat ranges for new spark plugs available for the Model A today. You may find some older plugs like those in **Fig 13** at swap meets that have different heat ranges, but be wise; old used plugs are great for looks but may not be so good for dependability.

It is estimated that for each 1000 miles driven, the plug gap increases by .001" due to erosion of the electrodes from the arcing they sustain. It's good to check and adjust your plug gaps about every 5000 miles. By keeping your carburetor in top working order, your ignition system tuned up and the plug gaps set right, a good set of plugs will last a long time. Do this and your spark plugs will never cry "foul."

Fig.